University of São Paulo
"Luiz de Queiroz" College of Agriculture

Soil mesostigmatid mites (Acari: Mesostigmata) inhabiting rose fields and neighboring vegetation in the Bogota plateau and their potential role as biological control agents of *Frankliniella occidentalis* (Insecta: Thysanoptera)

Diana Marcela Rueda-Ramírez

Thesis presented to obtain the degree of Doctor in Science. Area: Entomology

Piracicaba
2018

Diana Marcela Rueda-Ramírez
Biologist

Soil mesostigmatid mites (Acari: Mesostigmata) inhabiting rose fields and neighboring vegetation in the Bogota plateau and their potential role as biological control agents of *Frankliniella occidentalis* (Insecta: Thysanoptera)

Advisor:
Prof. Dr. **GILBERTO JOSÉ DE MORAES**
Co-Advisor:
Prof. Dra. **AMANDA VARELA-RAMÍREZ**

Thesis presented to obtain the degree of Doctor in Science. Area: Entomology

Piracicaba
2018

Dados Internacionais de Catalogação na Publicação
DIVISÃO DE BIBLIOTECA – DIBD/ESALQ/USP

Rueda-Ramírez, Diana Marcela

Soil mesostigmatid mites (Acari: Mesostigmata) inhabiting rose fields and neighboring vegetation in the Bogota plateau and their potential role as biological control agents of *Frankliniella occidentalis* (Insecta: Thysanoptera) / Diana Marcela Rueda-Ramírez. - - Piracicaba, 2018.

237 p.

Tese (Doutorado) - - USP / Escola Superior de Agricultura “Luiz de Queiroz”.

1. Mesostigmata 2. Controle biológico 3. Presa complementar 4. Riqueza de espécies 5. Tabela de vida 6. Predação I. Título

To My Family

For being an inspiration

ACKNOWLEDGEMENTS

I am grateful to my family for being my support and my inspiration. To my parents Nora Elena Ramirez and Hernando Manuel Rueda for always having stimulated me to study and to progress, and for always being on my side (in addition to helping me many times as my laboratory and field assistants!). To my siblings Camila and Andres Mauricio, for being so wonderful and for making me want to be better every day.

To Andres Puerta Gonzalez for having been by my side in key moments, for having spent sleepless nights just accompanying me to do multiple things of the project, for challenging me and for simply supporting me.

To my adviser and guide, Prof. Dr. Gilberto J. de Moraes, who believed in me from the beginning and always keeping the door open for any question, even if it was silly.

To my co-adviser Prof. Dr. Amanda Varela, who supported me throughout the conduction of the studies in Colombia and who was always on my side since the beginning of my undergraduate studies.

To Dr. Johan Manuel Bogoya for accepting to be part of this project and supporting it, despite being a totally new area for him.

To Diana Marcela Rios Malaver and Mayerly Alejandra Castro, who helped me in several steps in this project. Both are true co-authors of some chapters of this thesis and, without them, it would have been impossible to carry out many of the sampling, experiments, mite mounting and measures of specimens.

To Everth Ebratt Ravelo, for helping me with the thrips identification, and to Jessica Lorena Vaca for helping me with mites and thrips mounting.

To Ferdy Alfonso Alvarado for supporting me and believing in my projects, so much so that he always managed to help me make them come true.

To the Association of Colombian Flower Exporters – ASOCOLFLORES – for helping me get in touch with the staff of each farm to carry out the collections.

To the staff of each of the farms, especially Rafael Boada, José Manuel Pardo (Agua Clara y Vuelven), Andres Millan (Flores el Futuro), Maria del Pilar Bravo (Wayuu Flowers), Karen Tatiana Peña (Elite Flowers) and each one of the monitors, for their willingness to receive me, help me with the collections, trip counts and for providing me information. Without their help this project would not have been possible to conduct.

To Maria del Pilar Blanco and Carlos Cuervo of Granja El Porvenir for their willingness to help me and to let me do the collections at their site, to contribute a little to the important project they have.

To all people who accompanied me and helped during the collections (Agustin Salazar, Andres Puerta, Andres Rueda, Diana Rios, Giovanna Arboleda, Dr. Juan Pablo Botero, Tatiana Cuervo). All were excellent field assistants!

To Augusto Ramirez-Godoy, Universidad Nacional de Colombia, for granting laboratory for processing the samples and for the support and friendship. To Juan Carlos Pinzón for helping me with several things during my time at Universidad Nacional de Colombia.

To Dr. Jandir C. Santos, Sofia Jimenez Jorge and Dr. Leticia Azevedo for their friendship and help with identifications.

To Santiago Correa for his support at the beginning of this process and his unconditional friendship.

To Dr. Rafael Moral for always being willing to answer my multiple questions in each of the statistical models that occurred to me.

To Dr. Alireza Nemati, Dr. Bruce Halliday, Dr. David Walter, Dr. Frederick Beaulieu, Dr. Grazielle Furtado, Dr. Mariusz Lewandowski, Dr. Mohamed W Negm and Dr. Shahrooz Kazemi for answering every single question about taxonomy and biology of each mite group.

To Lasaro Vanderlei Fernandes da Silva for his help and disposition.

To the laboratory and administrative staff members of “Departamento de Entomologia e Acarologia” of ESALQ/USP, José L. F. Piedade, Josenilton L. Mandro, Maria Marta Coletti, Rosângela A. da Silva.

To my friends of the Acarology Laboratory, Fernanda de C. N. Esteca, Geovanny S. P. Barroso, Grazielle F. Moreira, Jandir C. Santos, João B. da Cruz, João Paulo Z. Narita, Lina Marcela Gonzalez, João Pedro Martin, Marcela M. R. da Silva, Marina F. C. Barbosa, Marielle de M. Berto, Michele Ennes, Murilo P. Ferreira, Renan V. da Silva, Tiago Casaroto and Vinicius Borges da Silva for the help, making unforgettable my passage through the laboratory. All great people.

To Eric and Anat Palevsky for their friendship and unforgettable experiences and lessons.

To Professor Dr. Carlos H. W. Flechtmann (ESALQ) for his permanent availability to provide me information.

To “Programa de Pós-Graduação em Entomologia”, especially to the coordinator, Professor Dr. Fernando L. Cônsoli, and the secretary Andrea V. Sintoni, for supporting my activities.

To Escola Superior de Agricultura "Luiz de Queiroz" (ESALQ), University of São Paulo (USP), for the opportunity to carry out the course. To Pontificia Universidad Javeriana for the opportunity to do the Double-Diploma.

To COLCIENCIAS (Departamento Administrativo de Ciencia, Tecnología e Innovación, Colombia) for granting the scholarship (Process No. 617-2013, Chapter 3).

To “Vicerrectoria Academica” of “Pontificia Universidad Javeriana (Project No. 000000000007367) for partially support this research.

To council members (Peter Reutimann, Reinhard Gerecke, Peter Martin, Heinrich Schatz) of the Pro Acarologia Basiliensis foundation, Switzerland, for the donation of the microscope that was very useful for the identification of the specimens collected in this study.

To Dr. Jason Dunlop and Anja Friederichs of the Arachnologische Sammlung des Museums für Naturkunde (Berlin, Germany) for the loan of type specimens.

“I want to live in a world in which beings are only human, with no other titles than that, without hitting the head with a rule, with a word, with a label. I do not want anyone to be persecuted. I want the vast majority, the only majority, everyone, to be able to speak, read, listen, flourish. I never understood the fight but for it to end. I never understood rigor, but so that rigor does not exist. I have taken a path because I believe that this path brings us all to that lasting kindness. I fight for that obvious, extensive, inexhaustible kindness. I still have an absolute faith in human destiny, a conviction that is increasingly aware that we are approaching a great tenderness. I write knowing that over our heads, over all heads, there is the danger of the bomb, of the catastrophe, but this does not alter my hope. In this critical minute, in this flicker of agony, we know that the definitive light will enter through the half-open eyes. We will all understand each other. We will progress together. And this hope is irrevocable.”

Translation of a fragment of “Confieso que he vivido” – Pablo Neruda

CONTENTS

RESUMO

Ácaros Mesostigmata edáficos (Acari: Mesostigmata) presentes em culturas de rosas de corte e vegetação próxima na Sabana de Bogotá e o papel potencial destes ácaros como potenciais agentes de controle biológico de *Frankliniella occidentalis* (Insecta: Thysanoptera)

Tem sido freqüentemente mencionado que a Colômbia é um país "megadiverso", contendo um número maior de espécies que outros países, alguns dos quais com territórios muito mais extensos. No entanto, poucos sabem o que isso significa e os benefícios que podem ser obtidos dessa alta diversidade, com sua exploração adequada. Um dos benefícios refere-se ao uso sustentável de recursos biológicos. A Colômbia pode aproveitar a descoberta, a conservação ou a produção e a comercialização de espécies que servem como agentes de controle biológico de espécies que prejudicam certas atividades econômicas. O controle biológico aplicado envolve a possibilidade de explorar a biodiversidade nativa na forma de conservação ou biocomércio para uso em atividades como agricultura e pecuária. Assim, os estudos que compõem esta tese visam a iniciar o reconhecimento da riqueza de ácaros predadores no solo da região produtora de roseiras da Colômbia, e a avaliação de potenciais predadores representativos para uso no manejo de tripes, o mais importante grupo de pragas no cultivo de rosas na Colômbia. O Capítulo 1 abordou a importância da cultura, dos grupos de pragas e dos possíveis inimigos naturais encontrados na Colômbia. No Capítulo 2, os resultados de um levantamento geral dos ácaros de solo em quatro campos de cultivo de rosas em estufas durante um ano e meio foram apresentados. Além disso, a dinâmica populacional de ácaros e tripes no solo foi estudada, relacionando a variação nos níveis populacionais com fatores ambientais, incluindo fatores climáticos e do solo. Conhecendo a variação das populações ao longo do tempo sob as condições usuais de manejo de culturas pode ajudar a entender como um predador pode responder no campo quando usado em programas de controle de pragas. Para complementar esses dados, especialmente no que se refere à avaliação da fauna nativa, foram realizados levantamentos em fragmentos de vegetação secundária localizados próximos a dois dos campos de cultivo de rosas, num cultivo de rosa em outra área e um fragmento de vegetação secundária nas proximidades, e em dois fragmentos mais extensos e menos perturbados do planalto de Bogotá. Com este trabalho, foi possível verificar a grande riqueza de espécies de ácaros Mesostigmata (não incluindo os Uropodina) encontradas no solo do planalto de Bogotá. Apenas ácaros representativos da coorte Cercomegistina da subordem Trigynaspida e da coorte Gamasina da subordem Monogynaspida foram encontrados. Como esperado, espécies e famílias dominantes se assemelham aos grupos relatados em áreas temperadas, dadas as condições climáticas semelhantes. Tanto as densidades quanto o número de espécies são menores nos campos de cultivo de rosas do que nos fragmentos de vegetação secundária próximos, o que também era esperado tendo em vista o ecossistema muito mais uniforme nos campos cultivo de rosas. Além disso, a presença exclusiva de algumas espécies nestes campos sugere que estas tenham sido introduzidas com material relacionado ao sistema de cultivo ou que tenha havido uma mudança drástica na composição faunística, tornando abundantes em campos de cultivo de rosas as espécies que são raras na vegetação secundária,

devido às características do sistema de cultivo. A variação nas densidades e presença de espécies mostaram-se mais relacionadas às características do solo, especialmente níveis de matéria orgânica e pH, do que às características climáticas. Portanto, fragmentos da vegetação secundária, cujos solos tinham maior conteúdo de matéria orgânica, são mais semelhantes entre si, em termos de composição das espécies, do que aos campos de rosas próximos. Os resultados do Capítulo 2 indicaram a necessidade de estudos morfológicos e taxonômicos de várias das espécies encontradas, pelas descrições pouco detalhadas atualmente disponíveis ou pelo reconhecimento da ocorrência de espécies novas para a ciência. Assim, nos Capítulos 3 e 4, uma caracterização morfológica e a descrição de algumas das espécies novas encontradas em Ascidae, Blattisociidae e Melicharidae (Capítulo 3) e Laelapidae (Capítulo 4) foram apresentadas. Também foi observado que muitas das espécies descritas anteriormente e encontradas neste estudo necessitam de estudos semelhantes, a serem realizados no futuro. No entanto, através destes dois capítulos, os passos iniciais foram dados, para contribuir para o reconhecimento de grupos de ácaros pouco conhecidos na Colômbia, para facilitar futuros estudos ecológicos e o uso destas espécies em programas de controle de pragas. Os resultados do Capítulo 2 também serviram como base para a seleção de espécies a serem consideradas em uma avaliação inicial do potencial de membros da fauna mesostigmática colombiana como agentes de controle de *Frankliniella occidentalis* (Pergander), a espécie mais numerosa de tripes encontrada neste estudo. Duas das espécies de predadores mais encontradas, *Gaeolaelaps aculeifer* (Canestrini) e *Parasitus bituberosus* Karg, foram selecionadas para realizar a segunda parte deste trabalho, cujos resultados foram apresentados nos Capítulos 5 e 6, respectivamente. Para cada predador, o estudo consistiu na avaliação da capacidade de predação em *F. occidentalis* e das taxas de oviposição quando alimentando-se desta e de outras presas, assim como na determinação dos parâmetros de sua tabela de vida. *Gaeolaelaps aculeifer* é atualmente usado em outros países para o controle de diferentes pragas, incluindo tripes. Os resultados mostraram que ambos os predadores são capazes de se alimentar e se reproduzir quando pré-pupas e pupas de *F. occidentalis* fazem parte de suas dietas. As características biológicas da população colombiana de *G. aculeifer* são comparáveis àquelas relatadas para outras populações do mesmo predador, sugerindo seu potencial para uso no controle de *F. occidentalis* na Colômbia. Embora a presença de uma presa complementar (*Aleuroglyphus ovatus* (Troupeau)) no sistema tenha levado a uma pequena redução de sua taxa de predação de pupas e pupas de *F. occidentalis*, observou-se que *A. ovatus* pode ser usado como alimento factício para a criação massal ou como alimento complementar em liberações periódicas, quando a praga não seja suficientemente abundante para manter a população deste predador. Foi demonstrado que a deutoninfa de *P. bituberosus* precisa de um estímulo para a emergência dos adultos, que, neste caso correspondeu ao seu pareamento com um ácaro do sexo oposto. Os nematoides não apenas são necessários na dieta na fase imatura desse predador, mas também melhoram seu desempenho, como indicado pela maior fecundidade e pelas taxa liquida de reproducao e capacidade innata de aumentar em numero dessa presa. Os resultados indicaram como justificável a realização de estudos em maior escala sobre o possível uso de *G. aculeifer* e *P. bituberosus* no controle de tripes, por meio de liberações periódicas, bem como a avaliação de outras espécies predadoras encontradas com menor frequência. As avaliações em larga escala consistiriam inicialmente em experimentos em vasos e,

posteriormente, em semi-campo e campo. Os resultados da relação entre densidade de predadores e fatores ambientais também sugerem ser importante a realização de estudos que avaliem a possibilidade de aumentar o desempenho dos predadores, aumentando o nível de matéria orgânica do solo ou o pH.

Palavras-chave: Mesostigamata, controle biológico, presa complementar, riqueza de espécies, tabela de vida, predação

ABSTRACT

Soil mesostigmatid mites (Acari: Mesostigmata) inhabiting rose fields and neighboring vegetation in the Bogota plateau and their potential role as biological control agents of *Frankliniella occidentalis* (Insecta: Thysanoptera)

It has been frequently mentioned that Colombia is a "megadiverse" country, containing a larger number of species than other countries, some of which with much larger territories. However, very few people know what this means and about the benefits that can be obtained from that high diversity, with its proper exploration. One of the benefits refers to the sustainable use of biological resources. Colombia can take advantage of the discovery, conservation or production, and commercialization of species that serve as biological control agents of species that harm certain economic activities. Applied biological control involves the possibility to exploit native biodiversity in the form of conservation or biocommerce for use in activities such as agriculture and livestock. Thus, the studies composing this thesis aimed at initiating the recognition of the richness of predatory mites in the soil of the major rose-producing region of the country, and the evaluation of potential representative predators for use in the management of thrips, the most important pest group on rose cultivation in Colombia. Chapter 1 addressed the importance of the crop, the pest groups and the possible natural enemies to be found in Colombia. In Chapter 2, the results of a general survey of the soil mites in four rose fields in greenhouses during one year and a half was presented. Additionally, the population dynamics of soil the mites and thrips was studied, relating the variation in population levels with environmental factors, including climatic and soil factors. Knowing the variation of populations over time under the usual conditions of crop management can help to understand how a predator can respond in the field when used in pest management programs. To complement those data, especially in what refers to the evaluation of the native fauna, surveys were carried out on patches of secondary vegetation located near two of the rose fields, in a rose field in another area and a patch of secondary vegetation nearby, and in two more extensive and less disturbed patches of the Bogota plateau. With this work, it was possible to verify the great richness of species of soil non-Uropodina Mesostigmata found in the soil of the Bogotá plateau. Only representative mites of the cohort Cercomegistina of the suborder Trigynaspida and of the cohort Gamasina of the suborder Monogynaspida were found. As expected, species and dominant families resemble those reported in temperate areas, given the similar climatic conditions. Both densities and number of species are lower in rose fields than in secondary vegetation patches nearby, which also was expected from the much more uniform ecosystem in rose fields. Additionally, the exclusive presence of some species in rose fields suggests either the introduction of those species with material related to the cultivation system or a drastic change in faunistic composition, turning rare field species abundant in rose fields because of the cultivation system. The variation in densities and presence of species was shown to be more related to soil, especially organic matter and pH, than to climatic characteristics. Therefore, patches of secondary vegetation, whose soils had higher content of organic matter, are more similar to each other, in terms of composition of species, than to the nearby rose fields. The results of the Chapter 2 indicated the need for morphological and taxonomic

studies of several of the species found, either because of the poorly detailed descriptions currently available or because of the recognition of new species for science. Thus, in Chapters 3 and 4, the morphological characterization and the description of some of the new species found in the Ascidae, Blattisociidae and Melicharidae (Chapter 3) and Laelapidae (Chapter 4) were presented. It was also observed that many of the previously described species found in this study also need similar studies to be conducted in the future. However, through these two chapters, initial steps were taken to contribute to the recognition of scarcely known mites groups in Colombia to facilitate future ecological studies and the use of those species in pest management programs. The results of Chapter 2 also served as base to select species to be considered in an initial evaluation of the potential of members of the Colombian mesostigmatic fauna as control agents of *Frankliniella occidentalis* (Pergander), the most numerous thrips species found in this study. Two of the most frequently found predator species, *Gaeolaelaps aculeifer* (Canestrini) and *Parasitus bituberosus* Karg, were selected to carry out the second part of this work, whose results were presented in Chapters 5 and 6, respectively. For each predator, the study consisted of the evaluation the predation capacity on *F. occidentalis*, the oviposition rates on this and other prey species, and of the determination of their life table parameters. *Gaeolaelaps aculeifer* is presently used in other countries for the control of different pests including thrips. The results showed that both predators are able to feed and reproduce when pre-pupae and pupae of *F. occidentalis* were part of their diets. The biological characteristics of the Colombian population of *G. aculeifer* are comparable to those reported for other populations of the same predator, suggesting its potential for use to control *F. occidentalis* in Colombia. Although the presence of a complementary prey (*Aleuroglyphus ovatus* (Troupeau)) in the system led to a small reduction of its predation rate of *F. occidentalis* pre-pupae and pupae, the results show that *A. ovatus* can be used as factitious food for mass rearing or as complementary food in periodic releases, when the pest in not abundant. It was shown that *P. bituberosus* deutonymph needs a stimulus for the emergence of adults, which, in this case, was the pairing with a mite of the opposite sex. Nematodes are not only necessary in the diet in the immature stage of this predator, but also improve its performance, as indicated by the higher fecundity and the net and intrinsic reproductive rates on this prey. The results indicated as warranted the conduction of larger scale investigations on the possible use of *G. aculeifer* and *P. bituberosus* for thrips control, by periodic releases, as well as the evaluation of other predator species found less frequently. Larger-scale evaluations would initially consist of experiments in pots and later on at the semi-field and field conditions. Results of the relation between predator density and environmental factors also suggest to be important the conduction of studies to evaluate the possibility to increase predator performance by increasing the level of soil organic matter content or pH level.

Keywords: Mesostigmata, biological control, complementary prey, species richness, life table, predation

RESUMEN

Ácaros Mesostigmata edáficos (Acari: Mesostigmata) presentes en cultivos de rosa y vegetación próxima en la Sabana de Bogotá y su papel potencial como agentes de control biológico de *Frankliniella occidentalis* (Insecta: Thysanoptera)

Es frecuentemente mencionado que Colombia es un país "megadiverso" y que está por encima en número de especies de países con áreas mucho más extensas. Sin embargo, muy pocos saben lo que puede significar esto y sobre los beneficios que se pueden obtener de esta gran diversidad, con apropiada explotación. Uno de los beneficios se refiere al uso sostenible de sus recursos biológicos. Colombia puede aprovechar el descubrimiento, la conservación o la producción y la comercialización de especies que sirven como agentes de control biológico de especies que afectan ciertas actividades económicas. El control biológico aplicado implica la posibilidad de explotar la biodiversidad nativa en forma de conservación o biocomercio para su uso en actividades como la agricultura y la ganadería. Por lo tanto, los estudios que componen esta tesis tienen como objetivo iniciar el reconocimiento de la riqueza de los ácaros depredadores en el suelo de la región productora de rosas más importante del país, y la evaluación de posibles depredadores representativos para su uso en el manejo de trips, importante grupo de plagas en rosa en Colombia. El Capítulo 1 abordó la importancia del cultivo, los grupos de plagas y los posibles enemigos naturales que pueden ser encontrados en Colombia. En el Capítulo 2, se presentaron los resultados de un sondeo general de los ácaros edáficos en cuatro cultivos de rosas en invernaderos durante un año y medio. Además, se estudió la dinámica de la población de los ácaros del suelo y los trips, relacionando la variación en los niveles poblacionales con los factores ambientales, incluidos los factores climáticos y del suelo. Conocer la variación de las poblaciones a lo largo del tiempo bajo las condiciones usuales de manejo de cultivos puede ayudar a comprender cómo un depredador puede responder en el campo cuando es utilizado en programas de manejo de plagas. Para complementar esos datos, especialmente en lo que se refiere a la evaluación de la fauna nativa, se realizó también un sondeo en parches de vegetación secundaria localizados cerca de dos de los rosales, en un cultivo de rosa en otra área y un parche de vegetación secundaria cercana, y en dos fragmentos más extensos y menos alterados en la Sabana de Bogotá. Con este trabajo, fue posible comprobar la gran riqueza de especies de Mesostigmata no Uropodina edáficos que se pueden encontrar en el suelo de la Sabana de Bogotá. Únicamente se encontraron ácaros representativos de la cohorte Cercomegistina del suborden Trigynaspida y de la cohorte Gamasina del suborden Monogynaspida. Como era de esperar, las especies y las familias dominantes que se encontraron se parecen a las reportadas en áreas templadas, dadas las condiciones climáticas similares. Tanto las densidades como el número de especies son menores en los campos de rosas que en los parches de vegetación secundaria cercanos, lo que también se esperaba de un ecosistema mucho más uniforme como es el cultivo de rosas. Asimismo, la presencia exclusiva de algunas especies en los cultivos de rosas sugiere la introducción de esas especies con material relacionado con el sistema de cultivo o un cambio drástico en la composición faunística, convirtiendo las especies poco frecuentes en abundantes en los campos de rosas debido al sistema de cultivo. La variación en las

densidades y la presencia de especies estuvo más relacionada con el suelo, especialmente con la materia orgánica y el pH, que con las características climáticas. Por lo tanto, los parches de vegetación secundaria, cuyos suelos tienen un mayor contenido de materia orgánica, son más similares entre sí, en términos de composición de especies, que a los campos de rosas cercanas. Los resultados del Capítulo 2 indicaron la necesidad de estudios morfológicos y taxonómicos de varias de las especies encontradas, ya sea por las descripciones poco detalladas actualmente disponibles o por el reconocimiento de nuevas especies para la ciencia. Entonces, en los Capítulos 3 y 4, se presentó caracterización morfológica y descripciones de algunas de las nuevas especies encontradas en Ascidae, Blattisociidae y Melicharidae (Capítulo 3) y Laelapidae (Capítulo 4). También se observó que muchas de las especies descritas anteriormente que se encuentran en este estudio también necesitan estudios similares que se llevarán a cabo en el futuro. Sin embargo, a través de estos dos capítulos, se tomaron los pasos iniciales para contribuir al reconocimiento de grupos de ácaros escasamente conocidos en Colombia para facilitar futuros estudios ecológicos y su uso en programas de manejo de plagas. Los resultados del Capítulo 2 también sirvieron como base para seleccionar especies a ser consideradas en una evaluación inicial del potencial de los miembros de la fauna colombiana de ácaros Mesostigmata como agentes de control de *Frankliniella occidentalis* (Pergander), una de las especies de trips más numerosas encontradas en este estudio. Dos de las especies más frecuentemente encontradas, *Gaeolaelaps aculeifer* (Canestrini) and *Parasitus bituberosus* Karg, fueron seleccionadas para llevar a cabo la secunda parte de este trabajo, cuyos resultados son presentados en los Capítulo 5 y 6, respectivamente. Para cada depredador, el estudio consistió en la evaluación de la capacidad de depredación de *F. occidentalis*, las tasas de oviposición en esta y otras especies presa, y la determinación de los parámetros del ciclo de vida. *Gaeolaelaps aculeifer* es actualmente usado en otros países para el control de diferentes plagas, incluyendo trips. Los resultados mostraron que ambos depredadores son capaces de de alimentarse y reproducirse cuando pupas y pre-pupas de *F. occidentalis* hacen parte de su dieta. Las características biológicas de la población colombiana de *G. aculeifer* son comparables a las reportadas para otras poblaciones del mismo depredador, lo que sugiere su potencial para controlar *F. occidentalis* en Colombia. Aunque la presencia de una presa complementaria (*Aleuroglyphus ovatus* (Troupeau)) en el sistema condujo a una pequeña reducción de la tasa de depredación de pre-pupas y pupas de *F. occidentalis*, los resultados muestran que *A. ovatus* puede usarse como alimento artificial para la cría masiva o como alimento complementario en liberaciones periódicas, cuando la plaga no es abundante. Se demostró que la deutoninfa de *P. bituberosus* necesita un estímulo para la emergencia de adultos, que, en este caso, fue la agrupación con un ácaro del sexo opuesto. Los nematodos no solo son necesarios en la dieta en la etapa inmadura de este depredador, sino que también mejoran su rendimiento, como lo indica la mayor fecundidad y las tasas de reproducción neta e intrínseca cuando el depredador es alimentado con esta presa. Los resultados indicaron que se justifica la realización de investigaciones a mayor escala sobre el posible uso de *G. aculeifer* y *P. bituberosus* para el control de trips, mediante liberaciones periódicas o en control biológico conservativo, así como la evaluación de otras especies de depredadores encontradas con menos frecuencia. Las evaluaciones a gran escala consistirían inicialmente en experimentos en macetas y más tarde en las condiciones de semicampo y campo. Los resultados de la relación entre la

densidad de los depredadores y características del suelo también sugieren que es importante la realización de estudios para evaluar la posibilidad de aumentar el rendimiento de los depredadores al aumentar el nivel de contenido de materia orgánica del suelo o el nivel de pH.

Palabras claves: Mesostigmata, control biológico, presa complementaria, riqueza de especie, tabla de vida, depredación

1. INTRODUCTION

Agriculture is one of the main economic activities in Colombia, contributing about 7% to the country´s Gross Domestic Product (Romero-Álvarez, 2011). Within the agricultural sector, the production of cut flowers results in the annual income of about US $ 1,300 million from exportation to many countries and in the employing of more than 130,000 people, directly and indirectly (ASOCOLFLORES, 2018, 2013; Reyes, 2017). Colombia stands out as the second world exporter of flowers, and the first exporter to the United States of America (Manrique-Ramírez et al., 2014; Reyes, 2017). Of the flowers purchased in United States, 80% are produced in Colombia (Manrique-Ramírez et al., 2014; Reyes, 2017). Roses are the main exported cut flowers, corresponding to approximately 30% of the total exports of these products (Fenalco, 2017).

Floriculture is concentrated mainly in the Andean region of Colombia. Of the total area destined for floriculture, 72% are located in Cundinamarca, in the Bogotá plateau, with rose as the main product (Reyes, 2017) because of the high demand and appreciation in the international market. This region has been consolidated as an important area of flower production since 1965, due to the excellent soil conditions, climate, luminosity, water availability, elevation and strategic location (ASOCOLFLORES, 2013; Cárdenas and Rodríguez, 2011; Manrique-Ramírez et al., 2014; McQuaid, 2011).

This important economic activity in Colombia has faced different challenges since its beginning. Among the current difficulties limiting the production and marketing of this important product are phytosanitary problems. Pests constitute a crucial phytosanitary problem affecting the quality, productivity and commercialization of flowers (Valcárcel, 2013). Among these, insects of the order Thysanoptera (thrips), especially of the family Thripidae, are of utmost importance to rose, carnation and other cut flowers and many cultivated plants. Most damaging thrips species belong to the genera *Frankliniella* and *Thrips*, favored by the temperature and humidity levels prevailing in the greenhouses in which cut flowers are produced. These insects cause deformations, scars and necrosis in plants (Chisholm and Lewis, 1984; Mound, 1971; Tommasini and Maini, 1995), highly undesirable because the value of the product is given by its appearance. In addition, they hamper commercialization, because of the high phytosanitary requirements of importers (Valencia, 2013).

Among the control strategies currently used for thrips control, chemical applications are the most common (Bustillo-Pardey, 2009; Cannon et al., 2007a; Garzo et al., 2000; ICA

and ASOCOLFLORES, 2003; Vargas and Ubillo, 2005), with products such as Abamectina, Spinosad, Methiocarb and other systemic pesticides (Cloyd, 2009), which can select resistant populations of insects, pollute the environment and reduce wildlife (Buitrago-Villanueva et al., 2010). Thus, the development of alternative and complementary control strategies is considered necessary, including biological control, that is, the control of a given pest with the use of other organisms, its natural enemies, including predators, parasites or pathogens. The natural enemies selected for practical use are commonly termed biological control agents.

In intensive agricultural production, when more than one pest needs to be controlled, very often biological control is not possible for the reduction of all pests, and some of them need to be controlled by other strategies, including chemical control. The combination of different control measures is referred to as Integrated Pest Management (IPM). This practice is already adopted in Colombia by some small-scale producers. However, additional studies are needed to increase the efficiency of the practice, allowing wider adoption.

Biological control of thrips pests has been conducted in other countries. Most of the efforts in this sense has focused on thrips developmental stages that inhabit aerial plant parts, with the use of microorganisms such as *Beauveria bassiana* (Balsamo) (Bustillo-Pardey, 2009; Cannon et al., 2007a; Gill et al., 2001); predatory mites such as *Amblyseius swirskii* Athias-Henriot (Buitenhuis et al., 2015; Calvo et al., 2015; Farkas et al., 2016; Van Houten et al., 2005; van Lenteren et al., 2011), *Amblydromalus limonicus* (Garman and McGregor) (van Houten et al., 1995), *Neoseiulus cucumeris* (Oudemans) (Capinera, 2001; Ebssa et al., 2006; Van Houten et al., 2005) and *Iphiseius degenerans* Berlese (Van Houten et al., 2005); and predatory hemipterans such as *Orius strigicollis* (Poppius) (Cannon et al., 2007b; Kim et al., 2004) and *Orius insidiosus* (Say) (Avellaneda et al., 2016).

Some effort has also been dedicated to the search of natural enemies to control thrips on the soil surface. The last two thrips immature phases, pre-pupae and pupae, are usually found in this habitat. Some studies have evaluated the possible use of entomopathogenic nematodes. such as species of *Steinernema* (Steinernematidae) and *Heterorhabditis* (Heterorhabditidae) (Capinera, 2001; Ebssa et al., 2004; Laznik and Trdan, 2008).

Predatory mites of different families of the mesostigmatid cohort Gamasina found naturally in this habitat have also been evaluated. In Germany, it has been observed that *Stratiolaelaps miles* (Berlese) and *Gaeolaelaps aculeifer* (Canestrini) (Laelapidae) are predators of the soil phases of *F. occidentalis* (O. Berndt et al., 2004; Oliver Berndt et al., 2004). In Denmark, *Lasioseius fimetorum* Karg (Blattisociidae) was tested as a predator of eggs and larvae of *F. occidentalis* (Enkegaard and BrØdsgaard, 2000). In the Netherlands,

Messelink and De Kogel (2005) showed that *Macrocheles robustulus* (Berlese) and *Macrocheles subbadius* (Berlese) (Macrochelidae) were the main predatory mite species of *F. occidentalis* pupae, reporting reduction of 80% of the pupal population in experimental trials. Messelink & Holstein-Saj (2008) also observed in the Netherlands that *M. robustus* controlled *F. occidentalis* better (up to 70% reduction) than *G. aculeifer* (reduction of up to 50%). In Brazil, *Protogamasellopsis posnaniensis* Wisniewski and *Cosmolaelaps jaboticabalensis* Moreira, Komplem & Moraes were evaluated, observing their potential as biological control agents of *F. occidentalis* (Castilho et al., 2009; Moreira et al., 2015). It has been reported that an unidentified species of *Stratiolaelaps* consumed different stages of *Thrips palmi* Karny in the laboratory (López-Bermúdez, 2014). Some of the species listed above are already commercialized for thrips control (van Lenteren, 2011). A major advantage of the use of predators on the soil instead of on the plants is the reduced risk of their detection on exported roses in quarantine.

1.1. Thrips in rose production

Thrips are insects of the order Thysanoptera, whose main species are commercial crop pests. About 90% of the pest species of this order belong to the famlily Thripidae (Moritz et al., 2004; Reitz et al., 2011). These insects are known as prominent pests of different cultures in several countries around the world.

These insects are characterized by presenting only the left mandible fully developed and presenting in the adult stage two pairs of wings with marginal fringe of long cilia (Mound, 2005). The thrips are highly polyphagous, being able to feed not only the contents of the cells of different plants, but also of pollen and some arthropods (Alves-Silva and Del-Claro, 2010; Reitz et al., 2011).

Many species are opportunistic polyphagous, being able to feed from a wide variety of plants, but achieving reproductive success only in some of them (Reitz et al., 2011). The feeding of different plant tissues leads to the formation of necrotic and silvery zones, besides deformations when the feeding takes place in shoots (Chisholm and Lewis, 1984; Mound, 1971). These damages are highly important in ornamental crops, which depend on their aesthetic value. In these crops, control threshold is close to zero for thrips, leading to the intensive use of different pesticides (Reitz et al., 2011; Valencia, 2013).

The intensive use of pesticides, added to the biological characteristics of the thrips, has led to the selection of resistant populations of different species. The first case of resistance

was reported in California where a resistant population of *F. occidentalis* was selected for the intensive use of insecticides in vegetable crops in the 1970s and 1980s. This was then repeatedly found around the world (Kirk and Terry, 2003; Reitz, 2009).

The selection of resistant populations of the different thrips species seems to be due to their polyphagous behavior, which allows these insects to have an arrangement of metabolic pathways to detoxify the secondary components of plants, which may represent a pre-adaptation to detoxify the insecticides (Reitz et al., 2011; Rosenheim et al., 1996). Jensen (2000) found certain insecticidal degrading enzymes that are produced by populations of *F. occidentalis* resistant to some of these products. Another important factor for the acquisition of resistance of these insects is the haplo-diploid reproduction, because hemi-zygote males are directly exposed to selection (Denholm et al., 1998; Reitz et al., 2011).

Thrips are not only difficult to control because of the high chances of being selected resistant populations, but also because of other characteristics such as their high reproductive and dispersal capacity and their reclusive behavior. The high reproductive capacity of many species allows these insects to achieve high densities under suitable conditions. Their dispersion is by wind and flight to nearby crops or in agricultural products transported by man to different places (Morse and Hoddle, 2006). Also, their behavior of hiding in different plant structures allows the infestation not to be easily detected and insects to be easily transported in plant material (Chacón, 2002; Reitz, 2009; Reitz et al., 2011).

Different authors (Arevalo et al., 2003; Calixto, 2005; Cardenas and Corredor, 1993) have considered that the most important thrips species in the Colombian floriculture are *F. occidentalis*, *Frankliniella panamensis* Hood, *Thrips palmi* Karny and *Thrips tabaci* Lindeman (Thysanoptera: Thripidae). However, thrips fauna in rose cultivation and details about thrips dynamics have not been studied in detail in this country.

Frankliniella occidentalis is also an important pest in other crops in Colombia (Arevalo et al., 2003; Calixto, 2005; Chacón, 2002). This insect was described with specimens from the western United States and apparently spread throughout the world from the late 1970s to the 1980s. It has a large number of hosts, although its preference for certain of these may depend on the population (Mound, 2005). Different authors consider that it constitutes a complex of different species, which is currently supported by molecular evidence (Reitz et al., 2011). This is one of the thrips species most found in the Bogota plateau (Arevalo et al., 2003; Calixto, 2005; Cardenas and Corredor, 1993).

Frankliniella panamensis was described from specimens collected in flowers in Panama (Hood, 1925). This species has been found in Colombia in various crops, in

Cundinamarca and Antioquia, in areas where flower cultivation is found (Arevalo et al., 2003; Calixto, 2005; Cardenas and Corredor, 1993). It has become particularly important because there has been an increase in interceptions of flower shipments from Colombia by quarantine authorities in several countries (Gunawardana et al., 2017).

Thrips palmi is a species of great importance in different crops. It has been described from southern Asia and has been reported in many other countries since 1978 (Reitz et al., 2011). In Colombia, it was first detected in 1997 in Valle del Cauca and later in Antioquia, where it has caused considerable damage (Guarín-Molina, 2003). This insect is specially monitored in the Bogota plateau, especially in ornamental crops for exports for being a regulated pest in some countries, especially in Europe (Cannon et al., 2007a; International Plant Protection Convention (IPPC), 2016).

Thrips tabaci seems to have originated in Central Asia. From there, it then spread around the world, attacking different plants, especially of the families Compositae, Cruciferae, Cucurbitaceae, Malvaceae and Solanaceae (Chacón, 2002).

These four species have similar and characteristic thripid life cycle, consisting of an egg phase, two active larval instars, quiescent prepupal and pupal stages, and the adult (Moritz, 1997). The eggs are deposited by the female within any non-woody tissue of the aerial part of the plant, through the incision of the vegetal tissue with the ovipositor (Moritz, 1997; Reitz et al., 2011). Due to the protection of plant tissues, eggs are difficult to detect, being also little affected by chemical products.

The two active larval instars are similar to the adult, from which they are distinguished by the absence of wings and genital organs. They occupy the same ecological niche as adults (Moritz, 1997). Larvae and adults may be variably distributed in crops, but are commonly grouped in protected places such as flowers, buds or leaf junction (Reitz et al., 2011). With this, its detection and control in the crops is difficult.

Some predatory species that can control thrips in Colombia have been reported. Chacón (2002) found Anthocoridae hemipterans with high levels of predation associated with thrips. Avellaneda et al. (2016) reported a population of *O. insidious* in the Bogota plateau preying on thrips, and Muñoz-Cárdenas et al. (2014) tested *Balaustium* sp. in the Bogota plateau as predator of different organisms, including *F. occidentalis*.

Pre-pupal and pupal stages are generally found outside the plant, in the litter or in the upper layers of the soil, although some may remain on the plant when flower architecture is complex, as in *Chrysanthemum* species. In roses it has been observed that between 87 and 95% of the larvae of *F. occidentalis* drop to the ground to pupate (Buitenhuis and Shipp,

2008). Chemical control in these phases has not been explored, but alternative methods such as biological control are currently under consideration.

1.2. Mesostigmata: important edaphic predators

Although the composition and proportion of different groups of invertebrates in the soil depend on the conditions at the collecting site, mites are generally the dominant group, reaching up to 85% of the invertebrate fauna (Morais et al., 2013). They are important in soil not only for the abundance, not rarely up to 100,000 individuals/ m^2 in temperate forests (Coleman et al., 2004; Morais et al., 2013), and diversity, but also for the variety of feeding habits, which allows them to have a wide range of strategies and to explore different soil resources (Lavelle and Spain, 2005). These organisms may be necrophagous, fungivorous, saprophagous, detritivorous, coprophagous, nematophagous, phytophagous and predatory (Walter and Proctor, 2013).

Mites are characterized by their influence on the soil through the control of populations of other organisms, such as fungi and small invertebrates, and the dispersion of important microorganisms in the decomposition and mineralization of organic matter (Coleman et al., 2004; Lavelle and Spain, 2005). These organisms have been used as indicators of environmental pollution, because their response in density and diversity can be influenced by changes such as those generated in agricultural production systems (Sánchez-Moreno et al., 2009). The mite groups most used as indicators are the Oribatida (Ruf et al., 2003) and the Mesostigmata (Bedano and Ruf, 2010; Ruf, 1998; Ruf and Beck, 2005), for their important role in processes that occur in the soil.

Edaphic Mesostigmata belong to an abundant and diverse group present universally in the soil. Although fungivorous and detritivorous mesostigmatid species are known in the soil, these mites are also well-known edaphic predators of other small invertebrates, including organisms that can cause damage to plants (Coleman et al., 2004; Koehler, 1999, 1997; Krantz and Ainscough, 1990, Stirling, 2014). Many species, especially of the subcohorts Dermanyssiae and Parasitiae, are considered aggressive predators that have a very active prey searching behavior on leaves and in the soil (Walter and Proctor, 2013). Although several mesostigmatid mites are currently recognized as important predators of other organisms in the soil, species belonging to few families, especially Laelapidae and Macrochelidae, are currently produced and used to control some pest organisms (Carrillo et al., 2015; Gerson et al., 2003).

1.3. Context of the research

The increase in the population of thrips in cut flower commercial production is reflected in the large number of interceptions being recorded in the destination countries of exports of Colombian agricultural products, of which United States is the principal. Although the interceptions of thrips have decreased since 2015, trips are still among the four most common insects found in shipments arriving in the countries that import Colombian flowers. Of the insects intercepted in Colombian flowers between 2015 and 2017, approximately 18% belong to Thysanoptera, among which species of *Thrips* and *Frankliniella* stand out (ICA-APHIS, unpublished data). The cargoes are returned or destroyed when the presence of at least one living or dead organism (insect) is detected. The economic losses that are registered by these insects indicate that current control strategies are not sufficiently effective.

These insects can cause reduction of the production and the quality of the flowers, for their direct and indirect damages. Direct damage corresponds to the destruction of the cells of plant tissue (Chisholm and Lewis, 1984; Corredor, 2004; Demirozer et al., 2012; Mound, 1971), while indirect damage corresponds to the virus transmission. Some thrips species, especially *Frankliniella occidentalis* (Pergante), transmit the disease known as Tomato Spotted Wilt Virus (TSWV). This disease turns plants useless for commercialization because of their aesthetic damage (Gill et al., 2001; Reitz, 2009; Tommasini and Maini, 1995).

The management of edaphic stages of thrips is an unexplored strategy in Colombia, promising good results based on results of research carried out in other countries. This strategy would interrupt the life cycle of thrips at a time when insects are not hidden in plant structures.

Mesostigmatid mites include predators that can be used in floriculture to control thrips in their edaphic phases. However, basic knowledge of these mites is still scarce in Colombia, which makes their practical use difficult. Therefore, it is necessary to expand knowledge, in order to use it to benefit an economic activity that generates significant income for the country.

As in the development of any biological control strategy, it is first necessary to understand the ecology of the habitat, starting with the determination of details of its physical qualities and biological composition (Parra et al., 2002; Zucchi, 2002). Under natural conditions, high abundance and diversity of mites are found in the soil, including species of the order Mesostigmata, many of which are predators. Knowledge about those mites may provide valuable options for the biological control of thrips pests. Being Colombia a leading

country in relation to biodiversity, the search for native edaphic predators for thrips control seems promising.

This thesis aims to answer the following questions: 1) what are the edaphic mesostigmatid mites in rose fields and in the natural vegetation prevailing in areas where rose production takes place in the Bogota plateau, Colombia most important rose production region?; 2) how is the population dynamics of the edaphic mesostigmatid mites in those areas?; 3) what are the predominant thrips species in rose fields in greenhouses and how are their dynamics in that region?; 4) do the most common mesostigmatid species show promise to justify further evaluation for use in practical control of the main thrips pests?

1.4. Research strategy

The work here reported was divided in two parts. The first part of the work consisted of the identification of the non-Uropodina Mesostigmata mite species present in rose fields and fragments or patches of natural vegetation at different stages of disturbance. This mite group is expected to contain large number of predatory mites. This part was divided into three chapters (2-4). Chapter 2 includes the identification of the mites in each of those two general habitats and information about the dynamics of their populations and of thrips populations. This chapter was followed by the morphological characterization of some of the species collected, including the description of some new species, presented in Chapters 3 and 4.

The second part involved biological studies of two species, selected by the high frequency with which they were found in the first part of the work. These studies are presented in Chapters 5 and 6, dealing with the predatory capacity and life table parameters of each species on *Frankliniella occidentalis* (Pergande) and other prey used as control.

References

Alves-Silva, E., Del-Claro, K., 2010. Thrips in the Neotropics: What do we know so far? Trends Entomol. 6, 77–88.

Arevalo, E., Quintero, O., Correa, G., 2003. Reconocimiento de trips (Insecta: Thysanoptera) en floricultivos de tres corregimientos del municipio de Medellín, Antioquia (Colombia). Rev. Colomb. Entomol. 29, 169–175.

ASOCOLFLORES, 2018. El Sector Floricultor en Colombia 2018.

ASOCOLFLORES, 2013. Una apuesta por el mercado local. Florycultura Colomb. Rev. la Asoc. Colomb. Floric. 17–18.

Avellaneda, J., Diaz, M., Acosta, D., Rodriguez, D., Cantor, F., 2016. Colecta de antocóridos y determinación de su capacidad depredadora sobre adultos de *Frankiniella occidenatils* (Pergande) (Thysanoptera, Thripidae). Rev. Fac. ciencias basicas 12, 8–21. https://doi.org/http://dx.doi.org/10.18359/rfcb.1850

Bedano, J.C., Ruf, A., 2010. Sensitivity of different taxonomic levels of soil Gamasina to land use and anthropogenic disturbances. Agric. For. Entomol. 12, 203–212. https://doi.org/10.1111/j.1461-9563.2009.00470.x

Berndt, O., Meyhöfer, R., Poehling, H.M., 2004. The edaphic phase in the ontogenesis of Frankliniella occidentalis and comparison of *Hypoaspis miles* and *Plypoaspis aculeifer* as predators of soil-dwelling thrips stages. Biol. Control 30, 17–24. https://doi.org/10.1016/j.biocontrol.2003.09.009

Berndt, O., Poehling, H.M., Meyhöfer, R., 2004. Predation capacity of two predatory laelapid mites on soil-dwelling thrips stages. Entomol. Exp. Appl. 112, 107–115. https://doi.org/10.1111/j.0013-8703.2004.00185.x

Buitenhuis, R., Murphy, G., Shipp, L., Scott-Dupree, C., 2015. *Amblyseius swirskii* in greenhouse production systems: a floricultural perspective. Exp. Appl. Acarol. 65, 451–464. https://doi.org/10.1007/s10493-014-9869-9

Buitenhuis, R., Shipp, J.L., 2008. Influence of plant species and plant growth stage on *Frankliniella occidentalis* pupation behaviour in greenhouse ornamentals. J. Appl. Entomol. 132, 86–88. https://doi.org/10.1111/j.1439-0418.2007.01250.x

Buitrago-Villanueva, I., Muñoz-Cárdenas, K., Bustos, A., Cantor, F., 2010. Evaluation of host plants for the production of the thrips *Frankliniella occidentalis* (Thysanoptera : Thripidae) as prey supply for its controllers. Rev. Fac. Ciencias Básicas 6, 12–23.

Bustillo-Pardey, A.E., 2009. Evaluación de insecticidas químicos y biológicos para controlar *Frankliniella occidentalis* (Thysanoptera: Thripidae) en cultivos de espárragos. Rev. Colomb. Entomol. 35, 12–17.

Calixto, 2005. Trips del suborden Terebrantia (Insecta: Thysanoptera) en la Sabana de Bogotá. Rev. Colomb. Entomol. 31 (2), 207-213.

Calvo, F.J., Knapp, M., van Houten, Y.M., Hoogerbrugge, H., Belda, J.E., 2015. *Amblyseius swirskii*: What made this predatory mite such a successful biocontrol agent? Exp. Appl. Acarol. 65, 419–433. https://doi.org/10.1007/s10493-014-9873-0

Cannon, R.J.C., Matthews, L., Collins, D.W., 2007a. A review of the pest status and control options for *Thrips palmi*. Crop Prot. 26, 1089–1098. https://doi.org/10.1016/j.cropro.2006.10.023

Cannon, R.J.C., Matthews, L., Collins, D.W., Agallou, E., Bartlett, P.W., Walters, K.F.A., Macleod, A., Slawson, D.D., Gaunt, A., 2007b. Eradication of an invasive alien pest, *Thrips palmi*. Crop Prot. 26, 1303–1314. https://doi.org/10.1016/j.cropro.2006.11.005

Capinera, J.L., 2001. Order Thysanoptera—Thrips, in: Handbook of Vegetable Pests. Academic Press, San Diego, pp. 535–550. https://doi.org/https://doi.org/10.1016/B978-012158861-8/50013-2

Cardenas, E., Corredor, D., 1993. Especies de trips (Thysanoptera : Thripidae) mas comunes en invernaderos de flores de la sabana de Bogota. Agron. Colomb. 10, 132–143.

Cárdenas, L., Rodríguez, M., 2011. Estudio de la agroindustria de las flores en Colombia y la creación de una empresa productora de flores de corte. Bogota: Univ. la Sabana. 166 p.

Carrillo, D., Moraes, G.J. de, Peña, J.E. (Eds.), 2015. Prospects for Biological Control of Plant Feeding Mites and Other Harmful Organisms. Springer International Publishing, Switzerland. https://doi.org/10.1007/978-3-319-15042-0

Castilho, R.C., de Moraes, G.J., Silva, E.S., Silva, L.O., 2009. Predation potential and biology of *Protogamasellopsis posnaniensis* Wisniewski & Hirschmann (Acari: Rhodacaridae). Biol. Control 48, 164–167. https://doi.org/10.1016/j.biocontrol.2008.10.004

Chacón, E.D., 2002. Búsqueda de depredadores nativos de trips en la sabana de Bogotá y evaluación de su eficacia sobre *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thiripidae) bajo condiciones de laboratorio. Universidad Nacional de Colombia-Bogotá.

Chisholm, I.F., Lewis, T., 1984. A new look at thrips (Thysanoptera) mouthparts, their action and effects of feeding on plant tissue. Bull. Entomol. Res. 74, 663–675. https://doi.org/DOI: 10.1017/S0007485300014048

Cloyd, R., 2009. Western flower thrips (*Frankliniella occidentalis*) management on ornamental crops grown in greenhouses: Have we reached an impasse. Pest Technol. 3, 1–9.

Coleman, D.C., Crossley Jr., D.A., Hendrix, P.F., 2004. Secondary Production: Activities of Heterotrophic Organisms—The Soil Fauna, in: Coleman, D.C., Crossley, D.A.J., Hendrix, P.F. (Eds.), Fundamentals of Soil Ecology. Academic Press, Burlington, pp. 79–185. https://doi.org/https://doi.org/10.1016/B978-012179726-3/50005-8

Corredor, D., 2004. Propuesta para la implementación de un manejo preciso de trips *Frankliniella occidentalis* (Pergande). Universidad Nacional de Colombia-Bogotá.

Demirozer, O., Tyler-Julian, K., Funderburk, J., Leppla, N., Reitz, S., 2012. *Frankliniella occidentalis* (Pergande) integrated pest management programs for fruiting vegetables in Florida. Pest Manag. Sci. 68, 1537–1545. https://doi.org/10.1002/ps.3389

Denholm, I., Cahill, M., Dennehy, T.J., Horowitz, A.R., 1998. Challenges with Managing Insecticide Resistance in Agricultural Pests, Exemplified by the Whitefly *Bemisia Tabaci*. Philos. Trans. Biol. Sci. 353, 1757–1767.

Ebssa, L., Borgemeister, C., Poehling, H., 2004. Effects of post-application irrigation and substrate moisture on the efficacy of entomopathogenic nematodes against western flower thrips, *Frankliniella occidentalis*. Entomol. Exp. Appl. 112, 65–72. https://doi.org/10.1111/j.0013-8703.2004.00184.x

Ebssa, L., Borgemeister, C., Poehling, H.M., 2006. Simultaneous application of entomopathogenic nematodes and predatory mites to control western flower thrips *Frankliniella occidentalis*. Biol. Control 39, 66–74. https://doi.org/10.1016/j.biocontrol.2006.02.005

Enkegaard, A., BrØdsgaard, H.F., 2000. *Lasioseius fimetorum*: A soil-dwelling predator of glasshouse pests? BioControl 45, 285–293. https://doi.org/10.1023/A:1009981920402

Farkas, P., Bagi, N., Szabó, Á., Ladányi, M., Kis, K., Sojnóczki, A., Reiter, D., Pénzes, B., Fail, J., 2016. Biological control of thrips pests (Thysanoptera: Thripidae) in a commercial greenhouse in Hungary. Polish J. Entomol. 85, 437–451. https://doi.org/https://doi.org/10.1515/pjen-2016-0028

Fenalco, 2017. Boletín Nº 46 Boletín Económico Sectorial Sector Floricultor. Investiga: Observatorio Económico de Comercio - Fenalco Antioquia.

Garzo, E.I., Collar, J.L., Muniz, M., Fereres, A., 2000. Eficacia del fipronil (EXP 60720A) en el control poblacional de *Frankliniella occidentalis* Pergande (Thysanoptera: Thripidae) en condiciones de laboratorio. Investig. Agrar. Prod. y Prot. Veg. 15, 57–65.

Gerson, U., Smiley, R.L., Ochoa, R., 2003. Mites (Acari) for Pest Control. Blackwell Science Ltd, Oxford. https://doi.org/10.1002/9780470750995

Gill, S., Clement, D.L., Dutky, E., 2001. Plagas y enfermedades de los cultivos de flores: estrategias biologicas. Ediciones Hortitecnia.

Guarín-Molina, J.H., 2003. *Thrips palmi* Karny en el Oriente Antioqueño, Corporación Colombiana de Investigación Agropecuaria. Centro de Investigación la Selva, Corpoica regional cuatro. Programa Nacional de Transferencia de Tecnología Agropecuaria, Pronatta, Rionegro, Antioquia, Colombia.

Gunawardana, D.N., Li, D., Masumoto, M., Mound, L.A., O'Donnell, C.A., Skarlinsky, T.L., 2017. Resolving the confused identity of *Frankliniella panamensis* (Thysanoptera: Thripidae). Zootaxa 4323, 125–131. https://doi.org/10.11646/zootaxa.4323.1.10

Hood, J.D., 1925. New Species of *Frankliniella* (Thysanoptera). Bull. Brooklyn Entomol. Soc. 20, 71–83.

ICA, ASOCOLFLORES, 2003. Plagas y enfermedades de carácter cuarentenario en flores de corte. Produmedios, Bogotá, D.C.

International Plant Protection Convention (IPPC), 2016. DP 1 : *Thrips palmi* Karny. Food and Agriculture Organization of the United Nations. International Plant Protection Convention, Rome.

Jensen, S.E., 2000. Insecticide Resistance in the Western Flower Thrips, *Frankliniella occidentalis*. Integr. Pest Manag. Rev. 5, 131–146. https://doi.org/10.1023/A:1009600426262

Kim, D.I., Park, J.D., Kim, S.G., Kim, S.S., Paik, C.H., 2004. Biological Control of *Thrips palmi* (Thysanoptera: Thripidae) with Orius strigicollis (Hemiptera: Anthocoridae) on Cucumber in Plastic Houses in the Southern Region of Korea. J. Asia. Pac. Entomol. 7, 311–315. https://doi.org/10.1016/S1226-8615(08)60232-0

Kirk, W.D.J., Terry, L.I., 2003. The spread of the western flower thrips *Frankliniella occidentalis* (Pergande). Agric. For. Entomol. 5, 301–310. https://doi.org/10.1046/j.1461-9563.2003.00192.x

Koehler, H.H., 1999. Predatory mites (Gamasina, Mesostigmata). Agric. Ecosyst. Environ. 74, 395–410. https://doi.org/10.1016/S0167-8809(99)00045-6

Koehler, H.H., 1997. Mesostigmata (Gamasina, Uropodina), efficient predators in agroecosystems. Agric. Ecosyst. Environ. 62, 105–117. https://doi.org/10.1016/S0167-8809(96)01141-3

Krantz, G.W., Ainscough, B.D., 1990. Acarina: Mesostigmata (Gamasida), in: Dindal, D.L. (Ed.), Soil Biology Guide. A Wiley-Interscience Publication, New York, pp. 583–666. https://doi.org/10.1016/0038-0717(91)90088-2

Lavelle, P., Spain, A., 2005. Soil Ecology. Dordrecht Kluwer Academic Publishers, Boston.

Laznik, Ž., Trdan, S., 2008. Entomopathogenic and entomoparasitic nematodes as biological control agents of thrips. Acta Phytopathol. Entomol. Hungarica 43, 317–322. https://doi.org/10.1556/APhyt.43.2008.2.15

López-Bermúdez, R., 2014. Evaluación de la capacidad de depredación de la especie de Stratiolaelaps sp. (Acari: Laelapidae) en poblaciones de *Thrips palmi* karny (Thysanoptera: Thripidae). Universidad Nacional de Colombia, Palmira.

Manrique-Ramírez, L.N., Zuleta-Zea, D., Agudelo-Ochoa, A.F., Burgos-Zuleta, S.A., Jerez-Cano, D., Mejía-Tabares, J.D., Pereira-Ruíz, M.P., Palacio-Trujillo, V., Manrique Ramírez, L.N., 2014. Floricultura colombiana en contexto: experiencias y oportunidades en Asia pacífico. Online J. Mundo Asia Pacifico 3, 52–79.

McQuaid, J., 2011. The Secrets Behind Your Flowers Chances [WWW Document]. Smithson. Mag. URL https://www.smithsonianmag.com/travel/the-secrets-behind-your-flowers-53128/ (accessed 4.29.18).

Messelink, G., Holstein-saj, R. Van, 2008. Improving thrips control by the soil-dwelling predatory mite *Macrocheles robustulus* (Berlese). Integr. Control Prot. Crop. 32, 135–138.

Messelink, G.J., De Kogel, W.J., 2005. Impact of chrysanthemum cultivar, fertilization and soil-dwelling predatory mites on *Frankliniella occidentalis*. Proc. Netherlands Entomol. Soc. Meet. 16, 101–107.

Morais, J.W., Oliveira, F.L., Braga, R.F., Korasaki, V., 2013. Mesofauna, in: Moreira, F.M.S., Cares, J.E., Zanetti, R., Stürmer, S.L. (Eds.), O ecossistema solo: componentes, relações ecológicas e efeitos na produção vegetal. Universidade Federal de Lavras, Lavras, pp. 183–200.

Moreira, G.F., de Morais, M.R., Busoli, A.C., de Moraes, G.J., 2015. Life cycle of *Cosmolaelaps jaboticabalensis* (Acari: Mesostigmata: Laelapidae) on *Frankliniella occidentalis* (Thysanoptera: Thripidae) and two factitious food sources. Exp. Appl. Acarol. 65, 219–226. https://doi.org/10.1007/s10493-014-9870-3

Moritz, G., 1997. Structure, Growth and Development (Chapter 2), in: Lewis, T. (Ed.), Thrips as Crop Pests. CAB International, Wallingford, pp. 15–64.

Moritz, G., Mound, L.A., Morris, D.C., Goldarazena, A., 2004. Pest Thrips of the World — Visual and Molecular Identification of Pest Thrips , Cd-Rom. https://doi.org/10.1653/024.092.0326

Morse, J.G., Hoddle, M.S., 2006. Invasion Biology of Thrips. Annu. Rev. Entomol. 51, 67–89. https://doi.org/10.1146/annurev.ento.51.110104.151044

Mound, L.A., 2005. Thysanoptera: Diversity and Interactions. Annu. Rev. Entomol. 50, 247–269. https://doi.org/10.1146/annurev.ento.49.061802.123318

Mound, L.A., 1971. The feeding apparatus of thrips. Bull. Entomol. Res. 60, 547–548. https://doi.org/DOI: 10.1017/S0007485300042309

Muñoz-Cárdenas, K., Fuentes, L.S., Cantor, R.F., Rodríguez, C.D., Janssen, A., Sabelis, M.W., 2014. Generalist red velvet mite predator (*Balaustium* sp.) performs better on a mixed diet. Exp. Appl. Acarol. 62, 19–32. https://doi.org/10.1007/s10493-013-9727-1

Parra, J.R.P., Botelho, P.S.M., Corrêa-Ferreira, B.S., Bento, J.M.S., 2002. Controle Biológico no Brasil: parasitóides e predadores, 1 ed. ed. Editora Manole Ltda., Barueri – SP. https://doi.org/10.5700/rausp1110

Reitz, S.R., 2009. Biology and ecology of the Western Flower Thrips (Thysanoptera: Thripidae): the making of a pest. Florida Entomol. 92, 7–13. https://doi.org/10.1653/024.092.0102

Reitz, S.R., Yu-lin, G., Zhong ren, L., 2011. Thrips: Pests of Concern to China and the United States. Agric. Sci. China 10, 867–892. https://doi.org/10.1016/S1671-2927(11)60073-4

Reyes, F., 2017. Desempeño del Sector Floricultor: Informe. Bogotá, D.C.

Romero-Álvarez, Y., 2011. Incidencia del PIB agropecuario en el PIB nacional. Evolución y transformación. Gestión y Desarro. 8, 49–60. https://doi.org/http://dx.doi.org/10.21500/01235834.1832

Rosenheim, J.A., Johnson, M.W., Mau, R.F.., Welter, S.C., Tabashnik, B.E., 1996. Biochemical Preadaptations, Founder Events, and the Evolution of Resistance in Arthropods. J. Econ. Entomol. 89, 263–273.

Ruf, A., 1998. A maturity index for predatory soil mites (Mesostigmata: Gamasina) as an indicator of environmental impacts of pollution on forest soils. Appl. Soil Ecol. 9, 447–452. https://doi.org/10.1016/S0929-1393(98)00103-6

Ruf, A., Beck, L., 2005. The use of predatory soil mites in ecological soil classification and assessment concepts, with perspectives for oribatid mites. Ecotoxicol. Environ. Saf. 62, 290–299. https://doi.org/10.1016/j.ecoenv.2005.03.029

Ruf, A., Beck, L., Dreher, P., Hund-Rinke, K., Römbke, J., Spelda, J., 2003. A biological classification concept for the assessment of soil quality: “Biological soil classification scheme” (BBSK). Agric. Ecosyst. Environ. 98, 263–271. https://doi.org/10.1016/S0167-8809(03)00086-0

Sánchez-Moreno, S., Nicola, N.L., Ferris, H., Zalom, F.G., 2009. Effects of agricultural management on nematode-mite assemblages: Soil food web indices as predictors of mite community composition. Appl. Soil Ecol. 41, 107–117. https://doi.org/10.1016/j.apsoil.2008.09.004

Stirling, G.R., 2014. Biological control of plant-parasitic nematodes: soil ecosystem management in sustainable agriculture, 2nd ed. ed. CABI Pub., Croydon, UK. https://doi.org/10.1079/9781780644158.0000

Tommasini, M.G., Maini, S., 1995. *Frankliniella occidentalis* and other thrips harmful to vegetable and ornamental crops in Europe. Wageningen Agric. Univ. Pap. 95, 1–42.

Valcárcel, F., 2013. El control biológico de plagas en la floricultura colombiana. Florycultura Colomb. Rev. la Asoc. Colomb. Floric. 37–39.

Valencia, E., 2013. Control y manejo de los Thrips en los sistenas de floricultura colombiana. Florycultura Colomb. Rev. la Asoc. Colomb. Floric. 45–49.

Van Houten, Y.M., Østlie, M.L., Hoogerbrugge, H., Bolckmans, K., 2005. Biological control of western flower thrips on sweet pepper using the predatory mites Amblyseius cucumeris, Iphiseius degenerans, A. andersoni and A. swirskii. IOBC/WPRS Bull. 28, 283–286.

van Houten, Y.M., van Rijn, P.C.J., Tanigoshi, L.K., van Stratum, P., Bruin, J., 1995. Preselection of predatory mites to improve year-round biological control of western flower thrips in greenhouse crops. Entomol. Exp. Appl. 74, 225–234. https://doi.org/10.1111/j.1570-7458.1995.tb01895.x

van Lenteren, J.C., 2011. The state of commercial augmentative biological control: Plenty of natural enemies, but a frustrating lack of uptake. BioControl 57, 1–20. https://doi.org/10.1007/s10526-011-9395-1

van Lenteren, J.C., Cock, M.J.W., Brodeur, J., Barratt, B.I.P., Bigler, F., Bolckmans, K., Haas, F., Mason, P.G., Parra, J.R.P., 2011. Will the Convention on Biological Diversity put an end to biological control? Rev. Bras. Entomol. 55, 1–5. https://doi.org/10.1590/S0085-56262011000100001

Vargas, R., Ubillo, A., 2005. Susceptibilidad de *Frankliniella occidentalis* (Thysanoptera: Thripidae) a Insecticidas en la Zona Central de Chile. Agric. Técnica 65, 437–441. https://doi.org/10.4067/S0365-28072005000400009

Walter, D.E., Proctor, H.C., 2013. Mites: Ecology, Evolution & Behaviour. Life at a Microscale, Second. ed. Springer, Dordrecht.

Zucchi, R.A., 2002. A taxonomia e o controle biológico de pragas, in: Parra, J.R.P., Botelho, P.S.M., Corrêa-Ferreira, B.S., Bento, J.M.S. (Eds.), Controle Biologico No Brasil. Editora Manole Ltda., Barueri - SP, pp. 17–27.

2. EDAPHIC NON-UROPODINA MESOSTIGMATID MITES (ACARI: MESOSTIGMATA) AND THRIPS (INSECTA: THYSANOPTERA) IN ROSE CULTIVATION AND SECONDARY VEGETATION AREAS IN THE BOGOTÁ PLATEAU, COLOMBIA)

ABSTRACT

Mesostigmatid mites are common predators in the soil, and some of these have been used as biological control agents of pest arthropods. Their use for that purpose in rose crops in Colombia is highly desirable, to complement the adopted pest management strategies. One of the first steps in the development of a biological control program is the determination of the natural enemies of the target pest in the target area. The objectives of this study were: 1) To identify the main species of mites of the order Mesostigmata (excluding Uropodina) in soils of rose fields and of the surrounding secondary vegetation in the Bogota plateau, relating their occurrence to soil characteristics; 2) To determine the dynamics of the density of those mites and of thrips in selected areas of that plateau. The study was conducted between August 2015 and December 2016, in four rose fields at Nemocon, Tocancipa Cogua and Guasca, and patches of secondary vegetation next to the latter two localities. Twenty soil samples were taken every two months from each area. Complementary samplings were conducted at irregular frequencies in a rose field and a patch of secondary vegetation of other region of the Bogota plateau (Facatativa) and in two patches of high Andean forest (La Calera and Soacha). Mites were extracted from the samples in Berlese funnels and mounted with Hoyer´s medium. It was observed that, despite the high species richness observed in the rose fields, the number of species was higher in patches of secondary vegetation and of Andean forest. In both rose cultivation and secondary vegetation, Parasitidae and Laelapidae were the dominant families throughout the study, but high proportions of Veigaiidae and Blattisociidae were also found in secondary vegetation. Species of *Parasitus* and *Gaeolaelaps* were the most dominant in all areas and sampling times. In rose plantations, the second dominant genus was *Cycetogamasus* (Parasitidae), while in secondary vegetation *Lasioseius* (Blattisociidae), *Paragamasus*, *Pergamasus* (Parasitidae) and *Veigaia* (Veigaiidae) were also dominant. Deutonymphs and adults were found in higher proportions than any other stage in rose plantations, while adults were invariably found in higher proportions in areas of secondary vegetation. Total mite abundance was linearly (and positively) correlated with content of organic matter, pH and presence of patch of secondary vegetation. The faunistic composition determined in this study is rather different from that of the surrounding Neotropical regions, given the high elevation of study sites (2460-2777 m) and the characteristic rose cultivation selection pressure, involving frequent use of pesticides. A total of 21 thrips species was found, distributed in four genera of the family Thripidae. The most frequent species were *Frankliniella panamensis* Hood, *Frankliniella occidentalis* (Pergande), *Thrips australis* (Bagnall) and *Thrips tabaci* Lindeman. The highest mean thrips density was observed in the municipality of Guasca, in April 2016. The study showed the great diversity of Mesostigmata in the areas where it was conducted (altogether, 96 species), at least eight of which new to science and several in need of better taxonomic characterization. The results indicated the need to focus subsequently in the conduction of taxonomic and biological studies, respectively to describe the new species collected and complement the description of previously described taxa, and to determine the potential of the most frequently found mites as biological control agents of the main thrips pest.

Keywords: Parasitidae; Laelapidae; Veigaiidae; Mite species; Andean region

2.1. Introduction

Flower fields constitute one of the most important agroecosystems in Colombia, both economically and socially, for allowing the income of approximately 1300 million dollars a year from exportation and for generating jobs to about 130,000 workers (ASOCOLFLORES 2011, 2018; Reyes 2017). Rose is one of the main flowers produced commercially in Colombia. Revenue from rose production reaches almost 30% of the total from flower exportation (ASOCOLFLORES 2011; Fenalco 2017), for the high demand for Colombian roses in the international market. Rose production in this country is mainly done in Cundinamarca Department, in the Bogotá plateau (Fenalco 2017).

Some of the main factors limiting rose production and commercialization are phytosanitary problems (Valcárcel 2013). Insects of the order Thysanoptera are considered the most important ornamental pests in Colombia, especially for attacking flowers (Valencia 2013). Given their small sizes and preference for secluded microhabitats, exported lots are not rarely returned or destroyed when those insects are found alive or dead on the exported products(Attavian 2014), causing heavy economic losses.

Although different strategies are used for thrips management in the field and after harvesting, control depends mostly on chemical applications (Garzo et al. 2000; Vargas and Ubillo 2005; Bustillo-Pardey 2009). This leads to high selection pressure for resistance and risks of producer intoxication and environmental pollution. Thus, alternative and complementary strategies, such as biological control, are currently highly valued for this and other arthropod pests (van Lenteren 2011), not only in Colombia but also in other countries.

In some countries thrips have been controlled biologically with the use of natural enemies on the plants and on the soil. On plants, control agents are mites of the family Phytoseiidae (e.g. *Amblyseius swirskii* Athias-Henriot and *Amblydromalus limonicus* (Garman and McGregor)) (van Lenteren 2011; Buitenhuis et al. 2015), and insects such as *Orius insidiosus* (Say) (Hemiptera: Anthocoridae), all of which feed mainly on thrips nymphs (van Lenteren 2011; Avellaneda et al. 2016). On the soil surface, control is done with the use of predatory mites (especially *Gaeolaelaps aculeifer* (Canestrini) and *Macrocheles robustulus* (Berlese)) (Messelink and Holstein-saj 2008; van Lenteren 2011), envisioning mainly the control of pre-pupae and pupae, found in the litter and the upper soil layer (Buitenhuis and Shipp 2008; Reitz 2009; Reitz et al. 2011). None of these thrips control agents have been commercially used in Colombia.

One of the first steps in the development of a biological control program is the determination of the natural enemies of the target pest in the target area, so that in a subsequent phase their efficiency could be compared, seeking the determination of the most promising. High mite diversity and abundance can be found in undisturbed soils. Given that Colombia is a leading country in relation to biodiversity (Lobo 2008), finding natural enemies adapted to local conditions that could be used for pest control is warranted.

The objectives of his work were: 1) To identify the main species of mites of the order Mesostigmata (excluding Uropodina) in soils of rose fields and of the surrounding secondary vegetation in the Bogota plateau, relating their occurrence to soil characteristics; 2) To determine the dynamics of the density of those mites and of thrips in selected areas of that plateau. The hypotheses to be tested were: 1) The fauna of the Bogotá plateau resembles that of temperate areas, given the prevailing environmental conditions of high altitude, despite the relative closeness of the plateau to the equator; 2) The number of species of non-Uropodina is much lower in rose fields than in the secondary vegetation, for the much more homogeneous environment in the former; 3) The predominant groups vary between collecting sites, given the different soil characteristics.

2.2. Material and Methods

2.2.1. Study sites and collection dates

Soil samples were periodically collected from four rose fields (in greenhouses, as usual in Colombia) and from areas of secondary vegetation near two of those rose fields. The greenhouses (each 70–80 x 80–95 m) were located in the municipalities of Cogua (hereafter indicated as CR), Guasca (GR), Nemocón (NR) and Tocancipa (TR).

Rose plants were 1–4 years old, about 2 m high, planted in the soil on beds at a spacing of 15–20 cm within beds and 80–100 cm between beds, using varieties (Table 1) typical for the production of a single flower per stem. Each greenhouse had 110–192 beds of 30–35 m in length, arranged in two blocks separated by a central corridor 2–3 m wide. The production system was continuous, with all phenological stages concurrently presented.

Soil fertilization in rose fields was done weekly, through the irrigation system (ferti-irrigation). All farms had biological control programs to manage spider mites using mainly *Neoseiulus californicus* (McGregor) and *Phytoseiulus persimilis* Athias-Henriot), but other

pests were mainly controlled chemically, as judged necessary by growers, but usually involving at least two applications a week.

The two patches of secondary vegetation were located respectively 60 and 150 m from the greenhouses at Cogua (hereafter indicate as CV) and Guasca (GV). Data from the secondary vegetation were expected to serve as a reference to the species native to the area, part of which could have been eliminated because of the adopted rose production system.

Samples were collected every other month, between August 2015 and December 2016. Sampling was preferably conducted in the first week of the month, except when that period corresponded to chemical sprays or use of other control methods. When that happened, sampling was conducted 1–2 weeks later.

Additionally, complementary samples were taken at irregular frequencies from other regions of the Bogota plateau (additional details presented in Table 1). They were collected from a greenhouse (FR) and a patch of secondary vegetation (FV) in the municipality of Facatativa, and from two patchs of high Andean forest in the municipalities of La Calera (LV) and Soacha (SV).

The climate of the region is classified as of the Cfb type, characterized by the temperate climate, without dry season, and with at least four month with average temperature above 10 ^{o}C (Köppen-Geiger classification system; Peel et al. 2007). Temperature and rainfall data were obtained from the closest weather station, located 8–10 km away (Source: ASOCOLFLORES, Canal Clima). A characterization of all greenhouses and secondary vegetation patches is provided in Table 1; their locations are shown in Figure 1.

2.2.2. Sample collection, mite extraction and identification

From each sampling site, 20 samples were collected at each date. In each greenhouse, the samples were uniformly distributed in a grid, each sampling site about 15 m from each other. Because of the irregular shape, samples in the vegetation patches, as much as possible, were also distributed in a grid, with distance between sampling sites varying from 3 to 15 m.

Each sample was collected with a cylinder (10 cm in diameter and 5 cm in length) totally inserted in the soil. At the center of each square formed by four neighboring mite sampling points, a sample of about 500 g of soil was collected to a depth of 5 cm for the characterization of different physicochemical variable (total of 12 samples). Each sample for mite collection was put in a plastic bag and transported to a laboratory in expanded

polystyrene foam boxes in which the temperature was maintained around 15 °C, where mites were immediately extracted using modified Berlese funnels. Each sample for physicochemical evaluation was also put in a plastic bag, transported to the laboratory and stored at 4°C (for at most 8 days), when analyses were performed.

Extracted non-Uropodina mesostigmatid mites were mounted in Hoyer's medium and first identified to family, based mainly on Lindquist, Krantz and Walter (2009). Adult females were identified to genera, based mainly on Bhattacharyya (1963), Farrier (1957), Hyatt (1980), Krantz and Ainscough (1990), and unpublished keys of the Acarology Summer Program (Soil Acarology, Ohio State University, 2014), and to species, based on the original descriptions and complementary descriptions.

The density of the species present in each sample was determined based on the total non-Uropodina Mesostigmata mites of all developmental stage. While doing so, pharate specimens were considered to belong to the younger stage. Richness and proportion of families was determined based solely on adult females.

2.2.3. Thrips monitoring, processing and identification

Only adult thrips were monitored, using traps, each consisting of a white rectangle of white acrylic (20 x 25 cm) maintained flat open and covered with motor oil on both sides. In each greenhouse where the periodic collections were performed, 24–27 traps (one trap per 100 m^2) were installed at the level of the flowers. Traps were examined weekly, counting the thrips and removing them for storage in 70% ethanol.

To remove oil residues, thrips were left for 48 h in Varsol® solvent and then washed in a solution of Axion® aloe vera liquid soap (3 mL : 20 mL distilled water). They were then placed in a 10% KOH solution for clarification, remaining in this solution for different periods, determined for each specimen by continuous observations under a dissecting microscope. After clarification, the specimens were washed again with distilled water and mounted on microscope slides in Hoyer's medium. Identification was done by a Thysanoptera specialist.

Table 1. Location, characteristics and dates of the collection of soil non-Uropodina mesostigmatid mites in the Bogota plateau (Cundinamarca, Colombia).

Municipality	Vereda	Farm	Coordinates DMS	Elevation (m)	Date of collection	Vegetation cover	Vegetation details	Code*
Cogua	El Mortiño	Agua Clara	05°03'23.3"N 073°55'44.4"W	2584–2589	14-Aug-15; 28-Sep-15; 1-Dec-15; 1-Feb-16; 4-Apr-16; 7-Jun-16; 8-Aug-16; 4-Oct-16; 12-Dec-16	Roses	Greenhouse with *Rosa* sp. Freedom var.	CR
Nemocón	Checua	Flores el Futuro	05°07'03.1–03.2"N 073°51'31.7–31.9"W	2584–2591	13-Aug-15; 2-Oct-15; 4-Dec-15; 4-Feb-16; 8-Apr-16; 10-Jun-16; 12-Aug-16; 7-Oct-16; 20-Dec-16	Roses	Greenhouse with *Rosa* sp. Freedom, Green Tea, Ocean Song and Sophie var.	NR
Facatativa	El Corzo	San Pedro	04°46'39.4–40.7"N 074°19'23.9–24.8"W	2572–2575	23-Aug-16; 11-Oct-16; 14-Dec-16	Roses	Greenhouse with *Rosa* sp. Freedom var.	FR
Tocancipa	El Porvenir	El Placer	04°59'19.3"N 073°54'15.9"W	2581–2601	19-Aug-15; 29-Sep-15; 2-Dec-15; 9-Feb-16; 5-Apr-16; 8-Jun-16; 9-Aug-16; 5-Oct-16; 13-Dec-16	Roses	Greenhouse with *Rosa* sp. Freedom var.	TR
Guasca	San José	La Toma	04°50'38.3"N	2572–	26-Aug-15;	Roses	Greenhouse with *Rosa* sp.	GR

Municipality	Vereda	Farm	Coordinates DMS	Elevation (m)	Date of collection	Vegetation cover	Vegetation details	Code*
			073°53'07.9"W	2575	5-Oct-15; 3-Dec-15; 2-Feb-16; 15-Apr-16; 9-Jun-16; 11-Aug-16; 6-Oct-16; 22-Dec-16		Freedom, Isabel, Matilda and Tiffany var.	
Cogua	El Mortiño	Agua Clara	05°03'19.00–23.4"N 073°55'42.4–44.3"W	2584–2609	14-Aug-15; 28-Sep-15; 1-Dec-15; 1-Feb-16; 4-Apr-16; 7-Jun-16; 8-Aug-16; 4-Oct-16; 12-Dec-16	Secondary vegetation	Patch of secondary vegetation of about 920 m^2 between greenhouses with rose cultivation. Shrubby vegetation mainly composed of *Pyracantha coccinea* M. Roem. and *Rubus glaucus* Benth. (both Rosaceae) and *Abutilon striatum* Dicks. ex Lindl. (Malvaceae)	CV
Facatativa	El Corzo	La Esmeralda	04°59'53.6–56.6"N 074°19'13.9–17.5"W	2576–2583	25-Aug-16; 14-Oct-16; 14-Dec-16	Secondary vegetation	Patch of secondary vegetation of about 7900 m^2 between greenhouses with rose cultivation. Arboreal and shrubby vegetation with *Agapanthus* sp. (Amaryllidaceae), *Sambucus perubiana* Kunth (Adoxaceae), *Solanum quitoense* Lam., *Solanum betaceum* Cav. (both Solanaceae), *Abutilon* spp. (Malvaceae), *Salix humboldtiana* Willd. (Salicaceae), *Ligustrum lucidum* W.T.Aiton (Oleaceae), *Acacia baileyana* F.Muell. (Leguminosae), *Eugenia* sp. (Myrtaceae), *Cotoneaster pannosus* Franch. (Rosaceae),	FV

Municipality	Vereda	Farm	Coordinates DMS	Elevation (m)	Date of collection	Vegetation cover	Vegetation details	Code*
							Lafoensia acuminata (Ruiz & Pav.) DC. (Lythraceae),	
Guasca	San José	La Toma	04°50´50.5–54.6"N 073°53´03.98-5.8"W	2676–2681	26-Aug-15; 30-Sep-15; 3-Dec-15; 2-Feb-16; 7-Apr-16; 9-Jun-16; 11-Aug-16; 6-Oct-16; 15-Dec-16	Secondary vegetation	Patch of secondary vegetation of about 4900 m^2 between greenhouses with rose cultivation. Arboreal and shrubby vegetation dominated by *Sambucus peruviana* Kunth (Adoxaceae), *Acacia* sp. (Fabaceae) and *Cucurbita* sp. (Cucurbitaceae)	GV
Soacha	San Francisco	Granja El Porvenir	04°34´31.9–33.7"N 074°17´50.87"W	2460–2508	10-Feb-15; 3-Jul-16	Secondary vegetation	Patch of forest of about 58780 m^2 with most conserved arboreal vegetation including *Cedrela* sp. (Meliaceae), *Juglans* sp. (Juglandaceae), *Cyathea* sp. (Cyatheaceae) and ferns	SV
La Calera	Mundo Nuevo	San José del Palmar	04°39´0.21"N 73°51´0.07"W	2736–2764	10-Jan-17	Secondary vegetation	Patch of forest of about 12420 m^2 with most conserved arboreal vegetation dominated mainly by *Weinmannia* spp. (Cunoniaceae), *Drymis granadensis* L. (Winteraceae), *Clusia multiflora* Kunth (Clusiaceae), *Ageratina tinifolia* (Kunth) R. M. King & H. Rob. (Asteraceae), as well as by species of Brunelliaceae, Lauraceae, Melastomataceae and Rubiaceae (Rangel-Ch & Ariza-N, 2000; IDEAM, 2011)	LV

* The first letter of each code indicates the municipality where the sampling was conducted, and the last, the vegetation cover: C = Cogua, Agua Clara farm; N = Nemocón, Flores el Futuro farm; T = Tocancipa, El Placer farm; G = Guasca, La Toma farm; R = rose fields; V = patches of secondary vegetation.

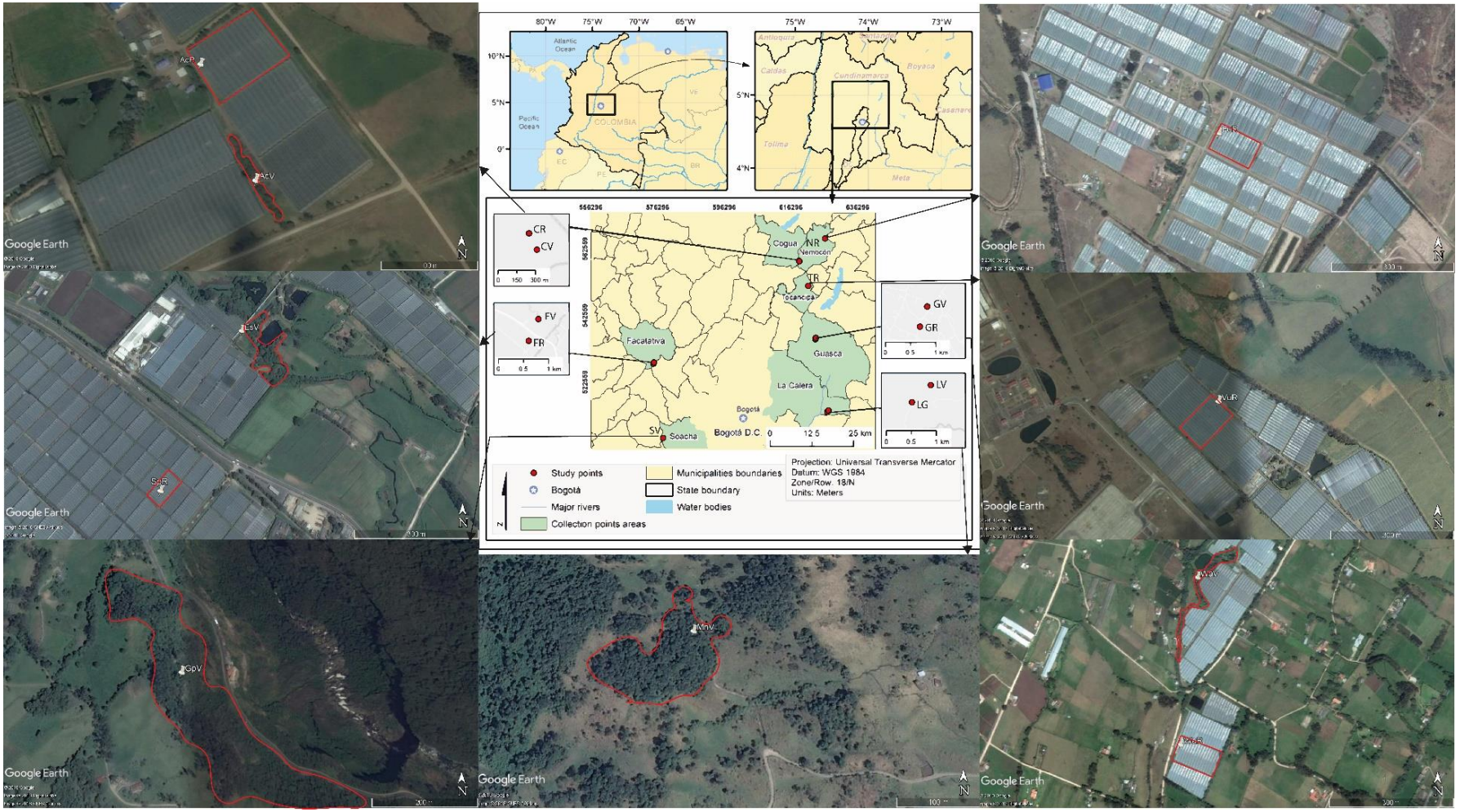


Figure 1. Location of the collecting sites in the Bogota plateau. The first letter of each code indicates the municipality where the sampling was conducted, and the last, the vegetation cover: **C** = Cogua, Agua Clara farm; **N** = Nemocón, Flores el Futuro farm; **T** = Tocancipa, El Placer farm; **G** = Guasca, La Toma farm; **R** = rose fields; **V** = patches of secondary vegetation

2.2.4. Soil physicochemical analyses

The following parameters were determined: pH (with potentiometer of a 1:1 v/v in distilled water), soil moisture (by gravimetric method, with precision of 0.01 g), percentage of organic matter (by calcination), texture (Bouyucos method) and electrical conductivity (conductivity measured in a suspension with 1:1 v/v in distilled water). The soils of all samples were classified as either sandy loam or silt loam (low clay content), and as non-saline (electrical conductivity lower than 0.98 dS/m, USDA, 1999).

2.2.5. Analysis

Spearman linear correlation analyses were conducted at 5% significance level to assess the influence of the following factors on total mite abundance in a given sampling month: total rainfall, average environmental and soil temperature, soil content of organic matter and water, pH, habitat (rose field= 0; secondary vegetation= 1), municipality (Cogua= 1, Guasca= 2, Nemocon=3, Tocancipa= 4) and sampling order.

Morisita-Horn similarity index was used to relate the non-Uropodina mesostigmatid mites obtained from periodic samplings (not of the complementary samplings) at the different sites and at different sampling occasions. Statistical analyses were done using the R, version 3.4.4 (The R foundation for Statistical Computing, 2018-03-15).

2.3. Results

2.3.1. Faunistic composition

A total of 17,139 non-Uropodina Mesostigmata was found in the periodic samplings, 7,594 of which in rose fields and 9,545 in patches of secondary vegetation.

Taking into account only adult females (given that in general only these can be identified reliably), the predominant families in rose fields were generally Parasitidae (36%), Laelapidae (30%), Ascidae (8%), Veigaiidae (7%), Macrochelidae and Ologamasidae (4%). In patches of secondary vegetation, the predominant families were Veigaiidae (26%), Parasitidae (20%), Laelapidae (19%), Blattisociidae (12%), Ologamasidae (5%) and Ascidae (5%) (Figures 2A, 3A and 4A).

In most sampling dates, Parasitidae was the dominant family in rose fields NR, TR and GR, except in December 2015 and April 2016 in NR, October 2015 and 2016 in TR and October and December 2015 in GR (Figure 2A, 3A and 4A). Highest variability of represented families occurred in the last sampling dates (August, October and December 2016), when families not previously found in this ecosystem were reported. In that same period, variability in mite density per sample was also highest, except for GR.

Gaeolaelaps aculeifer (Canestrini) and *Parasitus bituberosus* Karg were among the species most frequently found in both ecosystems (rose fields and patches of secondary vegetation) (Figures 6B, 7B and 8B). In rose fields, *P. bituberosus* was found in all sampling dates, while *G. aculeifer* was only not collected in October 2015, and August and December 2016 in NR, in December 2016 in TR, and in October and December 2016 in GR.

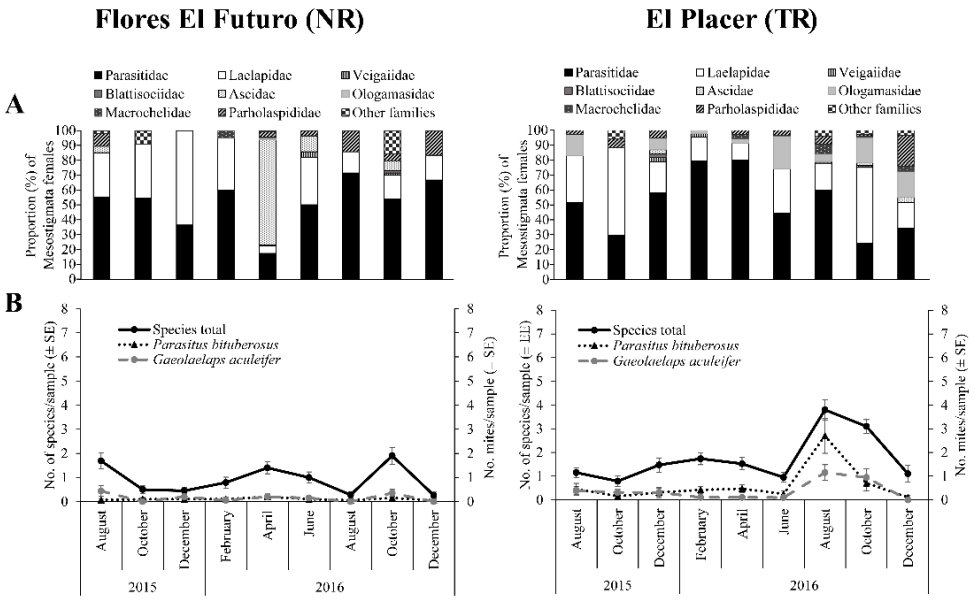


Figure 2. Proportions of (**A)** families of soil non-Uropodina Mesostigmata and (**B)** total numbers of species of non-Uropodina Mesostigmata, and number of adult females of *Parasitus bituberosus* and *Gaeolaelaps aculeifer* per sample (392.5 cm^3), in rose fields at Flores el Futuro farm - Nemocón (NR) and at El Placer farm - Tocancipa (TR) (Bogota plateau, Cundinamarca Colombia) from August 2015 to December 2016.

Higher variability of families was found in patches of secondary vegetation than in rose fields in all sampling dates, some families (e.g. Blattisociidae) being rarely found in rose fields (Figures 3A, 4A). This high variability of families also related with larger number of species per sample compared to that in greenhouses (Figures 3B, 4B).

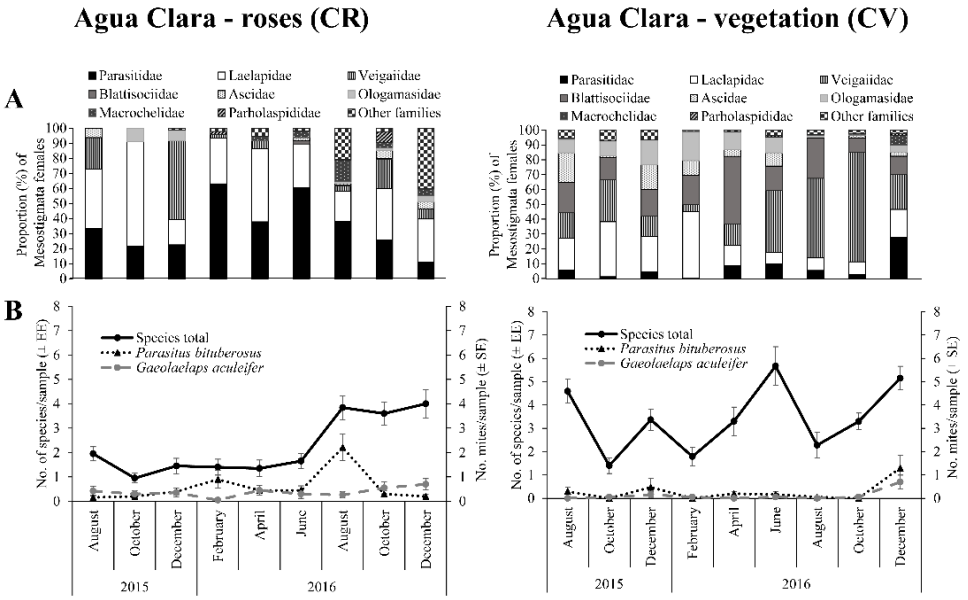


Figure 3. Proportions of (**A)** families of soil non-Uropodina Mesostigmata and (**B)** number of species of soil non-Uropodina Mesostigmata females, and number of females of *Parasitus bituberosus* and *Gaeolaelaps aculeifer* per sample (392.5 cm^3), in a rose field at (CR) and a patch of secondary vegetation (CV) at Agua Clara farm (Bogota plateau, Cogua, Cundinamarca, Colombia) from August 2015 to December 2016.

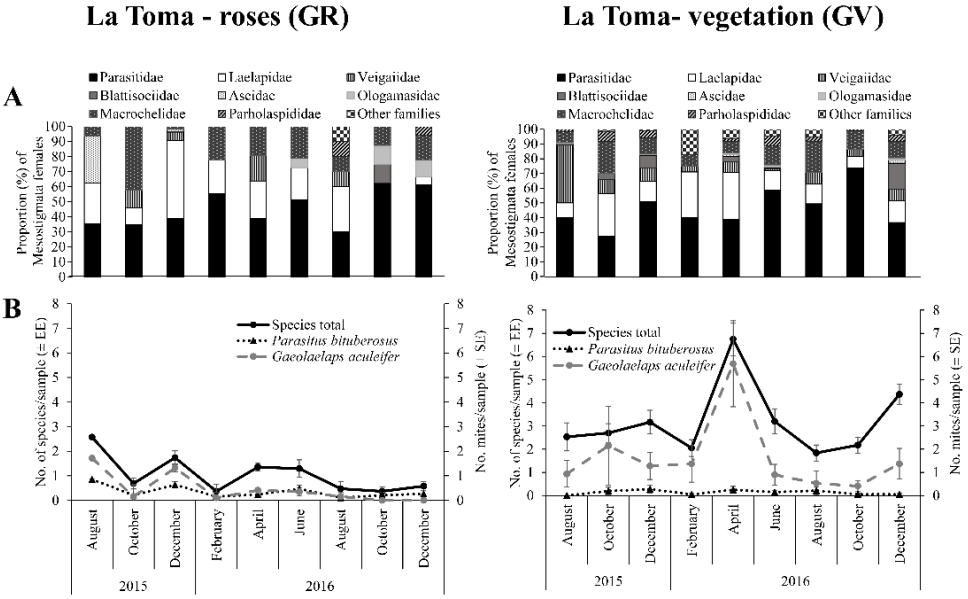


Figure 4. Proportions of (**A)** of families of soil non-Uropodina Mesostigmata and (**B)** total numbers of species of soil non-Uropodina Mesostigmata, and number of adult females of *Parasitus bituberosus* and *Gaeolaelaps aculeifer* per sample (392.5 cm^3) in a rose field (GR) and in a patch of secondary vegetation (GV) at La Toma farm (Bogota plateau, Guasca, Cundinamarca, Colombia) from August 2015 to December 2016.

Taking into account only the regular samplings (not including the complementary samplings), a total of 5,969 female specimens of 74 species, distributed in 48 genera of 17 families were collected (Table 2). Of these species, 48 were found in the greenhouses and 60

in the patches of secondary vegetation. Thirty-four species were found in both ecosystems. Most species (30 species) from rose fields were found in both Agua Clara (CR) and El Placer (TR).

Of the species identified, the parasitids *Cycetogamasus* sp. and *P. bituberosus*, and the laelapids *G. aculeifer* and *Gaeolaelaps* sp. nov were dominant in all sampling dates in rose fields (Table 2). *G. aculeifer*, *Gaeolaelaps* sp. nov. and *P. bituberosus* were also found frequently in areas of more conserved vegetation; however, instead of *Cycetogamasus* sp., both *Veigaia* sp. 3 (Veigaiidae) and *Paragamasus* sp. (Parasitidae) were found much more frequently. In patches of secondary vegetation, the following species were also very common: *Pergamasus* aff. *barbarus*, *Pergamasus* aff. *septentrionalis* (Parasitidae), *Lasioseius barbensiensis* Faraji & Karg and *Lasioseius* sp. 3 (Blattisociidae).

Epicriopsis (Ameroseiidae), *Asca* (Ascidae), *Blattisocius* (Blattisociidae), *Gymnolaelaps, Oloopticus* and *Stratiolaelaps* (Laelapidae), *Geholaspis* (Macrochelidae), *Pachyseius* (Pachylaelapidae), *Cornigamasus* and *Rhabdocarpais* (Parasitidae), *Amblyseius* (Phytoseiidae) and *Podocinum* (Podocinidae) were only found in soils of the patches of secondary vegetation (Table 2).

Table 2. Total numbers of soil non-Uropodina Mesostigmata collected in periodic samplings (bimonthly) in rose fields (Roses) and in patches of secondary vegetation (Vegetation) in the Bogotá plateau (Colombia) from August 2015 to December 2016.

		Roses			Vegetation		Total
Family	**Species**	**CR**	**NR**	**TR**	**GR**	**CV**	**GV**	
Ameroseiidae								
	Epicriopsis aff. *palustres*					2	5	7
	Epicriopsis sp. 1						26	26
	Sertitympanum aff. *aegypticum*	25		1				26
Ascidae								
	Arctoseius semiscissus (Berlese, 1892)	6		2	1	6	2	17
	Asca garmani Hurlbutt, 1963					80	1	81
	Asca lobata De Leon, 1967					29	6	35
	Iphidozercon sp. nov				2	37	1	40
	Protogamasellus sp. nov		1					1
	Protogamasellus aff. *mica*	23	123	5	13			164
Blattisociidae								
	Blattisocius dentriticus (Berlese, 1918)					1	1	2
	Cheiroseius latoventris Karg, 1998	1			1		2	4
	Lasioseius barbensiensis Faraji & Karg, 2006	2	1	1		174	8	186
	Lasioseius sp. 1					141		141
	Lasioseius sp. 2					73	5	78
	Lasioseius sp. 3						54	54

Family	Species	Roses				Vegetation		Total
		CR	NR	TR	GR	CV	GV	
Digamasellidae								
	Digamasellus sp.	60		4				64
Laelapidae								
	Gaeolaelaps queenslandicus (Womersley, 1956)	27	6	17	2	1	5	58
	Gaeolaelaps aculeifer (Canestrini, 1884)	67	26	68	58	21	258	498
	Gaeolaelaps sp. 1	20		2		1		23
	Gymnolaelaps sp. 1					1		1
	Gaeolaelaps sp. nov.	161	29	80	6	231	20	527
	Oloopticus reticulatus Karg, 1978					50		50
	Stratiolaelaps scimitus (Womersley, 1956)					32		32
Macrochelidae								
	Geholaspis sp. 1					2		2
	Glyptholaspis sp. 1				2		3	5
	Glyptholaspis sp. 1A		1		1	18	95	115
	Macrocheles glaber (Müller, 1860)				2		62	64
	Macrocheles merdarius (Berlese, 1889)			1				1
	Macrocheles robustulus (Berlese, 1904)	49	1	13	31	11	2	107
Melicharidae								
	Proctolaelaps sp. 1	17		4		5	17	43
	Proctolaelaps sp. 2					8		8
	Proctolaelaps sp. 3					6		6
	Proctolaelaps sp. 4	1				1		2
	Proctolaelaps sp. 5					3		3
	Proctolaelaps sp. 6						1	1
Ologamasidae								
	Gamasiphis sp. 1	21	2	6	5	166	10	210
	Gamasiphis sp. 2	3		52		6		61
Pachylaelapidae								
	Pachyseius sp. 1					14	1	15
Parasitidae								
	Cornigamasus sp. nov.						1	1
	Cycetogamasus sp.	80	87	108	48	6	1	330
	Dyneogamasus sp.		1					1
	Ernogamasus sp.			1		65	3	69
	Neogamasus sp.	10	15	36			1	62
	Paragamasus sp.	6			1	7	355	369
	Parasitus bituberosus Karg, 1972	103	18	110	48	48	23	350
	Pergamasus aff. *barbarus*	36		6	3	8	124	177
	Pergamasus aff. *septentrionalis*	25	2	11	1	68	38	145
	Parasitus sp.						1	1
	Porrhostaspis lunulata Müller, 1859				1		38	39
	Rhabdocarpais sp.						23	23
	Trachygamasus sp.		8					8
	Unidentified	1	2	1			2	6
Parholaspididae								
	Gamasholaspis sp.	15		6	2	8	8	39
	Holaspina sp.		16	17			39	72

		Roses				Vegetation		Total
Family	**Species**	**CR**	**NR**	**TR**	**GR**	**CV**	**GV**	
Phytoseiidae								
	Amblyseius sp. 1						1	1
	Amblyseius sp. 2					4		4
	Proprioseiopsis neotropicus (Ehara, 1966)					1		1
	Neoseiulus barkeri Hughes, 1948	2	9	1				12
	Neoseiulus californicus (McGregor, 1954)			2				2
	Typhlodromus sp. 1		1					1
	Typhlodromus sp. 2					1		1
Podocinidae								
	Podocinum pacificum Berlese, 1895					13		13
Pyrosejidae								
	Pyrosejus sp.		2			8		10
Rhodacaridae								
	Protogamasellopsis sp. 1			1				1
	Protogamasellopsis sp. 2	1						1
	Rhodacarellus sp. 1			1				1
	Rhodacarellus sp. 2		1					1
Veigaiidae								
	Gamasolaelaps sp.	3				63	5	71
	Veigaia sp. 1					9		9
	Veigaia sp. 3	49	1	1	2	531	50	634
	Veigaia sp. 4	54		1	7	21	79	162
	Veigaia sp. 5	6	2	2	4	7	3	24
Unknown								
	Zygoseius sp. 1				1	1	10	12
	Zygoseius sp. 2	55				2	1	58
Total		929	355	561	242	1991	1391	5469

The first letter of each code indicates the municipality where the sampling was conducted, and the last, the vegetation cover: **C** = Cogua, Agua Clara farm; **N** = Nemocón, Flores el Futuro farm; **T** = Tocancipa, El Placer farm; **G** = Guasca, La Toma farm; **R** = rose fields; **V** = patches of secondary vegetation.

Taking into account species composition, the combinations of sites, vegetation type and sampling occasions comprised three large groups, the largest corresponding to rose fields (R), and others to patches of secondary vegetation at (CV) and at (GV) (Figure 5). Thus, species composition was more similar between all rose fields than between a rose field and the closest secondary vegetation patch. The only exception to this pattern was the sampling carried out in the rose field at Agua Clara farm (CR) in December 2015, more similar to patches of secondary vegetation on the same farm in August and October 2016. In the group containing only rose fields, there was no clear-cut separation of subgroups containing evaluations of any single farm, although there was a subgroup including samples of two farms, Flores el Futuro (NR) and El Placer (TR).

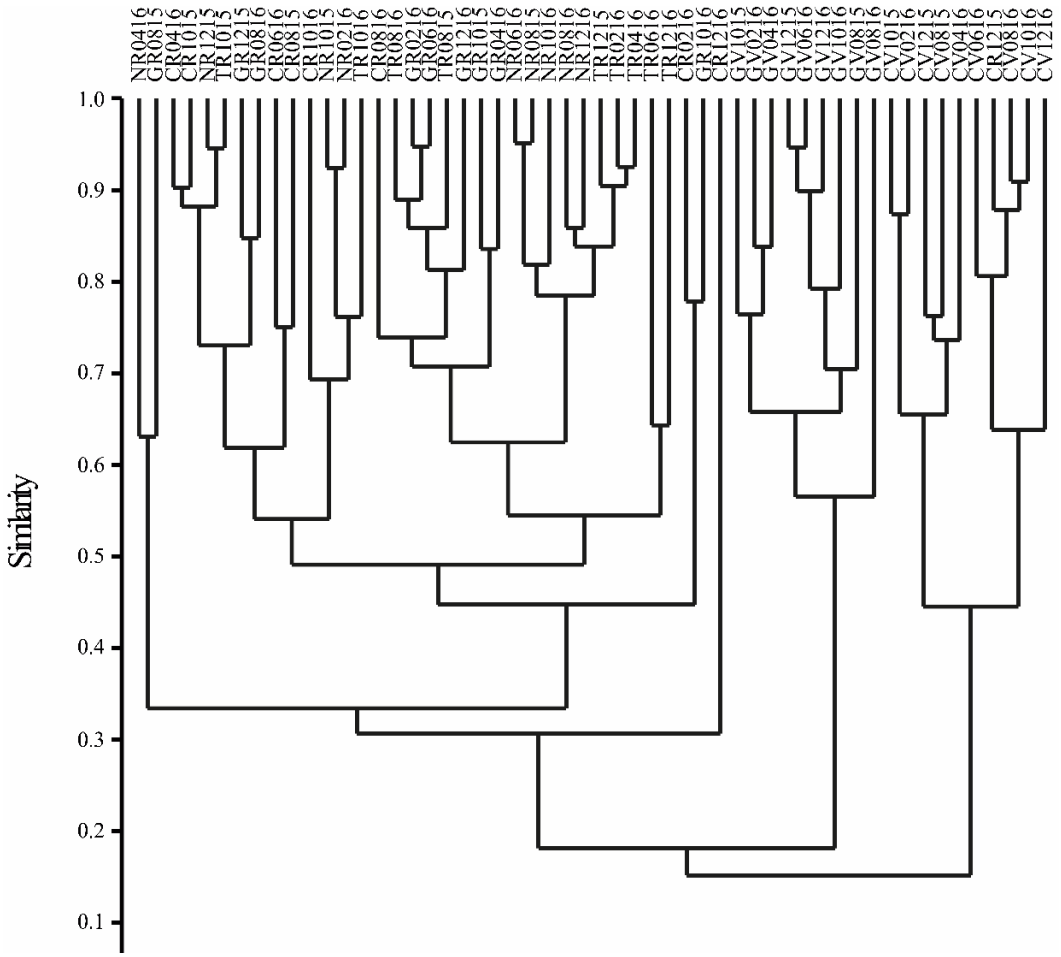


Figure 5. Dendrogram of similarity between samples taken bi-monthly from August 2015 to December 2016 from four rose fields and the two patches of secondary vegetation, grouped by the Morisita-Horn similarity index. The first letter of each code indicates the municipality where the sampling was conducted, and the last, the vegetation cover: C = Cogua, Agua Clara farm; N = Nemocón, Flores el Futuro farm; T = Tocancipa, El Placer farm; G = Guasca, La Toma farm; R = rose fields; V = patches of secondary vegetation; the first two numbers at the end of each code indicate the month of sampling, and the last two, the year.

A total of 1,093 specimens were found in the complementary samplings, of which 459 were females and could be identified to species. These corresponded to 49 species of 32 genera and 14 families (Table 3). The species collected on San Pedro farm (FR) were the same as those collected in periodic samplings in rose fields (CR, NR, TR, GR) added of *Proprioseiopsis* sp. Conversely, twenty-two other species were collected exclusively in the most conserved vegetation areas (FV, LV and SV), of which 18 were collected in the forest patchs (LV and SV) and four in the secondary vegetation patch of La Esmeralda farm (FV). The largest number of species was found in the two forest patchs (LV and SV, 21 species on each).

Table 3. Total numbers of soil non-Uropodina Mesostigmata collected in complementary samplings in a rose fields (Roses), a patch of secondary vegetation and two forest patchs (Vegetation) in the Bogotá plateau (Colombia) from August 2015 to December 2016.

		Roses	Vegetation			Total
Family	**Species**	**FR**	**SV**	**FV**	**LV**	
Ameroseiidae						
	Sertitympanum aff. *aegypticum*	1				1
Ascidae						
	Asca garmani Hurlbutt, 1963		51		4	55
	Gamasellodes andinus Rueda-Ramirez, Varela & Moraes, 2016		1		1	2
	Zerconopsis sp. nov.				5	5
Blattisociidae						
	Cheiroseius aff. *frenatus*				1	1
	Cheiroseius aff. *parvipulmonis*		1			1
	Cheiroseius sp. nov. 1		1		2	3
	Cheiroseius sp. nov. 2		4		2	6
	Cheiroseius neophalangoides Mineiro, Lindquist & Moraes, 2009				3	3
	Lasioseius barbensiensis Faraji & Karg, 2006		13			13
Laelapidae						
	Cosmolaelaps claviger (Berlese, 1883)			11		11
	Gaeolaelaps brevipellis Karg, 1979		20		5	25
	Gaeolaelaps queenslandicus (Womersley, 1956)		1			1
	Gaeolaelaps aculeifer (Canestrini, 1884)	58	3	18		79
	Gaeolaelaps sp. nov	17		31		48
	Oloopticus reticulatus Karg, 1978				1	1
	Oloopticus sp. 1		7			7
	Stratiolaelaps scimitus (Womersley, 1956)				1	1
Macrochelidae						
	Geholaspis sp. 2			1		1
	Glyptholaspis sp. 2				1	1
	Macrocheles mammifer Berlese, 1918			4		4
	Macrocheles sp. 5				2	2
	Macrocheles sp. 6		1			1
Melicharidae						
	Orolaelaps sp. nov.				1	1
	Proctolaelaps sp. 1		1			1
	Proctolaelaps sp. 6		3			3
Ologamasidae						
	Desectophis anthuriumsetis Rueda-Ramirez, Castilho & Moraes, 2013				5	5
	Gamasiphis sp. 1			30	1	31
	Gamasiphis sp. 2			2		2
Parasitidae						
	Cycetogamasus sp.	7				7
	Paragamasus sp. 2			1		1
	Parasitus bituberosus Karg, 1972	3		1		4
	Pergamasus aff. *barbarus*	2		4		6
	Pergamasus aff. *septentrionalis*	1		2		3

Family	Species	Roses	Vegetation			Total
		FR	SV	FV	LV	
	Rhabdocarpais sp.			1		1
Parholaspididae						
	Gamasholaspis sp.		5		1	6
Phytoseiidae						
	Amblyseius sp. 3				1	1
	Proprioseiopsis sp.	1				1
	Typhlodromus (*Anthoseius*) sp.1		1			1
Podocinidae						
	Podocinum pacificum Berlese, 1895		1			1
Rhodacaridae						
	Multidentorhodacarus triramulus (Karg, 1998)		41			41
	Rhodacarellus sp.			1		1
Veigaiidae						
	Gamasolaelaps sp.			1		1
	Veigaia sp. 1		4		3	7
	Veigaia sp. 2				2	2
	Veigaia sp. 3		42	1	1	44
	Veigaia sp. 4		11		1	12
	Veigaia sp. 5	2	1			3
Unknown						
	Zygoseius sp. 2	1				1
Total		93	213	109	44	459

The first letter of each code indicates the municipality where the sampling was conducted, and the last, the vegetation cover: **F** = Facatativa, San Pedro farm, **S** = Soacha, Granja el Porvenir farm, **L** = La Calera, Vereda Mundo Nuevo, Sector San José; **R** = rose fields; **V** = patches of secondary vegetation.

2.3.2. Thrips fauna

Of the Thysanoptera collected, about 460 individuals could be identified. A total of 21 species was found, distributed in four genera of the family Thripidae (Table 4). Species of the four genera were found in Agua Clara (CR) and La Toma (GR), the greenhouses in which most thrips species were recorded. In Flores el Futuro (TR) and El Placer (TR) only one species of the genus *Thrips* was found.

Table 4. Species of Thysanoptera (Thripidae) per genus collected in adhesive traps in greenhouses with *Rosa* sp. (Roses) in the Bogotá plateau (Colombia) from August 2015 to December 2016.

Genus	Species	Agua Clara (CR)	Flores el Futuro (NR)	El Placer (TR)	La Toma (GR)
Anaphothrips	*Anaphothrips obscurus* (Muller, 1776)	●			●
Frankliniella	*Frankliniella* aff. *oxyura* Bagnall, 1919			●	
	Frankliniella aff. *williamsi* Hood, 1915		●		
	Frankliniella auripes Hood, 1915				●
	Frankliniella brunnea (Priesner, 1932)		●		
	Frankliniella gardeniae Moulton, 1948				●
	Frankliniella gossypiana (Hood, 1936)				●
	Frankliniella minuta (Moulton, 1907)	●			
	Frankliniella nakaharai Sakimura & O'Neill, 1979	●			
	Frankliniella occidentalis (Pergande, 1895)		●	●	
	Frankliniella oxyura Bagnall, 1919				●
	Frankliniella panamensis Hood, 1925	●		●	●
	Frankliniella sp.	●	●	●	●
	Frankliniella sp. group *minuta*				●
	Frankliniella trisetosa Hood, 1942				●
Neohydatothrips	*Neohydatothrips humberto* Mound & Marullo, 1996				●
	Neohydatothrips sp.	●		●	
Thrips	*Thrips australis* (Bagnall, 1915)	●		●	●
	Thrips brevipilosus Moulton, 1927	●			●
	Thrips simplex (Morison, 1930)	●			
	Thrips tabaci Lindeman, 1889	●	●		●
Unidentified/ damage	Montaje con especímen danado	●	●	●	●
	Number of species/farm	10	5	6	13

The most frequent species were *Frankliniella panamensis* Hood, *Frankliniella occidentalis* (Pergande), *Thrips australis* (Bagnall) and *Thrips tabaci* Lindeman (Figure 9). However, the former was most frequent in CR and GR, while the latter was most frequent in NR and TR. In Flores el Futuro (NR), *F. panamensis* was not found. *T. palmi* was not found in any of the collections and in any of the greenhouses where periodic collections were made.

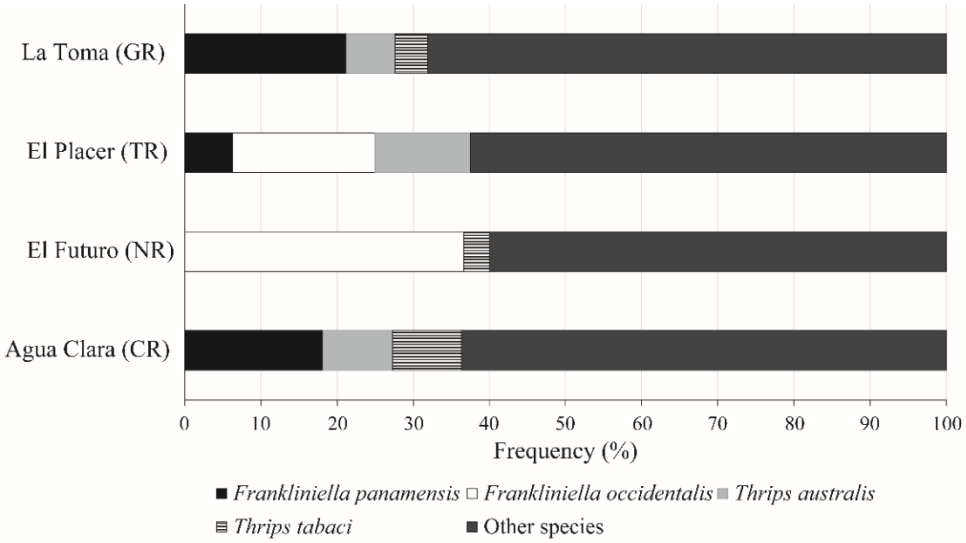


Figure 9. Frequency of encounter of Thysanoptera species collected in adhesive traps in greenhouses with *Rosa* sp. (Roses) in the Bogotá plateau (Colombia) from August 2015 to December 2016.

2.3.3. Mite and thrips population dynamics

In most rose fields, average mesostigmatid levels ranged between 1.7 and 14.1 specimens per sample (10 cm in diameter and 5 cm in length). A remarkable increase in density was observed in August and October 2016 in El Placer farm (TR), August 2015 in La Toma farm (GR) and August, October and December 2016 in Agua Clara farm (CR), in which average densities reached 21.3 to 39.4 specimens per sample. No major differences in density levels were observed between rose fields with or without neighboring secondary vegetation.

In secondary vegetation, densities were in most sampling dates considerably higher than in rose fields. However, densities varied considerably between sampling dates, ranging between 9.3 and 53.2 in Agua Clara (CV) and 9.2 and 81.6 in La Toma (GV). The highest density was observed in April, in La Toma, when 81.6 mites were found per sample, coinciding with a sudden increase in humidity from 19.6 to 40.4%

In all sampling dates the proportions of females and deutonymphs of mites in relation to other stages were considerably higher than those of other developmental stages in rose fields and secondary vegetation, whereas the proportion of adults was higher than that of deutonymphs in areas of secondary vegetation (Figures 6B, 7B and 8B). In most sampling dates the proportion of adult females was higher than of adult males, except in August and December 2016 in Flores el Futuro (NR), and December 2016 in Agua Clara (CR), in rose fields.

Also, in most sampling dates the proportions of deutonymphs and adults in rose fields were similar to each other in all collecting sites. In this case, the dominant mite family was Parasitidae. The exceptions corresponded to: a) higher the proportion of deutonymphs in all sampling dates in La Toma (GR); b) higher the proportion of adults in April 2016 in Flores el Futuro (NR), in October 2016 in El Placer (TR), and in August, October and December 2016 in Agua Clara (CR). In the exceptions listed under "a", the dominant family was Parasitidae, whereas in "b", the dominant family was not Parasitidae. Increases in the proportion of females coincided with increase in mean mite densities.

In relation to soil characteristics (Figures 6C, 7C and 8C), acidic pH was observed in all rose fields and patches of secondary vegetation, varying between 4.4 and 6.5. The highest organic matter content was observed in patches of secondary vegetation, varying between 26.4 and 48.2%, as compared to a range between 13.6 and 30.8% in rose fields.

Soil water content (humidity) was more variable in areas of secondary vegetation, in Agua Clara (CV) and La Toma (GV). In general, water content was higher in areas of secondary vegetation.

Considering the period in which the study was conducted, average air temperature was: Cogua (municipality of CR and CV) 13.0 °C, Guasca (municipality of GR and GV) 12.5 °C, Nemocon (municipality of NR) 14.3 °C and Tocancipa (municipality of TR) 13.4 °C (Figures 6D, 7D and 8D). Rainfall was about uniform throughout the study in all colleting sites, with monthly amount usually above 20 mm, and monthly maximum of at least 80 mm.

Total mite abundance was only linearly (and positively) correlated with content of organic matter ($r = 0.49$, $p < 0.005$), pH ($r = 0.39$, $p < 0.005$) and presence of patch of secondary vegetation ($r = 0.58$, $p < 0.005$).

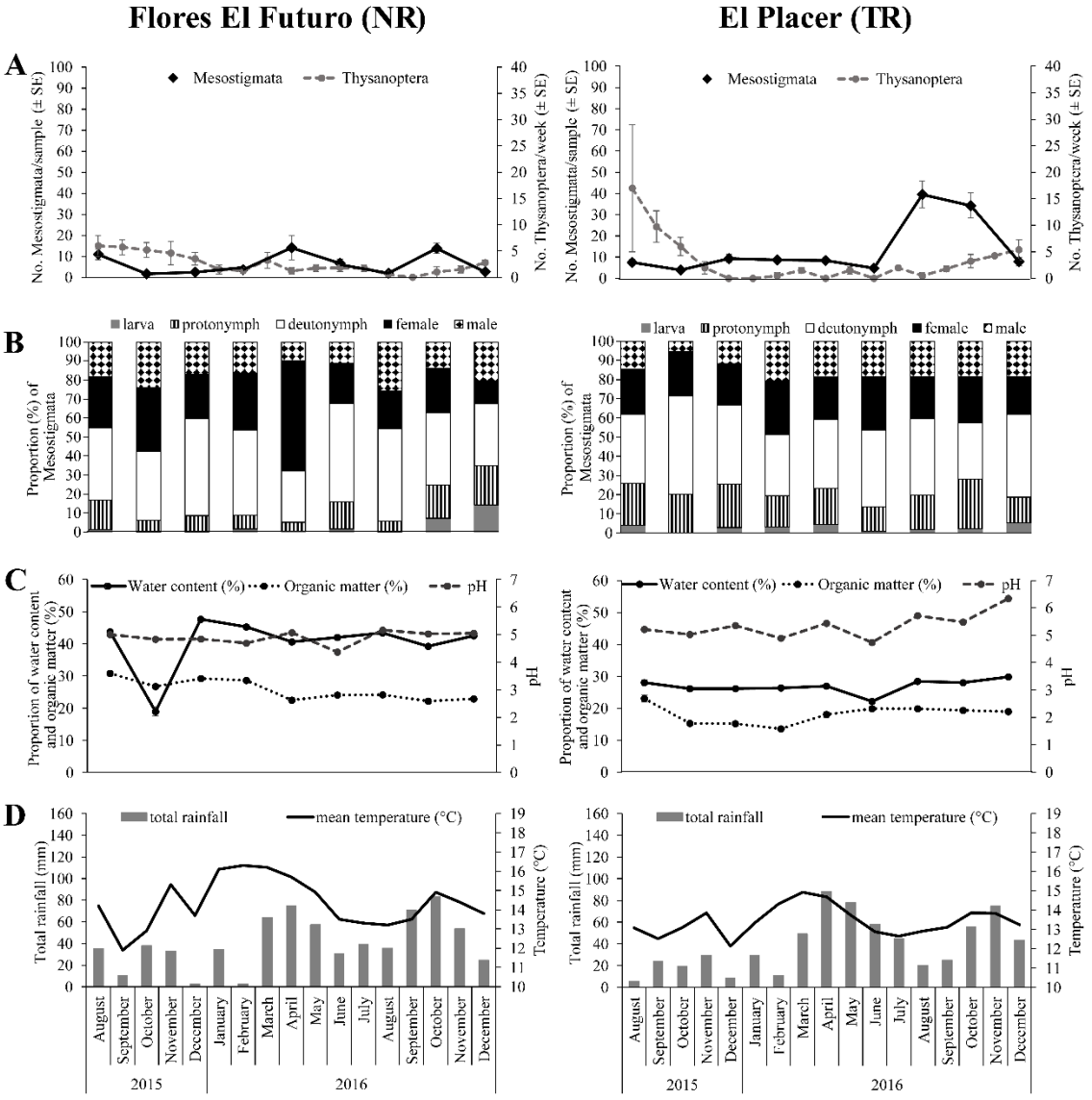


Figure 6. Dynamics of **(A)** number of soil non-Uropodina Mesostigmata per sample (392.5 cm^3 of soil); **(B)** proportion of mite developmental stages; **(C)** soil proportion of organic matter (%) and water content (%), and soil pH; **(D)** total rainfall (mm) and average temperature (°C). Rose field in a greenhouse at Flores el Futuro farm, Nemocon (NR) and El Placer farm, Tocancipa (TR) (Bogota plateau, Cundinamarca, Colombia).

The highest mean thrips density was observed in the municipality of Guasca (GR), in April 2016, which, in this case only, coincided with an increase in precipitation (Figure 6A, 7A and 8A); however, the correlation was not significant considering all farms ($p > 0.05$). The second highest mean number was found in August 2015, in Tocancipa (TR).

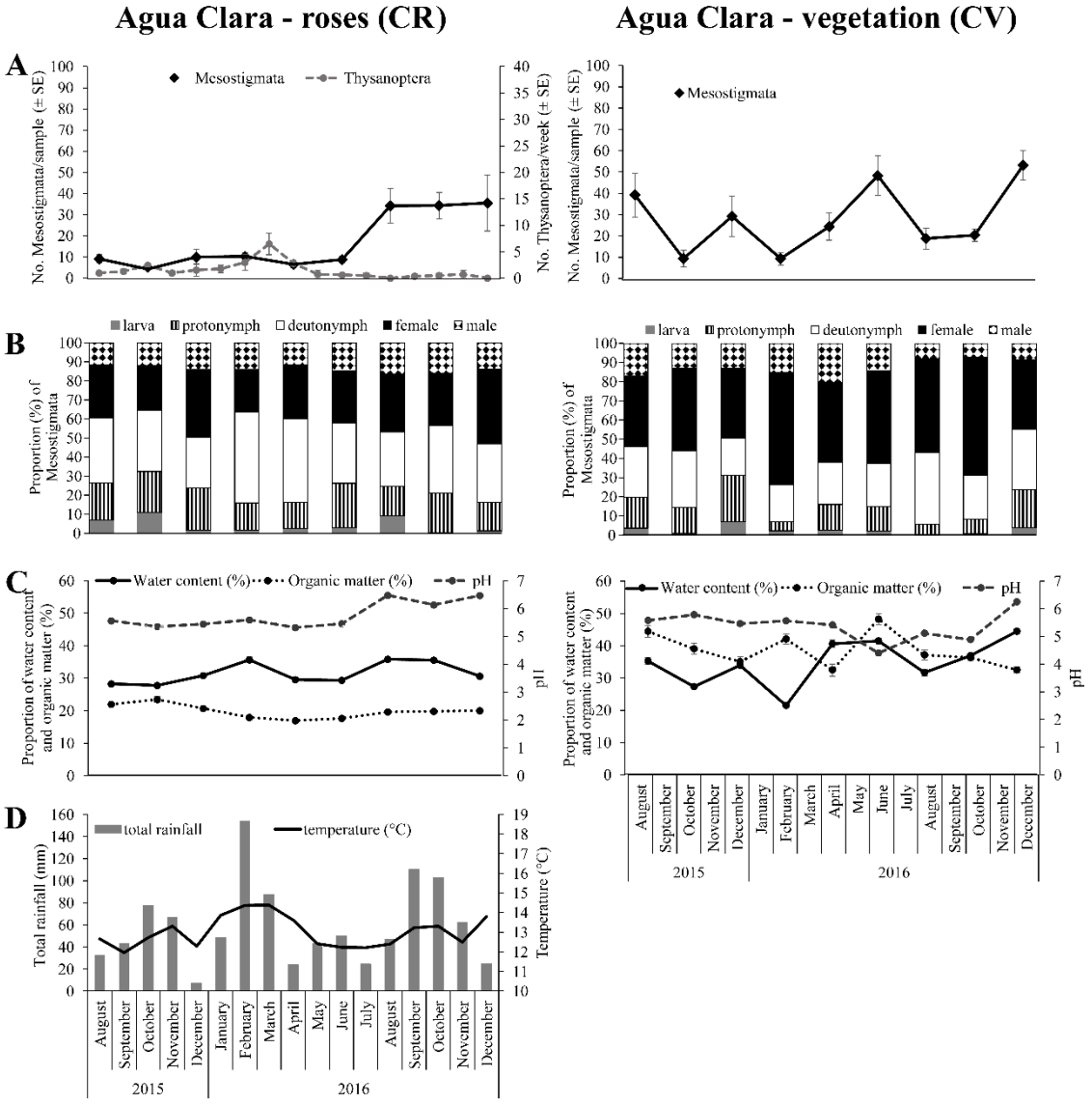


Figure 7. Dynamics of **(A)** number of soil non-Uropodina Mesostigmata per sample (392.5 cm^3 of soil); **(B)** proportion of mite developmental stages; **(C)** soil proportion of organic matter (%) and water content (%), and soil pH; **(D)** total rainfall (mm) and average temperature (°C); Rose field in a greenhouse (CR) and in a patche of secondary vegetation (CV) at Agua Clara farm, Cogua (Bogota plateau, Cundinamarca, Colombia).

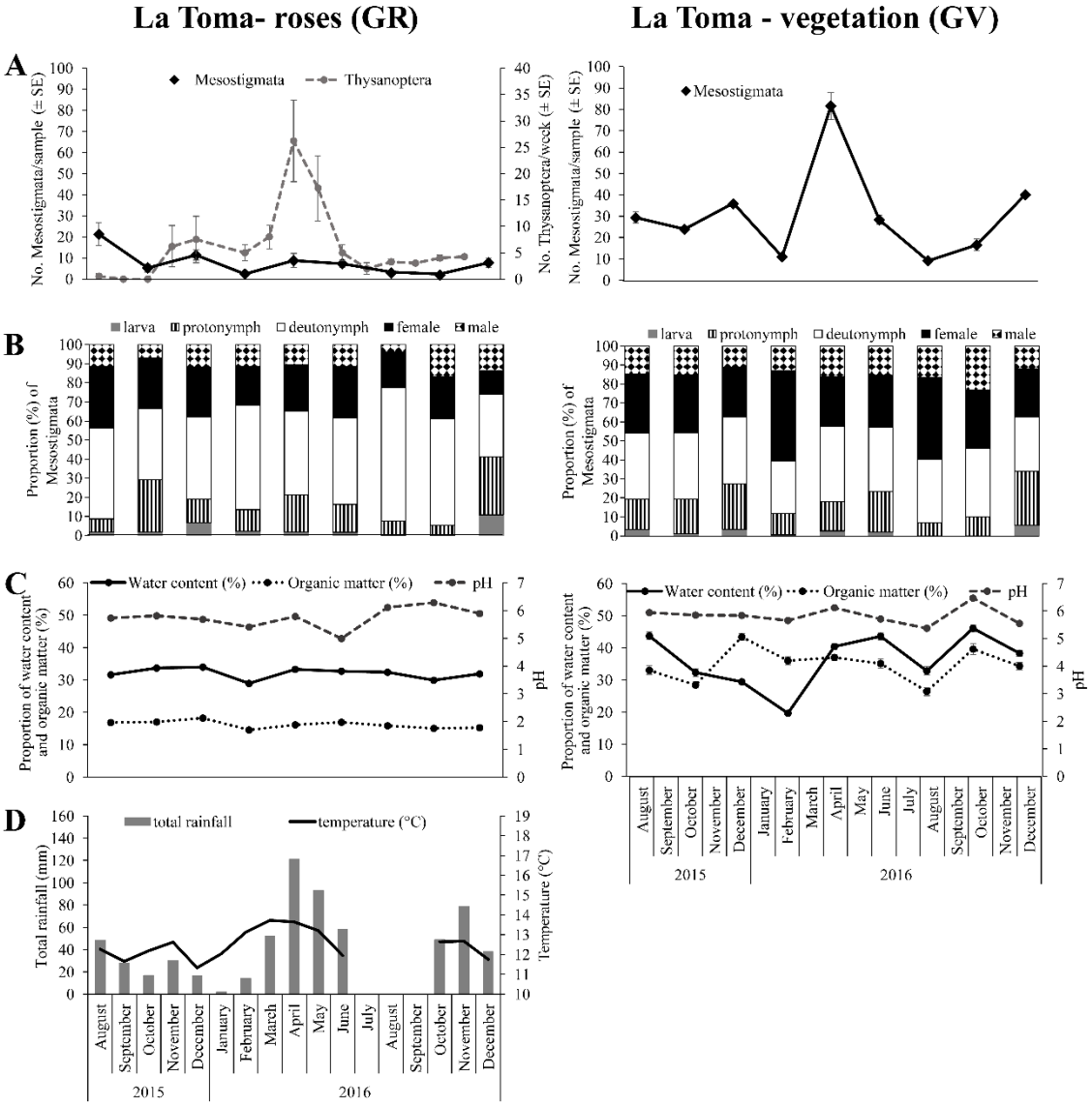


Figure 8. Dynamics of **(A)** number of soil non-Uropodina Mesostigmata per sample (392.5 cm^3 of soil); **(B)** proportion of mite developmental stages; **(C)** soil proportion of organic matter (%) and water content (%), and soil pH; **(D)** total rainfall (mm) and average temperature (°C); Rose field in a greenhouse (GR) and in a patch of secondary vegetation (GV) at La Toma farm, Gusca (Bogota plateau, Cundinamarca, Colombia). *Unavailable data.

2.4. Discussion

2.4.1. Mesostigmatid fauna

The results showed the great diversity of Mesostigmata in the areas where the study was conducted, given that altogether 96 species were found. Eight of those species could be determined to be new to science, while several others, after further taxonomic evaluations, could also be determined to be new. While identifying the species, it was clear that several of

them were not adequately characterized in the literature, given that their original descriptions were done long ago, when knowledge about the taxonomic importance of the different structures were not well realized.

The high proportion of Parasitidae in this study, especially in rose fields, was expected, given the dominance, within the Gamasina, of this family and of Veigaiidae in humus and litter in temperate areas (Micherdziński 1969; Karg 1993; Lindquist et al. 2009; Venancio et al. 2016), also the characteristic climate of the Bogota plateau (Peel et al. 2007). While the dominant parasitids in rose fields belonged to Parasitinae, the dominant species of the same family in the secondary vegetation belonged to Pergamasinae. Species of the first subfamily predominate in transient habitats (e.g. dung, compost), while species of the last subfamily are considered to be favored by stable habitats (Juvara-Bals 1972; Hyatt 1980; Castilho et al. 2015), which seems compatible with the results of the present study when comparing the secondary vegetation with rose fields. One of the species found in both ecosystems, *P. bituberosus*, was evaluated as a predator of different prey, including sciarid fly larvae and nematodes, in the study conducted by Szafranek et al. (2013), it was concluded that *P. bituberosus* is promising as biological control agent of sciarid fly larvae in mushroom culture. Thus, given that conclusion and the fact that it was frequently found throughout the present study, it is here concluded that this species deserves further attention in Colombia.

Another of the dominant families in this study, Laelapidae, has also been reported as abundant in temperate regions (Navarro-Campos et al. 2012; Manu et al. 2016; Venancio et al. 2016; Muñoz-Cárdenas et al. 2017b), but also in tropical regions (Fuentes et al. 2008). Two of the laelapid species found, *G. aculeifer* and *Stratiolaelaps scimitus* (Womersley), have been commercialized for the control of fungus gnats, thrips and mites (van Lenteren 2011; Moreira and Moraes 2015) in other countries. *Gaeolaelaps aculeifer* was frequently found in the samples, which makes this species a candidate for further evaluations in Colombia.

Although to a lesser extent, Macrochelidae was another of the abundant families, especially in the samples from the La Toma farm (Guasca), which is not surprising, given the common occurrence of species of this family in temperate regions (Venancio et al. 2016). Species of *Macrocheles* found in this study have been reported in several countries (Azevedo et al. 2017), especially *M. robustulus*, a species commercialized for the control of dipteran, thrips and lepidopteran immatures (van Lenteren et al. 2011).

The higher diversity and abundance of non-Uropidina soil mesostigmatids in samples of secondary vegetation and the different faunistic composition in comparison with rose fields

suggest that prevailing conditions in rose fields exert an important negative effect on some groups of mesostigmatid mites. Species of Veigaiidae have been reported mainly from substrates containing large amount of decaying organic material (Farrier 1957; Hurlbutt 1984), which was characteristic of the patches of secondary vegetation in samples of regular and complementary samplings. Likewise, despite the great species richness observed in rose fields, the number of species was higher in patches of secondary vegetation. Also, it was determined that many species were exclusively present in the two patches of Andean forest considered in complementary samplings. In the rose fields considered in the complementary samplings, the species found were the same as in fields of systematic samplings, about 50 km northwest of the rose fields sampled regularly.

With these results it was possible to verify, as expected, that soil non-Uropodina mesostigmatid mites resemble those reported in temperate areas. This was verified both in relation to the dominant mite families, and by the presence of species usually reported in countries far from the equator.

2.4.2. Mite population dynamics

This is the first study evaluating the dynamics of soil non-Uropodina mesostigmatids in rose cultivation. The use of agrochemicals might have affected the dynamics of these organisms in the soil, and thus the results of this study do not allow an interpretation of their natural fluctuation, affected only by natural environmental factors. However, the study allowed the determination of the species present in rose fields despite the effect of the chemicals. The presence of species known to have good potential as biological control agent in rose agroecosystems (*G. aculeifer* and *M. robustulus*) indicates their adaptation to agrochemical pressure, and the possibility to rely on their for practical use under those conditions.

In the study to determine the effect of environmental factors on the population level of non-Uropodina mesostigmatids, the observed significant (and positive) relation with organic matter and pH is in agreement with previous studies of other authors (Badejo 1990; Bedano et al. 2005; Manu et al. 2016). This result leads to the conclusion that increase in mesostigmatid predator density can be achieved by increasing organic matter content or soil pH (Muñoz-Cárdenas et al. 2017b, a). The driving factors behind those relationships are not known, but could be related to increasing availability of food items with increasing levels organic matter or pH.

In relation to mite age structure in rose field, the dominance of deutonymphs (by themselves or together with adults) when the dominant family was Parasitidae might be related to the fact that these mites migrate as deutonymphs (Castilho et al. 2015), these perhaps being thus more resistant to environmental stresses. However, several other factors could account for the higher proportions of deutonymphs and adults in relation to other stages determined in this study, as for example their higher extraction efficiency with Berlese funnel, employed in this study for mite extraction (Barberena-Arias et al. 2012).

2.4.3. Thrips fauna

Previous studies reported a total of 14 genera and 54 species of Thripidae in different plants in the Bogota plateau (Calixto 2005) and the presence of three genera in greenhouses of the same region (Cardenas and Corredor 1993; Forero 1999).

Apparently, only four of the species found in greenhouses in this study (*Thrips brevipilosus* Moulton, 1927; *Frankliniella oxyura* Bagnall, 1919; *Frankliniella gossypiana* (Hood, 1936); and *Frankliniella nakaharai* Sakimura & O'Neill, 1979) have not been previously reported in Colombia (Cardenas and Corredor 1993; Forero 1999; Calixto 2005). Three of these species (*F. oxyura*, *F. gossypiana* and *F. nakaharai*) have been previously reported in South America (Thrips Wiki contribuitors; Monteiro and Lima 2011; Goldarazena et al. 2012, 2014), while *T. brevipilosus* has been reported only in United States (Thrips Wiki contribuitors; Hoddle et al. 2004).

The two-dominant species in this study, *F. occidentalis* and *F. panamensis*, had already been reported as frequent in the flower-producing region of the Bogotá plateau (Cardenas and Corredor 1993; Forero 1999; Calixto 2005). However, the presence of *F. panamensis* in greenhouses has been reported as occasional and its presence in this habitat has been attributed to the disturbance of the surrounding environment (Forero 1999). In this study, a great frequency of *F. panamensis* was observed, especially in two of the farms in which a great diversity of species was found in the greenhouses. Therefore, it is necessary to examine the factors lately leading to increased entry of this and other species (such as *T. australis* and *T. tabaci*) in greenhouses where rose fields are found. The increased frequency of those thrips has led to their increasing interception in quarantine of importing countries (Gunawardana et al. 2017). In the case of *F. occidentalis*, its occurrence in high frequency is known in different crops around the world, especially in greenhouses (Tommasini and Maini

1995; Boissot et al. 1998; Kirk and Terry 2003; Trdan et al. 2003; Mound 2005; Morse and Hoddle 2006; Reitz et al. 2011; Fatnassi et al. 2015; Virteiu et al. 2015).

The fact that *T. palmi* was not been found in this study is highly positive, given fact that this is a quarantine pest to several countries (Cannon et al. 2007; International Plant Protection Convention (IPPC) 2016).

2.4.4. Thrips population dynamics

The non-significant relation between thrips population densities and levels of climatic factors in this study contrasts with the findings of other studies, which indicated significant and positive relation with factors such as temperature and rainfall (Boissot et al. 1998; Trdan et al. 2003; Fatnassi et al. 2015). This is not surprising, given that this information was not among the objectives of the present study. Thus, the methodology adopted was not adequate to obtain that information: thrips population levels were evaluated only inside the greenhouses where rose fields were located; thrips were subjected to chemical products periodically applied onto the plants; and the climatic data available for this study were obtained in meteorological stations and not within the greenhouses.

In summary, the results showed the need to focus subsequently in the conduction of taxonomic and biological studies, respectively to describe the new species collected and complement the description of previously described taxa, and to determine the potential of the most frequently found mites as biological control agents of the main thrips pest.

Acknowledgements

This research was partially supported by “Vicerrectoria Academica” of “Pontificia Universidad Javeriana (Project No. 000000000007367). We thank COLCIENCIAS (Departamento Administrativo de Ciencia, Tecnología e Innovación, Colombia) for the scholarship to the first author (Process No. 617-2013, Chapter 3). We also thank Council members (Peter Reutimann, Reinhard Gerecke, Peter Martin, Heinrich Schatz) of the foundation Pro Acarologia Basiliensis, Switzerland, for the donation of a microscope, which was very useful for the identification of the specimens in Colombia. To ASOCOLFLORES (The Association of Colombian Flower Exporters) and all the staff of the farms participating in this project. To Jessica Lorena Vaca, Diana Marcela Rios Malaver and Mayerly Alejandra Castro for the help in the field, and mounting mites and thrips. To Everth Emilio Ebratt Ravelo, for the identification of the thrips species.

References

ASOCOLFLORES (2011) Colombian Floriculture: General Information. Bogotá: Asocolflores.

ASOCOLFLORES (2018) El Sector Floricultor en Colombia 2018. 6

Attavian B (2014) Cut Flowers and Greenery Import Manual Cut Flowers and Greenery, First Ed. United States Department of Agriculture - USDA

Avellaneda J, Diaz M, Acosta D, et al (2016) Colecta de antocóridos y determinación de su capacidad depredadora sobre adultos de *Frankiniella occidenatils* (Pergande) (Thysanoptera, Thripidae). Rev Fac ciencias basicas 12:8–21. doi: http://dx.doi.org/10.18359/rfcb.1850

Azevedo LH, Castilho RC, Berto MM, De Moraes GJ (2017) Macrochelid mites (Mesostigmata: Macrochelidae) from Sao Paulo state, Brazil, with description of a new species of *Macrocheles*. Zootaxa 4269:413–426. doi: 10.11646/zootaxa.4269.3.5

Badejo MA (1990) Seasonal abundance of soil mites (Acarina) in two contrasting environments. Biotropica 22:382–390

Barberena-Arias MF, Gonzalez G, Cuevas E (2012) Quantifying variation of soil arthropods using different sampling protocols: is diversity affected? In: Sudarshana P, Nageswara-Rao M, Soneji JR (eds) Tropical Forests. InTech, Rijeka, pp 51–70

Bedano JC, Cantú MP, Doucet ME (2005) Abundance of soil mites (arachnida: Acari) in a natural soil of Central Argentina. Zool Stud 44:505–512

Bhattacharyya SK (1963) A revision of the British mites of the genus *Pergamasus* Berlese S. lat. (Acari: Mesostigmata). Bull Br Museum Natural Hist Zool 11:134–242

Boissot N, Reynaud B, Letourmy P (1998) Temporal analysis of Western Flower Thrips (Thysanoptera: Thripidae) population dynamics on Reunion Island. Environ Entomol 27:1437–1443. doi: 10.1093/ee/27.6.1437

Buitenhuis R, Murphy G, Shipp L, Scott-Dupree C (2015) *Amblyseius swirskii* in greenhouse production systems: a floricultural perspective. Exp Appl Acarol 65:451–464. doi: 10.1007/s10493-014-9869-9

Buitenhuis R, Shipp JL (2008) Influence of plant species and plant growth stage on *Frankliniella occidentalis* pupation behaviour in greenhouse ornamentals. J Appl Entomol 132:86–88. doi: 10.1111/j.1439-0418.2007.01250.x

Bustillo-Pardey AE (2009) Evaluación de insecticidas químicos y biológicos para controlar *Frankliniella occidentalis* (Thysanoptera: Thripidae) en cultivos de espárragos. Rev Colomb Entomol 35:12–17

Calixto (2005) Trips del suborden Terebrantia (Insecta: Thysanoptera) en la Sabana de Bogotá. Rev. Colomb. Entomol. 31:207–213

Cannon RJC, Matthews L, Collins DW (2007) A review of the pest status and control options for *Thrips palmi*. Crop Prot 26:1089–1098. doi: 10.1016/j.cropro.2006.10.023

Cardenas E, Corredor D (1993) Especies de trips (Thysanoptera : Thripidae) mas comunes en invernaderos de flores de la sabana de Bogota. Agron Colomb 10:132–143

Castilho RC, Venancio R, Narita JPZ (2015) Mesostigmata as Biological Control Agents, with Emphasis on Rhodacaroidea and Parasitoidea BT - Prospects for Biological Control of Plant Feeding Mites and Other Harmful Organisms. In: Carrillo D, de Moraes GJ, Peña JE (eds) Prospects for Biological Control of Plant Feeding Mites and Other Harmful Organisms. Springer International Publishing, Cham, pp 1–31

Farrier MH (1957) A revision of the Veigaiidae (Acarina). Tech Bull North Carolina Agric Exp Stn 124:1–103

Fatnassi H, Pizzol J, Senoussi R, et al (2015) Within-crop air temperature and humidity outcomes on spatio-temporal distribution of the key rose pest *Frankliniella occidentalis*. PLoS One 10:1–16. doi: 10.1371/journal.pone.0126655

Fenalco (2017) Boletín Nº 46 Boletín Económico Sectorial Sector Floricultor. Investiga: Observatorio Económico de Comercio - Fenalco Antioquia

Forero D (1999) Aspectos biológicos de *Thris palmi*, con anotaciones de un pequeño muestreo de thrips hecho en la Sabana de Bogotá. Asocolflores 56:41–49

Fuentes L, Vásquez C, Palma W, Bari C (2008) Prostigmata and mesostigmata mites associated to litter from the University Park UCLA, Lara State, Venezuela | Ácaros prostigmata y mesostigmata asociados a la hojarasca en el bosque de galería del Parque Universitario de la UCLA, Estado Lara, Venezuela. Neotrop Entomol 37:591–596. doi: 10.1590/S1519-566X2008000500015

Garzo EI, Collar JL, Muniz M, Fereres A (2000) Eficacia del fipronil (EXP 60720A) en el control poblacional de *Frankliniella occidentalis* Pergande (Thysanoptero: Thripidae) en condiciones de laboratorio. Investig Agrar Prod y Prot Veg 15:57–65

Goldarazena A, Gattesco F, Atencio R, Korytowski C (2012) An updated checklist of the Thysanoptera of Panama with comments on host associations. Check List 8:1232–1247. doi: 10.15560/8.6.1232

Goldarazena A, Infante F, Ortiz JA (2014) A preliminary assessment of thrips inhabiting a tropical montane cloud forest of Chiapas , Mexico. Florida Entomol 97:590–596. doi: 10.1653/024.097.0234

Gunawardana DN, Li D, Masumoto M, et al (2017) Resolving the confused identity of *Frankliniella panamensis* (Thysanoptera: Thripidae). Zootaxa 4323:125–131. doi: 10.11646/zootaxa.4323.1.10

Hoddle MS, Mound LA, Nakahara S (2004) Thysanoptera recorded from California, U.S.A.: a checklist. Florida Entomol 87:317–323. doi: 10.1653/0015-4040(2004)087[0317:trfcua]2.0.co;2

Hurlbutt HW (1984) A study of North-American Veigaia (Acarina, Mesostigmata) with comparisons of habitats of unisexual and bisexual forms. Acarologia 25:207–222

Hyatt KH (1980) Mites of the Subfamily Parasitinae (Mesostigmata: Parasitidae) in the British Isles. Bull Br Museum Nat Hist Zool 38:237–378

International Plant Protection Convention (IPPC) (2016) DP 1 : *Thrips palmi* Karny. Food and Agriculture Organization of the United Nations. International Plant Protection Convention, Rome

Juvara-Bals I (1972) Mixogamasus, un noveau genre de Parasitidae (Acariens: Anactinotriches) de Roumanie. Acarologia XIV:3–14. doi: 10.1051/acarologia/20142144

Karg W (1993) Teil 59. Acari (Acarina), Milben Parasitiformes (Anactinochaeta) Cohors Gamasina LEACH Raubmilben. Gustav Fischer Verlag Jena, Villengang, Germany

Kirk WDJ, Terry LI (2003) The spread of the western flower thrips *Frankliniella occidentalis* (Pergande). Agric For Entomol 5:301–310. doi: 10.1046/j.1461-9563.2003.00192.x

Krantz GW, Ainscough BD (1990) Acarina: Mesostigmata (Gamasida). In: Dindal DL (ed) Soil Biology Guide. A Wiley-Interscience Publication, New York, pp 583–666

Lindquist EE, Krantz GW, Walter DE (2009) Order Mesostigmata. In: Krantz GW, Walter DE (eds) A Manual of Acarology, 3rd editio. Texas Tech University Press, Lubbock, Texas, pp 124–232

Lobo M (2008) Importancia de los recursos genéticos de la agrobiodiversidad en el desarrollo de sistemas de producción sostenibles. Corpoica Cienc y Tecnol Agropecu 9:19–30. doi: 10.21930/rcta.vol9_num2_art:114

Manu M, Iordache V, Băncilă RI, et al (2016) The influence of environmental variables on soil mite communities (Acari: Mesostigmata) from overgrazed grassland ecosystems – Romania. Ital J Zool 83:89–97. doi: 10.1080/11250003.2015.1091897

Messelink G, Holstein-saj R Van (2008) Improving thrips control by the soil-dwelling predatory mite *Macrocheles robustulus* (Berlese). Integr Control Prot Crop 32:135–138

Micherdziński W (1969) Die Familie Parasitidae Oudemans 1901 (Acarina, Mesostigmata), Polska Aka. Państwowe Wydawnictwo Naukowe

Monteiro RC, Lima ÉFB (2011) Thysanoptera of Brazil. http://www.lea.esalq.usp.br/thysanoptera/. Accessed 19 Jun 2018

Moreira GF, Moraes GJ (2015) The Potential of Free-Living Laelapid Mites (Mesostigmata: Laelapidae) as Biological Control Agents. In: Carrillo D, de Moraes GJ, Peña JE (eds) Prospects for Biological Control of Plant Feeding Mites and Other Harmful Organisms. Springer International Publishing, Cham, pp 77–102

Morse JG, Hoddle MS (2006) Invasion biology of Thrips. Annu Rev Entomol 51:67–89. doi: 10.1146/annurev.ento.51.110104.151044

Mound LA (2005) Thysanoptera: diversity and interactions. Annu Rev Entomol 50:247–269. doi: 10.1146/annurev.ento.49.061802.123318

Muñoz-Cárdenas K, Ersin F, Pijnakker J, et al (2017a) Supplying high-quality alternative prey in the litter increases control of an above-ground plant pest by a generalist predator. Biol Control 105:19–26. doi: https://doi.org/10.1016/j.biocontrol.2016.11.004

Muñoz-Cárdenas K, Rueda-Ramirez D, Ersin F, et al (2017b) Alternative food for little-inhabiting predators decreases pest densities and above-ground plant damage. In: Muñoz-Cárdenas K (ed) What lies beneath? Linking litter and canopy food webs to protect arnamental crops. Ph.D. Thesis. University of Amsterdam, The Netherlands, pp 9–26

Navarro-Campos C, Pekas A, Moraza ML, et al (2012) Soil-dwelling predatory mites in citrus: Their potential as natural enemies of thrips with special reference to Pezothrips kellyanus (Thysanoptera: Thripidae). Biol Control 63:201–209. doi: 10.1016/j.biocontrol.2012.07.007

Peel MC, Finlayson BL, McMahon TA (2007) Updated world map of the Köppen-Geiger climate classification. Hydrol Earth Syst Sci 11:1633–1644. doi: 10.5194/hess-11-1633-2007

Reitz SR (2009) Biology and ecology of the Western Flower Thrips (Thysanoptera: Thripidae): the making of a pest. Florida Entomol 92:7–13. doi: 10.1653/024.092.0102

Reitz SR, Yu-lin G, Zhong ren L (2011) Thrips: pests of concern to China and the United States. Agric Sci China 10:867–892. doi: 10.1016/S1671-2927(11)60073-4

Reyes F (2017) Desempeño del Sector Floricultor: Informe. Bogotá, D.C.

Szafranek P, Lewandowski M, Kozak M (2013) Prey preference and life tables of the predatory mite Parasitus bituberosus (Acari: Parasitidae) when offered various prey combinations. Exp Appl Acarol 61:53–67. doi: 10.1007/s10493-013-9701-y

Thrips Wiki contribuitors Thrips Wiki. http://thrips.info/w/index.php?title=Main_Page&oldid=50799. Accessed 19 Jun 2018

Tommasini MG, Maini S (1995) *Frankliniella occidentalis* and other thrips harmful to vegetable and ornamental crops in Europe. Wageningen Agric Univ Pap 95:1–42

Trdan S, Bergant K, Jenser G (2003) Monitoring of western flower thrips (*Frankliniella occidentalis* Pergande, Thysanoptera) in the vicinity of greenhouses in different climatic conditions in Slovenia. Agric 1:1–6

Valcárcel F (2013) El control biológico de plagas en la floricultura colombiana. Florycultura Colomb Rev la Asoc Colomb Floric 37–39

Valencia E (2013) Control y manejo de los Thrips en los sistenas de floricultura colombiana. Florycultura Colomb Rev la Asoc Colomb Floric 45–49

van Lenteren JC (2011) The state of commercial augmentative biological control: Plenty of natural enemies, but a frustrating lack of uptake. BioControl 57:1–20. doi: 10.1007/s10526-011-9395-1

van Lenteren JC, Cock MJW, Brodeur J, et al (2011) Will the Convention on Biological Diversity put an end to biological control? Rev Bras Entomol 55:1–5. doi: 10.1590/S0085-56262011000100001

Vargas R, Ubillo A (2005) Susceptibilidad de *Frankliniella occidentalis* (Thysanoptera: Thripidae) a insecticidas en la zona central de Chile. Agric Técnica 65:437–441. doi: 10.4067/S0365-28072005000400009

Venancio R, Moraes GJ, Castilho RC, et al (2016) Diversity of soil gamasine mites (Acar : Mesostigmata) co-occurring with *Ixodes ricinus* tick (Acari : Ixodidae) in pastures of western Norway. Syst Appl Acarol 21:385–397

Virteiu A-M, Grozea I, Stef R, et al (2015) Analysis of the thrips fauna (Insecta: Thysanoptera) on flowers of roses in western part of Romania. Bull UASVM Ser Agric 72:608–609. doi: 10.15835/buasvmcn-agr

3. SOIL MITES OF THE FAMILIES ASCIDAE, BLATTISOCIIDAE AND MELICHARIDAE (ACARI: MESOSTIGMATA) FROM MOUNTAINOUS AREAS OF COLOMBIA

ABSTRACT

[Latest version of this work is already published: Rueda-Ramírez et al. (2016). Zootaxa 4127 (3): 493–514]. Soil mites of the Ascidae sensu Lindquist & Evans (1965) are poorly known in Colombia. This group, presently represented by the families Ascidae *sensu stricto*, Blattisociidae and Melicharidae, contains species known to prey on small arthropods and nematodes, thus having the potential to be used for the control of soil pests. The aim of this study was to identify species of this group from a fragment of Andean forest and a nearby grassland at the municipality of La Calera, Cundinamarca Department, Colombia, at about 2800 m of elevation. Nine species were found, including five new species, namely *Gamasellodes andinus* sp. nov., *Gamasellodes intermedius* sp. nov., *Protogamasellus caleraensis* sp. nov., *Cheiroseius mesae* sp. nov. and *Proctolaelaps colombianus* sp. nov. Morphological characterization of all the species and relevant soil characteristics of the sites where the mites were collected are presented.

Keywords: *Gamasellodes*; *Protogamasellus*; *Cheiroseius*; *Proctolaelaps*; New species; Colombia

3.1. Introduction

Mites of the families Ascidae, Blattisociidae and Melicharidae include soil species known to prey on small arthropods and nematodes, considered as potentially useful for the biological control of pest organisms (Moraes *et al.* 2015). They are also mentioned as indicators of the degree of alteration of an ecosystem, being considered by Ruf (1998), Ruf *et al.* (2003) and Ruf & Beck (2005) in their maturity index, used to classify ecosystem stability.

Mites of those families were until recently included in a single family, Ascidae (Lindquist *et al.* 2009; Lindquist & Evans 1965). These are poorly known in Colombia. Apparently the first publication about this group in Colombia included the record of *Proctolaelaps bickleyi* (Bram) (Melicharidae) in association with fungi on coconut fruits in Valle del Cauca Department (Zuluaga 1970), and of *Lasioseius phytoseioides* Chant (Blattisociidae), also on coconut fruits, in the municipality of Santa Marta (Zuluaga 1971). More recently, Imbachi-López *et al.* (2012) reported the occurrence of a species identified as *Lasioseius* near *meridionalis* Chant (Blattisociidae) in soil of the Cali – Buenaventura road, Valle del Cauca. Other papers referring to the occurrence of unidentified species of Ascidae *sensu lato* were published by Florez & Sanchez (1995), Álvarez *et al.* (2013) and Vásquez *et al.* (2013). The aim of this study was to determine ascid, blattisociid and melicharid mites

from a site at high altitude in Cundinamarca Department, to facilitate future ecological studies.

3.2. Material and methods

3.2.1. Study site

The study was conducted in two habitats, an Andean forest fragment and a grassland, at sector San José of Vereda Mundo Nuevo (04°39’ N, 73°51’ W), municipality of La Calera, Cundinamarca Department, Colombia, at about 2,800 m a.s.l. In this region, annual rainfall is about 935 mm and annual mean temperature is about 13°C.

The Andean forest fragment is dominated mainly by *Weinmannia* spp. (Cunoniaceae), *Drymis granadensis* Linnaeus (Winteraceae), *Clusia multiflora* Kunth (Clusiaceae), *Ageratina tinifolia* (Kunth) R. M. King & H. Rob. (Asteraceae), as well as by species of Brunelliaceae, Lauraceae, Melastomataceae and Rubiaceae (IDEAM - Instituto De Hidrología Meteorología y Estudios Ambientales de Colombia 2011; Rangel-Ch. & Ariza-N 2000). The grassland habitat was included in the study because it is a dominant ecosystem in this region, used mainly for raising dairy cows. It was dominated by *Pennisetum clandestinun* Hochstetter ex Chiovenda and *Lolium* sp. (both Poaceae). In USDA soil taxonomy, the type of soil is Inceptisol, Guadalupe formation, characterised as mineralised soils of recent origin and with a weak horizon development (Malagón 2003).

3.2.2. Mite collection, identification and description

Soil samples were collected between February and December, 2010. Each sample was collected with a cylinder (5 cm in diameter and 15 cm in length) totally inserted in the soil. The samples were taken to a laboratory where mites were extracted using modified Berlese funnels. The extracted mesostigmatic mites were mounted in Hoyer’s medium and identified to family, based mainly on Lindquist *et al.* (2009). Adult ascid, blattisociid and melicharid females were identified to genera, based mainly on Halliday *et al.* (1998), and species, based on the original descriptions and complementary descriptions.

Illustration of taxonomically important structures of the new species collected were made with a camera lucida attached to a phase contrast microscope and a digital camera connected to an interference contrast microscope; photos and illustrations were then processed

with a digital tablet, using the Adobe Illustrator® program. Measurements were taken with a graded ocular. Measurements of each structure are given in micrometres, with the average measurement for the specimens examined followed (in parentheses) by the respective ranges, for variable structures. Leg measurements refer to the distance between the base of the coxa to the tip of the tarsus (not including pretarsus). Setal nomenclature is based on Lindquist & Evans (1965), leg chaetotaxy is based on Evans (1963) and pore notation is based on and Lindquist & Moraza (2008). For the *Gamasellodes* species, nomenclature of opistogastric setae follows the interpretation of Walter (2003). The number of teeth of each cheliceral digit does not include the respective terminal hook. Voucher specimens of the species collected were deposited at the Mite Reference Collection of Departamento de Entomologia e Acarologia, Escola Superior de Agricultura “Luiz de Queiroz”, Universidade de São Paulo, Piracicaba, State of São Paulo, Brazil (ESALQ-USP), and Museo Javeriano de Historia Natural, Pontificia Universidad Javeriana, Bogotá, Colombia (MJHN-PUJ). Type depositories for the new species are indicated under "Specimens examined" for each species.

3.2.3. Soil physicochemical analyses

A small amount of soil of each sample was stored at 4°C until the analyses were done. The following parameters were determined: pH (with potentiometer of a 1:1 v/v in distilled water), soil moisture (by gravimetric method, with precision of 0.01 g), percentage of organic matter (by calcination), texture (Bouyucos method) and electrical conductivity (conductivity measured in a suspension with 1:1 v/v in distilled water). The soil of all samples of the forest fragment and of the grassland was classified as sandy loam or silt loam (low clay content), and as non-saline (electrical conductivity lower than 0.98 dS/m, USDA, 1999).

This work is published in the journal Zootaxa (Rueda-Ramírez *et al*. 2016)

3.3. Results

Forty-nine females belonging to nine species of the three families were found. Taxonomic information about these is subsequently provided.

3.3.1. Ascidae Voigts & Oudemans

***Arctoseius semiscissus* (Berlese)**

Laelaps (*Iphis*) *semiscissus* Berlese, 1892: 7.

Arctoseius bispinatus Weis-Fogh, 1948: 255 (first synonymised by Bernhard, 1963: 151).

Arctoseius bicuspidatus Willmann, 1949: 355 (first synonymised by Halliday et al., 1998: 16).

Arctoseius (*Arctoseiulus*) semiscissus.—Willmann, 1949: 357.

Arctoseius limburgensis Nesbitt, 1954: 20 (first synonymised by Halliday et al., 1998: 16).

Arctoseius sellnicki Karg, 1962: 45 (first synonymised by Bernhard, 1963: 151).

Laelaps semiscissus.—Hirschmann, 1962: 48.

Morphology (female, eight specimens measured).

Gnathosoma. Fixed cheliceral digit 30 (29–30) long, with four teeth and setiform pilus dentilis; movable digit 31 (30–33), with two teeth; anterior region of epistome with two subequal, pointed, smooth projections. Dorsal idiosoma. Dorsal shield smooth, entire, with lateral incisions at line of fusion between podonotal and opisthonotal shields; 392 (345–422) long and 203 (177–224) wide, with 31 pairs of setae. Unsclerotised cuticle with ten pairs of setae (s2, r2–r5, R1–R5). Setal measurements: j1 23 (19–25), j2 33 (30–35), j3 40 (37–43), j4 35 (33–36), j5 31 (27–35), j6 32 (28–35), J1 32 (31–32), J2 32 (30–34), J3 35 (35–35), J4 34 (33–36), J5 12 (11–12), z1 16 (15–17), z2 44 (40–49), z3 44 (40–50), z4 44 (41–49), z5 35 (30–37), z6 35 (31–39), Z1 39 (34–43), Z2 42 (38–45), Z3 46 (42–49), Z4 53 (50–57), Z5 57 (54–60), s1 27 (24–33), s2 24 (23–25), s3 48 (42–50), s4 49 (45–52), s5 47 (44–52), s6 46 (42–49), S1 44 (40–47), S2 45 (41–49), S3 44 (40–47), S5 50 (46–55), r2 30 (27–32), r3 37 (31–40), r4 31 (28–35), r5 32 (28–35), R1 30 (26–35), R2 29 (25–32), R3 28 (24–30), R4 27 (22–31), R5 29 (24–32); setae aciculate and smooth.

Ventral idiosoma. Base of tritosternum 18 (17–18) long and 13 (12–13) wide proximally; laciniae 58 (54–62), separated for about 90% of their total length, pilose. Presternal plates large, consolidated with sternal shield, lineate and bearing st1. Sternal shield smooth; 84 (78–95) long and 71 (65–77) wide at the widest level, with two pairs of setae and three pairs of lyrifissures; setae st1 29 (25–31), st2 27 (25–30), st3 24 (22–26), st4 20 (18–22). Distances st1–st3 79 (75–84), st2–st2 63 (60–65). Genital shield punctate; 96 (85–100) long and 47 (40–55) wide at the widest level; seta st5 20 (18–21); distance st5–st5 54 (49–59). One pair of ovoid metapodal plates. Anal shield small, ovate, weakly reticulate; 75 (70–78) long and 74 (66–80) wide, bearing only circumanal setae; para-anal setae 21 (20–23),

post-anal 39 (36–40); anus 20 (19–21) long. Unsclerotised cuticle around anal shield with eight pairs of setae (Jv1–Jv5, Zv1, Zv2 and Zv5). Endopodal and exopodal plates indistinct. Peritrematic plate narrow, abutting but not fused anteriorly with dorsal shield at level of z1 and extending posteriorly as a narrow strip behind coxa IV. Peritreme extending anteriorly to the median level of coxa II (level of s3). Setal measurements: Jv1 22 (20–25), Jv2 24 (22–26), Jv3 24 (20–25), Jv4 22 (20–23), Jv5 40 (37–43), Zv1 19 (15–21), Zv2 22 (18–26), Zv4 29 (27–32), Zv5 31 (26–35); setae aciculate and smooth.

Legs. Setation: genua I–IV: 12, 10, 7, 7; tibiae I–IV: 12, 9, 7, 6.

Material examined. Six and two females, respectively, from soil of the fragment of Andean forest (pH 3.6–4.4; organic matter 45%; humidity 60–73%; soil temperature 10–11°C), and of the grassland (pH 5.2; organic matter 57%; humidity 57%; soil temperature 13°C) in August and October, 2010.

Remarks. This species was originally described from Italy. The specimens examined are larger than reported by Kalúz & Fenďa (2005) in a complementary description based on mites collected in Slovakia (340 long and 151 wide). Concurrently, the setae are also longer, especially J5 (5 μ, in Slovakian specimens). Of the 18 specimens collected, eight were fixed by the gnathosoma to an adult Sciaridae (Diptera). This, as well as other species of this genus, have been reported phoretically on adult flies of that family and as predators of sciarid eggs and larvae (Binns 1972, 1974; Dmoch 1995 cited by Rudzińska 1998; Gerson et al. 2003).

Gamasellodes andinus sp. nov. (Figs 1–6)

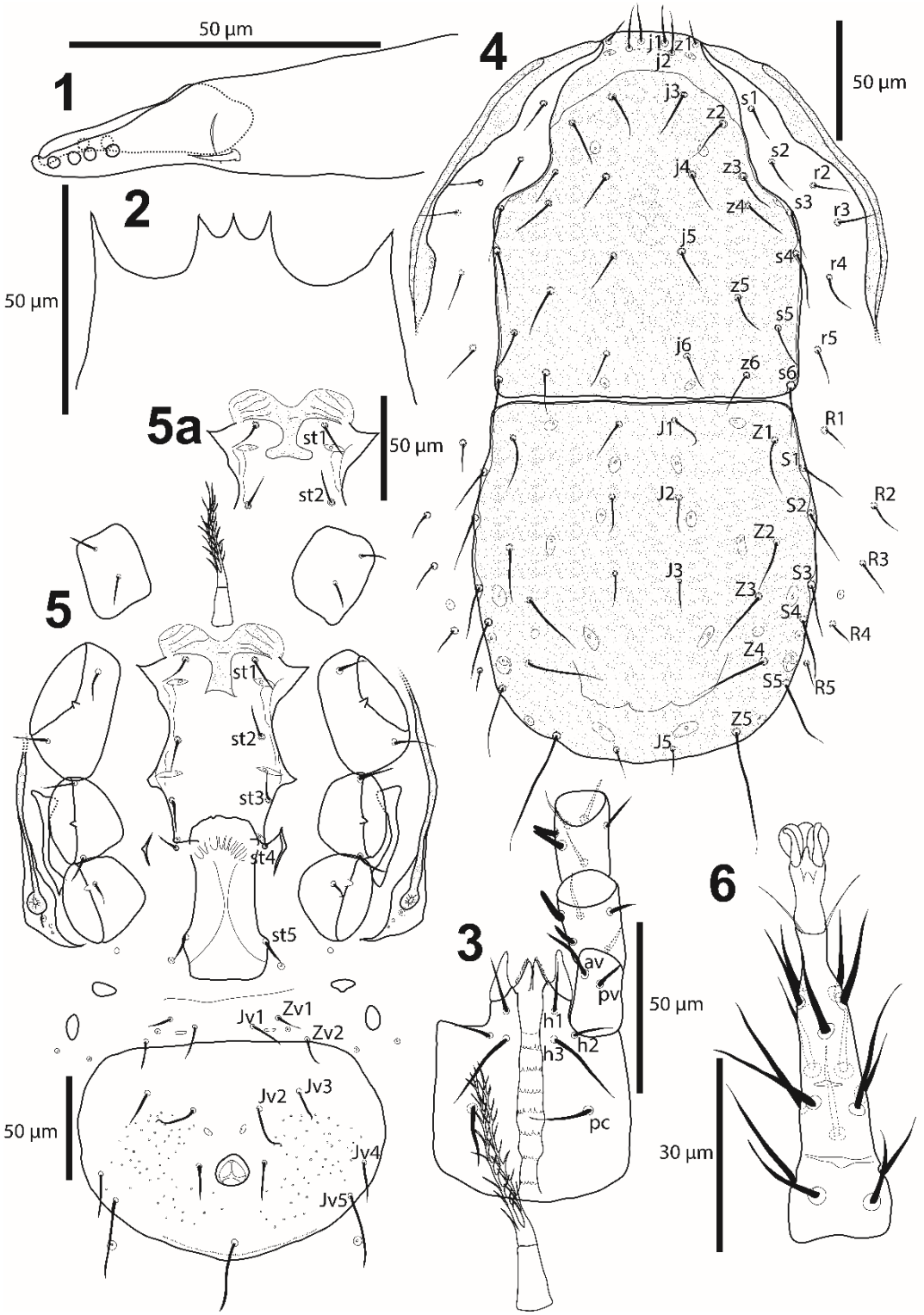
Specimens examined. Holotype female and two paratype females from soil of a fragment of Andean forest (pH 4.4–4.7; organic matter 44–54%; humidity 52–77%; soil temperature 9.5–10°C; collected by D. Rueda-Ramirez in June and August, 2010. Holotype and one paratype deposited at ESALQ-USP; one paratype female deposited at MJHN-PUJ.

Diagnosis. Anterior region of epistome with three subequal, pointed, smooth projections; podonotal shield with 16 pairs of setae (s1 and s2 on unsclerotised cuticle); opithonotal shield with 14 pairs of setae (J4 absent); two pairs of metapodal plates; ventrianal shield with four pairs of setae (Jv1, Zv1 and Zv2 on unsclerotised cuticle); exopodal plate only distinguishable as an elongate structure next to coxa III; peritreme extending anteriorly to level of median region of coxa I (region between z1 and s1); peritrematic plate barely fused with dorsal shield.

Description (female, three specimens measured).

Gnathosoma. Fixed cheliceral digit 29 (29–30) long, with four teeth; pilus dentilis indistinguishable; movable digit 30 long, with two teeth; dorsal and antiaxial lyrifissures and dorsal cheliceral seta distinct (Fig. 1). Numbers of setae on palp trochanter–tarsus: 2, 5, 6, 14, 15; palp tarsal apotele bifurcate. Anterior region of epistome with three subequal, pointed, smooth projections (Fig. 2). Deutosternal groove (Fig. 3) delimited by subparallel lateral lines, with eight transverse lines, the most distal smooth, others with 4–6 denticles each. Internal malae distinctly separated from each other; lateral margins fimbriate. Corniculi horn-shaped, about twice as long as basal width. Seta h3 about in longitudinal line with h1 and posteromesad of h2. Setal measurements: h1 15 (14–15), h2 11 (10–12), h3 22 (20–24), pc17 (15–18), palp trochanter av 20 (19–21), palp trochanter pv 13 (12–14); setae aciculate and smooth.

Dorsal idiosoma (Fig. 4). Idiosoma 308 (296–320) long and 132 (122–140) wide at widest level. Podonotal shield with a delineated slender strip along lateral margins, finely punctate; with a curved line crossing the shield anteriad of j3 and z2; 151 (147–155) long and 123 (122–125) wide at widest level; with 16 pairs of setae (j1–j6, z1–z6, s3–s6), four pairs of distinguishable lyrifissures and one pair of pores. Unsclerotised cuticle laterad of podonotal shield with six pairs of setae (s1, s2, r2–r5). Opisthonotal shield with a delineated slender strip anteriad of S4; finely puntate; with a wavy line anteriad of J5 and Z5; 153 (149–156) long and 135 (133–136) wide at widest level; with 14 pairs of setae, nine pairs of distinguishable lyrifissures and two pairs of pores. Unsclerotised cuticle laterad of opisthonotal shield with five pairs of setae (R1–R5) and a pair of lyrifissures (Rp). Measurements of setae: j1 13 (11–15), j2 18 (17–19), j3 20 (19–21), j4 19 (18–20), j5 17 (16–18), j6 21, J1 16, J2 16, J3 16, J5 13 (12–15), z1 10 (9–10), z2 21 (21–22), z3 17 (16–18), z4 20, z5 19 (18–20), z6 18, Z1 21 (20–22), Z2 21 (21–22), Z3 29 (29–30), Z4 32 (30–34), Z5 49 (47–50), s1 15 (14–15), s2 15 (14–16), s3 20 (19–21), s4 22 (21–24), s5 21 (20–21), s6 22 (21–23), S1 21 (20–21), S2 22 (21–23), S3 21 (20–22), S4 25 (25–26), S5 29 (29–30), r2 15 (14–15), r3 17 (15–18), r4 14 (13–15), r5 14 (13–15), R1 13 (12–14), R2 11 (11–12), R3 14 (12–15), R4 11 (10–12), R5 11 (10–11); setae aciculate and smooth.



Figures 1–6. *Gamasellodes andinus* sp. nov. Female. 1. Chelicera; 2. Epistome; 3. Hypostome and proximal palp segments; 4. Dorsal view; 5. Ventral view; 5a. Variation of sternal shield 6. Tarsus II.

Ventral idiosoma (Fig. 5). Base of tritosternum 17 (15–19) long and 10 (8–10) wide proximally; laciniae 52, separated for about 90% of their total length, pilose. Pre-sternal area weakly sclerotised, represented by two lobes fused with sternal shield, punctate and striate. Sternal shield mostly smooth, with scant faint striae along lateral margins and with a variably

shaped punctate indentation in anteromedian region (Figs 5, 5a); posterior margin lightly sclerotised; approximately 84 (83–85) long from anterior margin next to st1 to posterior margin and 61 (60–62) wide at widest level; with three pairs of setae and three pairs of lyrifissures; distances st1–st3 68 (66–69), st2–st2 41 (40–42). Fourth pair of sternal setae (st4) on unsclerotised cuticle, but very close to posterior margin of sternal shield. Genital shield smooth, bearing st5; extending posteriorly well behind coxa IV; 76 (75–77) long and 38 (37–39) wide at the widest level; distance st5–st5 36 (35–37); lyrifissure iv5 on unsclerotised cuticle, posterolaterad of st5. Two pairs of oval to subtriangular metapodal plates, the anterior transversely elongate and mesad of the longitudinally elongate posterior plate. Poststigmatic poroid gv2 inserted on unsclerotised cuticle behind coxa IV. Ventrianal shield smooth in the anterior third, punctate elsewhere; 100 (92–109) long and 133 (120–149) wide at widest level; with four pairs of setae (Jv2–Jv5) in addition to circumanal setae, and with one pair of distinguishable lyrifissures (posteromesad of Jv2); para-anal setae inserted slightly behind anterior margin of anal opening; the latter small, about 1/7 of shield length; 15 (14–15) long. Unsclerotised cuticle between genital and ventrianal shields with a slender sclerotised line followed by three pairs of setae (Jv1, Zv1 and Zv2), a pair of tiny transversely elong ate platelets and one pair of lyrifissures. Unsclerotised cuticle laterad of and posteriorad to ventrianal shield with two pairs and a pair of lyrifissures, respectively. Anterior section of endopodal plate fused with sternal shield; section behind sternal shield reduced to a v-shaped platelet between coxae III–IV. Exopodal plate only distinguishable as an elongate plate next to coxa III. Peritreme extending anteriorly to level of median region of coxa I (region between z1 and s1). Peritrematic plate narrow, barely fused anteriorly with dorsal shield at level of z1, with a lyrifissure next to r4 and with two lyrifissures and a pore behind each stigma. Setal measurements: st1 17 (15–18), st2 17 (15–19), st3 14 (13–15), st4 12 (11–12), st5 14 (13–15), Jv1 15 (15–16), Jv2 26 (25–26), Jv3 16 (15–17), Jv4 20 (17–22), Jv5 34 (31–37), Zv1 15 (13–16), Zv2 14, para-anal 18 (18–19), postanal 29 (27–30); setae aciculate and smooth.

Spermathecal apparatus. Not distinguishable.

Legs. Lengths: I: 236 (231–243); II: 194 (193–194); III: 166 (160–172); IV: 223 (219–231). Setation (legs I–IV): coxae: 2, 2, 2, 1; trochanters: 6, 5, 5, 5; femora: 12, 11, 6, 6; genua: 13, 11, 8, 9; tibiae: 13, 10, 8, 10; tarsi: I not counted, 18, 18, 18. All legs with pretarsi containing a pair of strongly sclerotised claws (Fig. 6); median section of pulvilli of legs I–IV rounded.

Adult male. Not found.

Etymology. The specific name *andinus* refers to “from the Andes”, South American mountain formation where the type locality is situated.

Remarks. *Gamasellodes andinus* sp. nov. is distinguished from all other *Gamasellodes* species by lacking J4. This species is most similar to *Gamasellodes magniventris* Mineiro, Lindquist & Moraes, 2009, described from Brazil, with a similar curved line crossing the shield anteriad of j3 and z2, a wavy line anteriad of J5 and Z5, and a broad ventrianal shield with a nearly straight anterior margin. However, the latter species differs from the species here described by having one pair of metapodal plates, presence of Zv3, opisthonotal shield with 15 pair of setae, and peritreme extending anteriorly to the region beside bases of setae z1.

***Gamasellodes intermedius* sp. nov.** (Figs 7–12)

Specimens examined. Holotype female and five paratype females from soil of a grassland (pH 5.5–6.1; organic matter 28–36%; humidity 71–75%; soil temperature 10–16°C); collected by D. Rueda-Ramirez in April and June, 2010. Holotype and two paratype females deposited at ESALQ-USP; two paratype females deposited at MJHNPUJ.

Diagnosis. Anterior region of epistome with three subequal projections of uniform width, each bifurcate; podonotal shield with sparse and light reticulation behind j4, smooth anteriorly, with a well define slender strip between z3 and s4, and with 17 pairs of setae (s2 on unsclerotised cuticle); j1, j2 and z1 almost in transverse line; opisthonotal shield mostly smooth, and with 16 pairs of setae (R5 inserted on posterior angle of dorsal shield); with two pairs of rounded to ovoid metapodal plates; ventrianal shield with four pairs of setae in additional to circumanal setae (Jv1, Zv1 and Zv2 on unsclerotised cuticle); peritreme short, extending anteriorly only to level of anterior margin of coxa IV (level of r5); peritrematic plate extending anteriorly to level between z1 and s1, not fused to dorsal shield.

Description (Female, six specimens measured).

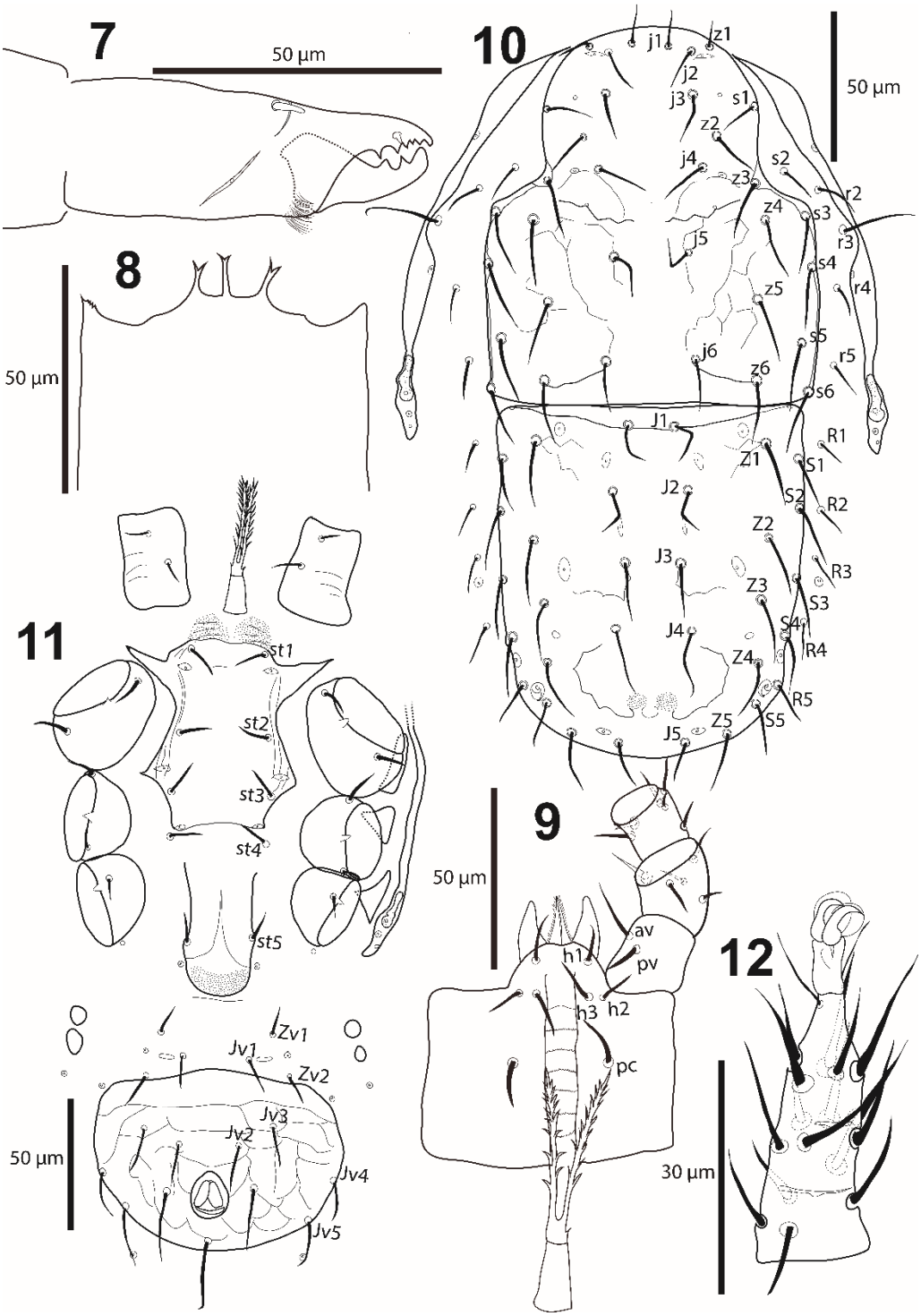
Gnathosoma. Fixed cheliceral digit 26 (25–27) long, with five teeth and setiform *pilus dentilis*; movable digit 26 (25–27) long, with two teeth; dorsal and antiaxial lyrifissures and dorsal cheliceral seta distinct (Fig. 7). Numbers of setae on palp trochanter–tarsus: 2, 5, 6, 14, 15; palp tarsal apotele bifurcate. Anterior region of epistome with three subequal projections of uniform width and each bifurcate (Fig. 8). Deutosternal groove (Fig. 9) delimited laterally by subparallel lines, with seven transverse lines, of which the most distal smooth and others with 9–15 denticles each. Internal malae distinctly separate from each

other; lateral margins fimbriate. Corniculi hornshaped, about 1.6 times as long as their basal width. Seta h3 about in longitudinal line with h1 and mesad of and in transverse line with h2. Setal measurements: h1 12 (11–13), h2 9 (8–10), h3 15 (13–17), pc 14 (13–15), palp trochanter av 17 (16–17), palp trochanter pv 11 (10–11); setae aciculate and smooth.

Dorsal idiosoma (Fig. 10). Idiosoma 240 (231–248) long and 112 (107–124) wide at widest level. Podonotal shield with sparse and light reticulation behind j4, smooth anteriorly, with well define slender strip between z3 and s4; 123 (117–129) long and 110 (107–115) wide at widest level; with 17 pairs of setae, two pairs of distinguishable lyrifissures and two pairs of pores; j1, j2 and z1 almost in transverse line. Unsclerotised cuticle laterad of podonotal shield with five pairs of setae (s2, r2–r5). Opisthonotal shield mostly smooth, with a line immediately behind J1 extending diagonally to anterolateral corners, with scant lines by Z1, a wavy line between J3 and Z3, and with a shallow ovoid depression between J4 and J5, more clearly discernable near posterior margin; 117 (114–119) long and 108 (105–110) wide; with 16 pairs of setae (R5 inserted on posterior angle of dorsal shield), six pairs of distinguishable lyrifissures and two pairs of pores. Setae J4 shorter than distance between their bases (24–26). Unsclerotised cuticle laterad of opisthonotal shield with four pairs of setae (R1–R4) and a pair of lyrifissures (Rp). Setal measurements: j1 11 (10–12), j2 14 (11–16), j3 18 (17–20), j4 19 (17–20), j5 16 (15–17), j6 16 (15–17), J1 16 (15–17), J2 18 (16–19), J3 18 (16–19), J4 22 (20–24), J5 13 (12–15), z1 9 (9–10), z2 17 (15–18), z3 19 (17–20), z4 21 (19–23), z5 21 (20–22), z6 20 (18–21), Z1 21 (20–23), Z2 21 (19–22), Z3 22 (20–23), Z4 22 (20–24), Z5 22 (21–24), s1 15, s2 12 (10–13), s3 20 (18–23), s4 22 (18–23), s5 21 (20–23), s6 20 (19–22), S1 18 (16–20), S2 19 (17–20), S3 21 (20–22), S4 21 (20–22), S5 20 (19–22), r2 14 (13–15), r3 25 (24–25), r4 11 (10–12), r5 11 (10–12), R1 10 (9–10), R2 10 (10–11), R3 12 (11–12), R4 13 (12–13), R5 14 (13–15); setae aciculate and smooth.

Ventral idiosoma (Fig. 11). Base of tritosternum 16 (15–16) long and 10 (9–10) wide proximally; laciniae 45 (44–46), separated for about 90% of their total length, pilose. Pre-sternal area weakly sclerotised, with light punctation distinguishable in some specimens. Sternal shield, mostly smooth, with scant faint marginal striae; posterior margin lightly sclerotised and lightly concave; approximately 65 (58–71) long and 54 (50–56) wide at widest level; with three pairs of setae and three pairs of lyrifissures (iv3 hardly distinguishable); distances st1–st3 55 (55–57), st2–st2 35 (34–35). Metasternal plates indistinguishable; however, fourth pair of sternal setae (st4) on unstriate, lightly sclerotised region. Genital shield narrow, mostly smooth, punctate along convex posterior margin, bearing st5 and extending posteriorly well behind coxa IV; 59 (56–61) long and 25 (24–26) wide at the widest

level; distance st5–st5 24 (23–25); lyrifissure iv5 on unsclerotised cuticle posterolaterad of st5.



Figures 7–12. *Gamasellodes intermedius* sp. nov. Female. 7. Chelicera; 8. Epistome; 9. Hypostome and proximal palp segments; 10. Dorsal view; 11. Ventral view; 12. Tarsus II.

Two pairs of ovoid to rounded metapodal plates. Ventrianal shield reticulate; 66 (65–67) long and 92 (87–95) wide at widest level; with four pairs of setae (Jv2–Jv5) in addition to

circumanal setae; para-anal setae inserted at about mid-length of anal opening; the latter small, about 1/5 of shield length; 14 (13–15) long. Unsclerotised cuticle between genital and ventrianal shields three pairs of setae (Jv1, Zv1 and Zv2), a pair of tiny transversely elongate platelets and a pair of lyrifissures. Unsclerotised cuticle laterad of and posteriorad to ventrianal shield with two pairs and a pair of lyrifissures, respectively. Anterior section of endopodal plate fused with sternal shield; section behind sternal shield indistinct. Exopodal plate reduced to triangular platelets between coxae II–III and III–IV and an elongate plate next to coxa II. Peritreme short, extending anteriorly only to level of anterior margin of coxa IV (level of r5). Peritrematic plate abutting but not fused to dorsal shield at level of z1 and s1 and ending as a blunt and slightly curved extension at level of posterior margin of coxa IV; with a lyrifissure next to s2 (median level of coxa II), a lyrifissure next to r4 (median level of coxa III), and a lyrifissure and a pore posterior to stigma. Setal measurements: st1 13 (11–14), st2 12 (11–13), st3 13 (11–13), st4 12 (10–13), st5 10 (10–11), Jv1 14 (11–15), Jv2 16 (15–17), Jv3 17 (16–18), Jv4 15 (13–17), Jv5 23 (22–24), Zv1 12 (11–13), Zv2 13 (11–14), para-anal 23 (20–24), post-anal 23 (22–24); setae aciculate and smooth.

Spermathecal apparatus. Not distinguishable.

Legs. Lengths: I: 211 (205–215); II: 150 (140–158); III: 139 (130–145); IV: 180 (170–189). Setation (legs I–IV): coxae: 2, 2, 2, 1; trochanters: 6, 5, 5, 5; femora: 12, 11, 6, 6; genua: 13, 11, 8, 9; tibiae: 13, 10, 8, 9; tarsi: not counted, 18, 18, 18. All legs with pretarsi containing a pair of strongly sclerotised claws (Fig. 12); median section of pulvilli of legs I–IV rounded.

Adult male. Not found.

Etymology. The specific name "*intermedius*" refers to fact that the morphological characteristics of this species are intermediate between *Protogamasellus* and *Gamasellodes*.

Remarks. This species is most similar to *Gamasellodes minor* Athias-Henriot, 1961, described from Algeria, with similar ornamentation on the posterior part of the opisthonotal shield, setae J4 shorter than the distance between their bases (respectively 18 and 23 in G. minor), and with short peritreme. However, the latter species differs from the species here described by having a continuous line connecting the bases of j4 and z3 and by having one less pair of opisthogastric setae (Zv2). In addition, the opisthonotal shield of *G. minor* has only 15 pairs (R5 inserted off dorsal shield). Although placed in *Gamasellodes*, the generic classification of this species is doubtful, because some characteristics are typical of *Protogamasellus*, namely the transverse line at level of setae J1, while other characteristics

are typical of *Gamasellodes*, namely the absence of a transverse line extending completely across the level of z6, the presence of nine setae on genu IV and the anterior region of epistome most often with three pointed or distally denticulate projections. Some species of *Gamasellodes* have short peritreme (Moraes *et al.*, 2016); however, except for G. minor, the peritreme extends at least to level of posterior half of coxa II.

***Protogamasellus caleraensis* sp. nov.** (Figs 13–15)

Specimens examined. Holotype female and a paratype female from soil of a grassland (pH 5.2–5.4; organic matter 29–39%; humidity 73%; soil temperature 16°C); collected by D. Rueda-Ramirez in April, 2010. Holotype deposited at ESALQ-USP; paratype deposited at MJHN, PUJ.

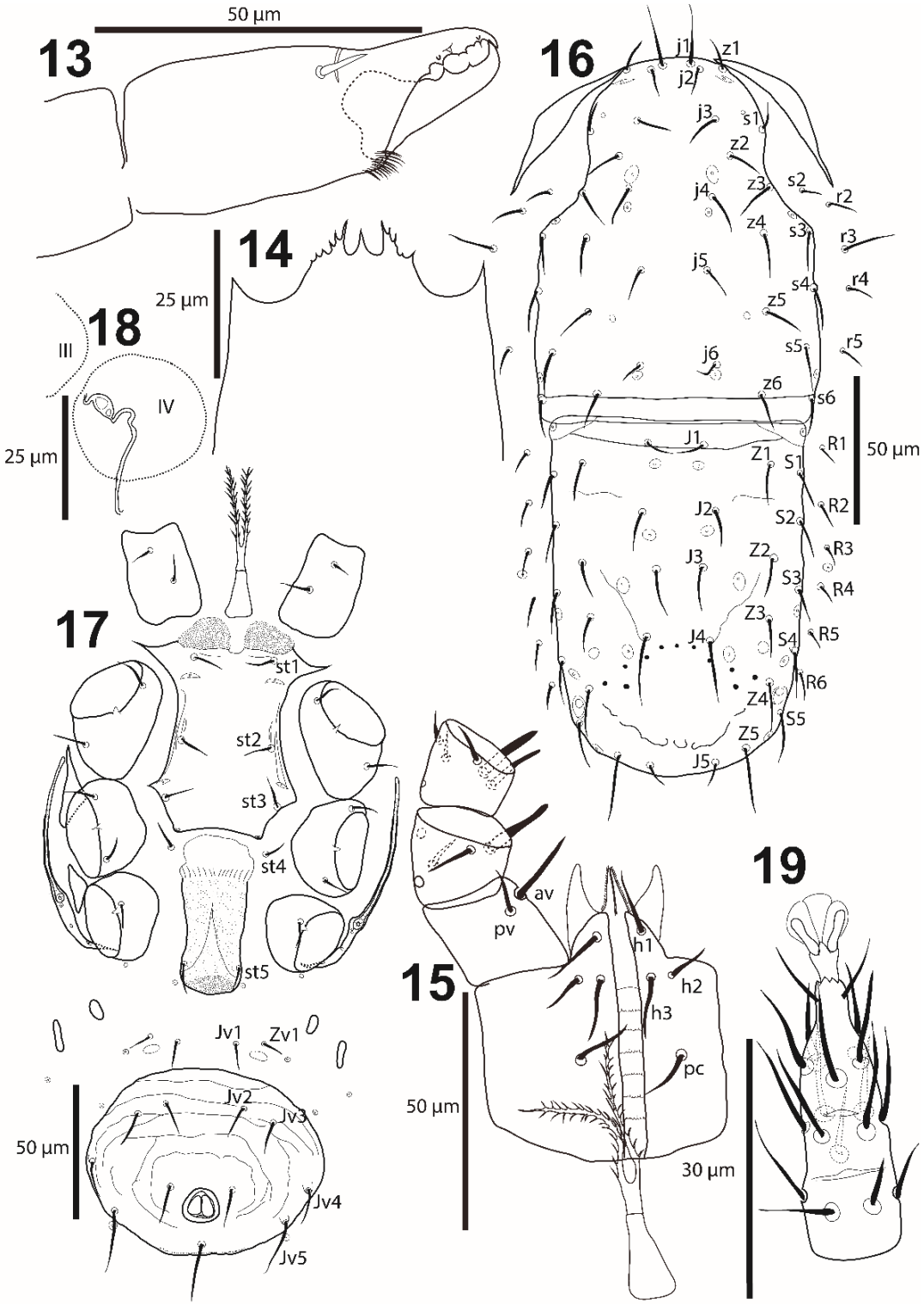
Diagnosis. Anterior region of epistome with three subtriangular projections, median smooth and laterals with external margins serrate and slightly longer than median projection; podonotal shield with a transverse line at level of z6, and with 17 pairs of setae (s2 on unsclerotised cuticle); opithonotal shield with a transverse line at level of J1 and with 15 pairs of setae; two pairs of metapodal plates; ventrianal shield with four pairs of setae in addition to circumanal setae (Jv1 and Zv1 on unsclerotised cuticle); peritreme short extending anteriorly to region between posterior margin and median level of coxa II (slightly behind level of r3); peritrematic plate indistinct, except for anterior end (subtriangular auxiliary anterolateral plate) and posterior end (slender and distally acuminating structure behind stigma).

Description (Female, two specimens measured).

Gnathosoma. Fixed cheliceral digit 23–25 long, with eight teeth and setiform pilus dentilis (two teeth externally to alignment of remaining teeth); movable digit 23–25 long, with two teeth; dorsal lyrifissure and dorsal cheliceral seta distinct; antiaxial lyrifissure indistinct (Fig. 13). Numbers of setae on palp trochanter–tarsus: 2, 5, 6, 14, 15; palp tarsal apotele bifurcate. Anterior region of epistome with three projections; median smooth, laterals with external margin serrate and slightly longer than median projection (Fig. 14). Deutosternal groove (Fig. 15) delimited by subparallel lines, with seven transverse lines, of which the most distal smooth and others with 6–8 denticles each. Internal malae distinctly separated from each other, lateral margins fimbriate. Corniculi hornshaped, about twice as long as basal width. Seta h3 about in longitudinal line with h1 and mesad of and in transverse line with h2. Setal measurements: h1 12, h2 9, h3 12, pc 12, palp trochanter av 14–15, palp trochanter pv 9–10; setae aciculate and smooth.

Dorsal idiosoma (Fig. 16). Idiosoma 250–259 long and 126–130 wide at widest level. Podonotal shield smooth, except for a transverse line at level of z6, delimiting a posterior more lightly sclerotised band; 124–127 long and 97–99 wide at widest level; with 17 pairs of setae, six pairs of distinguishable lyrifissures and two pairs of pores; seta j2 inserted almost in transverse line with insertions of j1 and z1. Unsclerotised cuticle laterad of podonotal shield with five pairs of setae (s2, r2–5). Opisthonotal shield smooth, except for a transverse line at level of J1, a diagonal wavy line between J4 and Z2, a pair of short transverse lines behind Z1, and an arched wavy and broken line anteriad of J5 and Z5; 126–127 long and 85–91 wide; with a series of eight punctiform depressions in an arched line between J4 and Z4; with 15 pairs of setae, eight pairs of distinguishable lyrifissures and two pairs of pores; pore between Z3 and Z4 distinctly large. Unsclerotised cuticle laterad of opisthonotal shield with six pairs of setae (R1–R6) and a pair of lyrifissures (Rp). Setal measurements: j1 20–22, j2 11–12, j3 13–14, j4 14–15, j5 13, j6 11, J1 12, J2 13, J3 19–22, J4 24, J5 15–16, z1 10–11, z2 12–14, z3 15, z4 15, z5 16, z6 10, Z1 14–15, Z2 15–16, Z3 16, Z4 16–18, Z5 24–25, s1 10–11, s2 11–12, s3 15–16, s4 13–15, s5 16–17, s6 16–17, S1 13–14, S2 14–15, S3 14–16, S4 18–19, S5 19–23, r2 12–13, r3 17–18, r4 10, r5 9, R1 8–9, R2 9–10, R3 9–10, R4 9–10, R5 9–10, R6 11; setae aciculate and smooth.

Ventral idiosoma (Fig. 17). Base of tritosternum 16–17 long and 9–10 wide proximally; laciniae 38–40, separated for about 80% of their total length, pilose. Pre-sternal area weakly sclerotised and weakly punctate. Sternal shield mostly smooth, with scant faint striae along lateral margins; anteromedian region more lightly sclerotised than remaining of the shield; posterior margin slightly concave; approximately 67–69 long and 39–40 wide at widest level; with three pairs of setae and three pairs of lyrifissures; distances st1–st3 54–55, st2–st2 33–34. Metasternal plates indistinguishable; however, fourth pair of sternal setae (st4) on unstriate, lightly sclerotized region. genital shield narrow, finely punctate, with posterior margin convex, bearing st5; extending slightly behind coxa IV, wider at base of anterior flap (23–24); 60–63 long; distance st5–st5 21–22; lyrifissure iv5 on unsclerotized cuticle, posterolaterad of st5. Two pairs of metapodal plates, the anterior ovoid and the posterior elongate. Ventrianal shield oval, reticulate; 68–70 long and 87–98 wide at widest level; with four pairs of setae (Jv2–Jv5) in addition to circumanal setae; para-anal setae inserted at level of the anterior margin of anal opening; the latter small, about 1/5 of shield length, 13 long. Unsclerotised cuticle around ventrianal shield with two pairs of setae (Jv1 and Zv1), a pair of platelets and four pairs of lyrifissures. Anterior section of endopodal plate fused with sternal shield; section behind sternal shield indistinct.



Figures 13–19. *Protogamasellus caleraensis* sp. nov. Female. 13. Chelicera; 14. Epistome; 15. Hypostome and proximal palp segments; 16. Dorsal view; 17. Ventral view; 18. Spermathecal apparatus; 19. Tarsus III.

Exopodal shield reduced to triangular platelets between coxae II–III and III–IV. Peritreme short extending anteriorly to region between posterior margin and median level of coxa II (slightly behind level of r3). Peritrematic plate indistinct, except for anterior end

(subtriangular auxiliary anterolateral plate) and posterior end (slender structure behind stigma). Setal measurements: st1 13, st2 13–14, st3 13–14, st4 11, st5 10–12, Jv1 10–11, Jv2 12–14, Jv3 14–16, Jv4 13–15, Jv5 23–24, Zv1 10–10, para-anal 15–16, post-anal 25; setae aciculate and smooth.

Spermathecal apparatus. Induction pore apparently between coxae III and IV; infundibulum ovoid (6 long and 3 wide); tubulus string-like; distinct section about 30 long (Fig. 18).

Legs. Lengths: I: 200–209; II: 143–145; III: 120–121; IV: 150–165. Setation (legs I–IV): coxae: 2, 2, 2, 1; trochanters: 6, 5, 5, 5; femora: 12, 11, 6, 6; genua: 13, 11, 8, 8; tibiae: 13, 10, 8, 9; tarsi: I not counted, 18, 18, 18. All legs with pretarsi containing a pair of strongly sclerotised claws (Fig. 19); median section of pulvilli of legs I–IV rounded.

Adult male. Not found.

Etymology. The specific name "*caleraensis*" refers to "La Calera", the type locality of this new species, and "*ensis*" denoting origin.

Remarks. This new species is most similar to *Protogamasellus brevicornis* Shcherbak, 1976, described from South Africa; both with a large, rounded pore between Z3 and Z4; and setae j1, Z5 and r3 distinctly longer than the other dorsal setae. However, in P. brevicornis Jv4 is inserted on unsclerotised cuticle; insertions of Jv2 (mentioned as Jv3) and Jv3 (mentioned as Zv3) in transverse line; and anterior margin of ventrianal shield straight.

3.3.2. Blattisociidae Garman

***Blattisocius keegani* Fox**

Blattiosocius [sic] *keegani* Fox, 1947: 599.

Melichares (*Blattisocius*) *keegani*.—Evans, 1958: 209.

Melichares keegani.—Hirschmann, 1962: 30; Sinha et al., 1962: 546.

Blattisocius keegani.—Haines, 1978: 21; Treat, 1975: 94.

Morphology (female, two specimen measured).

Gnathosoma. Fixed cheliceral digit 19–20 long, with three teeth; movable digit 27–28, with a single tooth; anterior region of epistome smooth, with a small rounded median lobe and with two lateral elongate and sharp extensions.

Dorsal idiosoma. Dorsal shield reticulate, 475–500 long and 190–223 wide, with 33 pairs of setae. Unsclerotised cuticle with 17 pairs of setae (r2–r6, R1–R6, UR1–UR6). Setal measurements j1 20–21, j2 30–33, j3 33–36, j4 31, j5 34, j6 33, J1 35, J2 35, J3 36–38, J4 34, J5 34–36, z1 21–22, z2 36–38, z3 34, z4 and z5 broken, z6 36–38, Z1 37–42, Z2 39, Z3 37, Z4 37–41, Z5 52–54, s1 30–31, s2 36–38, s3 38, s4 39, s5 35, s6 42–44, S1 40, S2 40–43, S3 41–43, S4 41–44, S5 41–45, r2 39, r3 41, r4 43, r5 42, r6 45, R1 46, R2 44, R3 44, R4 45, R5 42, R6 45, UR1 41, UR2 36, UR3 38, UR4 40, UR5 42, UR6 44. Dorsal setae smooth, except J3–J5 and Z5, serrate.

Ventral idiosoma. Base of tritosternum 12–13 long and 14–15 wide proximally; laciniae 73–75, separated for about 45% of their total length, pilose. Presternal area lightly sclerotised, transversely striate. Sternal shield with sinuous longitudinal striae, 95–110 long and 72–82 wide, with three pairs of setae and two pairs of lyrifissures; setae st1 37–41, st2 35–36, st3 34–35, st4 35. Distances st1–st3 80–92, st2–st2 70–81. Genital shield longitudinally striate; 170–175 long and 80–82 wide at the widest level; seta st5 34; distance st5–st5 63–70. Two pairs of elongate metapodal plates. Ventrianal shield subpentagonal, slightly concave near Jv2, reticulate, 154–177 long and 88–105 wide, with three pairs of setae (Jv1–Jv3); anus 25 long. Unsclerotised cuticle around ventrianal shield with seven pairs of setae (Jv4, Jv5, Zv1–Zv5). Discrete endopodal plates absent. Exopodal plate narrow. Peritrematic plate narrow, extending anteriorly to level of s1 and tapered posteriorly to fuse with remnant of exopodal shield beside coxa IV. Peritreme short, reaching posterior margin of coxa III. Setal measurements Jv1 31–35, Jv2 41, Jv3 46–54, Jv4 55–50, Jv5 70–72, Zv1 40, Zv2 44–50, Zv3 45–44, Zv4 49–46, Zv5 54, para-anal 24–25, post-anal 40.

Legs. Setation: genua I–IV: 13, 11, 9, 9; tibiae I–IV: 13, 10, 8, 10.

Material examined. Two females respectively from soil of a fragment of Andean forest (pH 4.5; organic matter 27%; humidity 48%; soil temperature 9.5°C) and of a grassland (pH 5.6; organic matter 51%; humidity 58%; soil temperature 16°C) in August and October, 2010.

Remarks. The specimens collected fit well the redescription provided by Britto *et al.* (2012) based on specimens from Brazil.

***Cheiroseius mesae* sp. nov.** (Figs 20–28)

Specimens examined. Holotype and a three paratype females from soil of a fragment of Andean forest (pH 3.8–4.3; organic matter 37–82%; humidity 47–70%; soil

temperature 9–12°C); collected by D. Rueda-Ramirez in August and October, 2010, deposited at ESALQ-USP; a paratype with same collection data deposited at MJHN-PUJ.

Diagnosis. Anterior region of epistome with three distally denticulate projections (in some specimens at least one projection non-denticulate); deutosternum with eight transverse lines, of which the first smooth and the others with progressively larger number of denticles; dorsal shield covering the idiosoma and extending ventrolaterally, with a network of ridges and depressions and with 39 pairs of setae; a pair of metapodal plates; a pair of elongate platelets between genital and ventrianal shields; ventrianal shield with four pairs of setae in addition to circumanal setae (Jv1, Jv5, Zv1 and Zv3 and Zv5 on unsclerotised cuticle); peritreme wide extending anteriorly to the bases of j1, with post-stigmatic extension narrower than pre-stigmatic section; peritrematic plate wide, fused to dorsal shield at level of s1.

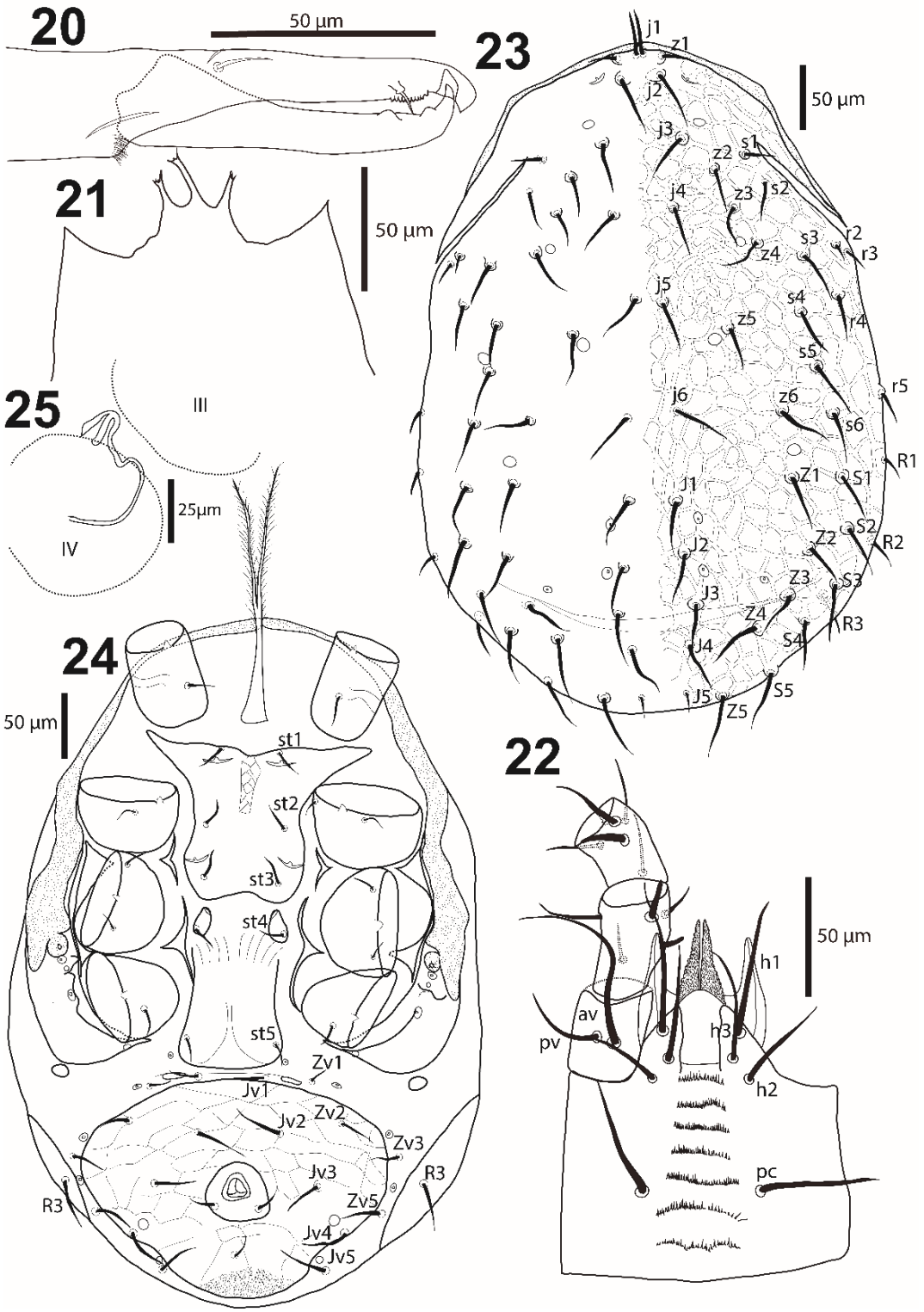
Description (Female, three specimens measured).

Gnathosoma. Movable cheliceral digit with two teeth, 77 (77–78) long; fixed digit 81 (80–82) long, with a short ridge bearing 10–12 fine denticles matching interval between teeth of movable digit, with setiform *pilus dentilis* and subterminal notch matching apex of movable digit; dorsal and paraxial lyrifissure and dorsal seta distinct (Fig. 20). Numbers of setae on palp trochanter–tarsus: 2, 5, 6, 14, 15; palp tarsal apotele bifurcate; palp trochanter seta av much longer than the pv seta of the same segment. Anterior region of epistome with three projections slightly wider at the base, all distally denticulate (in some specimens at least one projection nondenticulate); median projection slightly longer (Fig. 21). Deutosternal region (Fig. 22) without delimiting lateral lines and with eight transverse lines, the first of which (most distal) smooth, the second with 22 denticles and other lines with progressively larger number of denticles; the last with about 35 denticles; most basal line w-shaped. Internal malae distinctly separated from each other, covered with tiny spines giving the appearance of crenulate margins. Corniculi horn-shaped, with a ventro-longitudinal carina, about twice as long as basal width. Seta h3 slightly mesad of h1 and well anteriad of h2. Setal measurements: h1 64 (63–65), h2 41 (40–43), h3 48 (47–49), pc 46 (44–48), palp trochanter av 80 (77–82), palp trochanter pv 37 (36–39); setae aciculate and smooth.

Dorsal idiosoma (Fig. 23). Dorsal shield entire, covering the idiosoma and extending ventrolaterally, with a network of ridges and depressions; 515 (480–533) long and 342 (330–361) wide. Podonotal region with 22 pairs of setae, one pair of lyrifissures and four pairs of pores. Opisthonotal region with 17 pairs of setae (one specimen with R1 on unsclerotised cuticle, and thus with 16 pairs of setae on the opisthonotal region of the shield), three pairs of lyrrifisures and a pair of pores. Setal measurements j1 39 (38–40), j2 44 (42–

48), j3 45 (44–47), j4 41 (40–42), j5 41 (40–42), j6 44 (43–45), J1 46 (45–47), J2 46 (45–47), J3 47 (45–48), J4 45 (43–46), J5 16 (16–17), z1 25 (24–25), z2 41 (40–42), z3 39 (37–40), z4 45 (43–47), z5 27 (26–29), z6 44 (42–45), Z1 47 (45–48), Z2 46 (45–48), Z3 45 (42–47), Z4 43 (42–44), Z5 50 (47–52), s1 20 (19–20), s2 34 (32–35), s3 40 (38–42), s4 45 (44–45), s5 46 (44–50), s6 47 (45–48), S1 43 (41–45), S2 47 (46–48), S3 44 (43–45), S4 45 (44–45), S5 48 (46–50), r2 20 (20–21), r3 25 (25–26), r4 38 (37–40), r5 27 (26–28), R1 27, R2 32 (31–33), R3 37 (36–37); setae stout and smooth, most of which inserted on tubercles.

Ventral idiosoma (Fig. 24). Line separating the base from the remaining of tritosternum indistinct. Whole tritosternum 189 (181–193) long; separated laciniae corresponding to 50% of total length of tritosternum, pilose. Pre-sternal platelets absent. Sternal shield smooth except for a reticulate, elongate anteromedian area, 113 (110–115) long and 94 (88–100) wide at level between coxae III and IV, with three pairs of setae and two pairs of lyrifissures; distances st1–st3 103 (100–109), st2–st2 66 (62–70). Fourth pair of sternal setae (st4) and third pair of sternal lyrifissures (iv3) on metasternal plates. Genital shield smooth, posterior margin slightly convex; 129 (124–134) long and 76 (75–78) wide at the widest level; distance st5–st5 68 (65–70). Lyrifissure iv5 on unsclerotised cuticle, posterolaterad of st5. One pair of ovoid metapodal plates. Ventrianal shield subtriangular, reticulate; 165 (162–170) long and 238 (234–245) wide; with four pairs of setae (Jv2–Jv4, Zv2) in addition to circumanal setae and a large pore anteromesad of Jv4; para-anal setae inserted behind posterior margin of anal opening; the latter small, about 1/8 of shield length, 18 (18–19) long. Unsclerotised cuticle around ventrianal shield with five pairs of setae (Jv1, Jv5, Zv1, Zv3 and Zv5), a pair of transversely elongate platelet, three pairs of lyrifissures and a pair of pores. Anterior section of endopodal plate fused with sternal shield; section between coxae II–III and III–IV reduced to two elongate V-shaped platelets. Exopodal plate distinct around coxa III with triangular sections between coxae II–III and III–IV, connected by a narrow bridge. Peritrematic plate wide, fused anteriorly with dorsal shield at level of s1 and with exopodal shield at level of coxa IV, with a pore and a pair of lyrifissures behind each stigma. Peritreme wide, extending anteriorly to the bases of j1, almost meeting anterior end of each other; with post-stigmatic extension narrower than pre-stigmatic section. Setal measurements: st1 21 (20–22), st2 26 (25–27), st3 27 (26–27), st4 24 (23–25), st5 28 (25–30). Jv1 26 (25–27), Jv2 42 (41–44), Jv3 40 (37–45), Jv4 28 (25–30), Jv5 41 (39–43), Zv1 19 (17–20), Zv2 29 (27–32), Zv3 22 (20–23), Zv5 40 (37–42), para-anal 25 (22–28), post-anal 23 (21–25); setae stout and smooth.



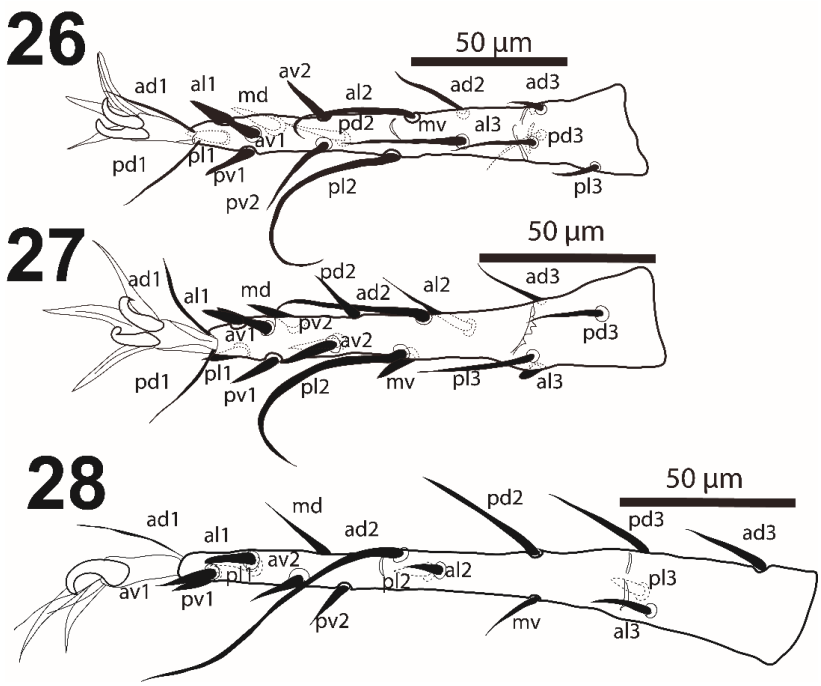
Figures 20–25. *Cheiroseius mesae* sp. nov. Female. 20. Chelicera; 21. Epistome; 22. Hypostome and proximal palp segments; 23. Dorsal idiosoma; 24. Ventral idiosoma; 25. Spermathecal apparatus.

Spermathecal apparatus. Induction pore apparently between coxae III and IV; infundibulum ovoid to subtriangular (about 13 long); tubulus string-like; distinct section about 75 long (Fig. 25).

Legs. Lengths: I: 574 (560–588); II: 415 (410–356); III: 398 (380–401); IV: 534 (530–551).–Setation (legs I–IV): coxae: 2, 2, 2, 1; trochanters: 6, 5, 5, 5; femora: 12, 11, 6, 6; genua: 13, 10, 8, 9; tibiae: 13, 10, 8, 10; tarsi: I not counted, 18, 18, 18. Leg I with small pretarsi and claw. Legs II–IV with a pair of strongly sclerotised claws, median section of pulvilli acute and paradactyli acuminate. Setae al2 (ca. 50) and pl2 of tarsus II (ca. 70), ad2 and pd2 of tarsus III (ca. 65), and ad2 of tarsus IV (ca. 85) longer than other setae of the same segment and distally curved (Fig. 26–28).

Etymology. This species is named after Nora Cristina Mesa Cobo, eminent Colombian acarologist.

Remarks. This new species is most similar to *Cheiroseius trispinosus* Karg, 1981 described from Venezuela by having post-stigmatic extension of the peritreme, ventrianal shield with four pairs of setae in addition to circumanal setae, and similar size (530–550 long and 340–350 wide in *C. trispinosus*). However, the sternal shield of *C. trispinosus* does not have a median reticulate area and its setae Z5 (75) and J4 (70) are much longer than in the species here described.



Figures 26–28. Cheiroseius mesae sp. nov. Female. 26. Tarsus II; 27. Tarsus III; 28. Tarsus IV.

***Cheiroseius* aff. *trilobus* Karg**

Cheiroseius (Cheiroseius) trilobus Karg, 1981: 67.

Cheiroseius (Cheiroseius) trilobus.—Karg, 1998a: 54.

Morphology (female, one specimen measured).

Gnathosoma. Movable cheliceral digit 45, with two small teeth; fixed digit 47 long, with a deep subapical notch matching apex of movable digit followed by short ridge (ca. 5 μm long) bearing approximately eight fine denticles. Anterior region of epistome with three projections; median projection subtriangular, longest, sharptipped and smooth; lateral projections subapically and externally denticulate.

Dorsal idiosoma. Podonotal and opisthonotal shields fused, 420 long and 245 wide, with 36 pairs of setae. Unsclerotised cuticle with six pairs of setae (r5, R1–R5). Setal measurements: j1 10, j2 45, j3 41, j4 48, j5 42, j6 46, J1 42, J2 (longer than the distance to the base of J3) 43, J3 (longer than the distance to the base of J4) 40, J4 49, J5 16, z1 27, z2 33, z3 40, z4 45, z5 28, z6 41, Z1 50, Z2 46, Z3 53, Z4 50, Z5 52, s1 21, s2 31, s3 45, s4 45, s5 47, s6 47, S1 47, S2 45, S3 47, S4 50, S5 51, r2 20, r3 20, r4 36, r5 25, R1 19, R2 22, R3 25, R4 25, R5 27; setae stout and smooth.

Ventral idiosoma. Tritosternum not adequately positioned for measurements. Presternal platelets absent. Sternal shield smooth, 85 long and 68 wide, with three pairs of setae and two pairs of lyrifissures; setae st1 17, st2 16, st3 16, st4 18. Distances st1–st3 70, st2–st2 42. Genital shield smooth, 69 long and 59 wide at the widest level; seta st5 19; distance st5–st5 46. One pair of ovoid metapodal plates. Ventrianal shield reticulate, with three pairs of setae (Jv2, Jv3 and Zv2) in addition to circumanal setae, 100 long and 132 wide; anus 13 long. Unsclerotised cuticle around ventrianal shield with five pairs of setae (Jv1, Jv4, Jv5, Zv1 and Zv3). Anterior section of endopodal plate fused with sternal shield; sections between coxae II–III and III–IV reduced each to an elongate v-shaped platelet. Exopodal plate consolidated with peritrematic shield; the latter plate wide, fused anteriorly with dorsal shield at level of s1 and extending posteriorly to level of posterior margin of coxa IV. Peritreme wide, extending anteriorly to base of j1, without post-stigmatic extension. Setal measurements: Jv1 17, Jv2 20, Jv3 20, Jv4 21, Jv5 20, Zv1 15, Zv2 15, Zv3 13, para-anal 19, post-anal 15; all setae stout and smooth.

Legs. Setation: genua I–IV: 13, 10, 8, 9; tibiae I–IV: 13, 10, 9, 10. Tarsi II–IV with a macroseta each (25, 38 and 53, respectively).

Material examined. A female from soil of a fragment of Andean forest–(pH 4.0; organic matter 33%; humidity 46%; soil temperature 9°C) in December, 2010.

Remarks. The specimen examined is most similar to *Cheiroseius tetrados* Karg, 1998 and *Cheiroseius trilobus* Karg, 1981, both of which were described from Ecuador, also without post-stigmatic extension of the peritreme, ventrianal shield with three pairs of setae in

addition to circumanal setae and j1 is much shorter than other dorsal setae. However, both are shorter (dorsal shield 310–340 long and 200 wide in *C. tetrados* and 340–360 long and 200–250 wide in *C. trilobus*). Additionally, in *C. tetrados* j2 (s1 in the original description, 30) and Z5 (40) are shorter, sternal setae (20) are slightly longer, and sternal shield has a longitudinal anteromedian reticulate region (lacking in the specimen examined). Conversely, *C. trilobus* has S5 (60) slightly longer than the specimen examined. The identity of this specimen should be confirmed with the collection of additional specimens and an evaluation of the types of those similar species.

***Cheiroseius* aff. *neophalangioides* Mineiro, Lindquist & Moraes**

near *Cheiroseius neophalangioides* Mineiro, Lindquist & Moraes, 2009: 4.

Morphology (female, one specimen measured).

Gnathosoma. Movable cheliceral digit 61, with a small tooth; fixed digit 65 long, with a deep subapical notch matching the apex of movable digit, followed by short ridge (ca. 6 μm long) bearing approximately seven denticles. Anterior region of epistome with three smooth, subtriangular projections; anteromedian projection longest.

Dorsal idiosoma. Podonotal and opisthonotal shields fused, reticulate, 445 long and 275 wide, with 36 pairs of setae. Unsclerotised cuticle with seven pairs of setae (r5, R1–R6). Setae j1 40, j2 43, j3 48, j4 45, j5 48, j6 45, J1 49, J2 broken, J3 48, J4 50, J5 12, z1 33, z2 38, z3 44, z4 51, z5 30, z6 44, Z1 55, Z2 54, Z3 55, Z4 (longer than the distance to the base of Z5) 50, Z5 42, s1 36, s2 36, s3 44, s4 49, s5 50, s6 52, S1 48, S2 56, S3 54, S4 54, S5 43, r2 34, r3 36, r4 45, r5 35, R1 33, R2 32, R3 34, R4 35, R5 35, R6 37; setae stout and smooth.

Ventral idiosoma. Base of tritosternum 30 long and 12 wide proximally; laciniae 118, separated for about 50% of their total length, pilose. Presternal platelets absent. Sternal shield smooth except for a reticulate anteromedian area; 104 long and 94 wide, with three pairs of setae and two pairs of lyrifissures; setae st1 24, st2 24, st3 26, st4 22. Distances st1–st3 87, st2–st2 65. Genital shield smooth, 100 long and 93 wide at the widest level; seta st5 24; distance st5–st5 76. One pair of ovoid metapodal plates. Ventrianal shield reticulate, with three pairs of setae (Jv2, Jv3 and Zv2) in addition to circumanal setae; 127 long and 190 wide. Unsclerotised cuticle around ventrianal shield with seven pairs of setae (Jv4, Jv5, Zv1–Zv5). Anterior section of endopodal plate fused with sternal shield; section between coxae II–III and III–IV reduced each to an elongate, v-shaped platelet. Expopodal plate consolidated with peritrematic plate; the latter wide, fused anteriorly with dorsal shield at level of j2 and

extending posteriorly to the posterior margin of coxa IV. Peritreme wide, extending anteriorly to base of j1, without post-stigmatic extension. Setal measurements: Jv1 30, Jv2 26, Jv3 25, Jv4 27, Jv5 35, Zv1 14, Zv2 26, Zv3 30, para-anal 24, post-anal broken; setae stout and smooth.

Legs. Setation: genua I–IV: 12, 10, 8, 9; tibiae I–IV: 13, 10, 9, 10. Leg IV 735 long; tarsus IV with macroseta (ad3) 84 long.

Material examined. One female from soil of a fragment of Andean forest–(pH 3.4; organic matter 95%; humidity 78%; soil temperature 9°C) in December, 2010.

Remarks. The specimen examined is similar to *Cheiroseius neophalangioides* Mineiro, Lindquist & Moraes, 2009, described from Brazil, by the long leg IV (about 1.7 times as long as the dorsal shield) and ad3 of tarsus IV as a macroseta. However, *C. neophalangioides* is smaller (dorsal shield 375–390 long and 250–255 wide) and it has shorter z1 (18–20), st3 (17–18), st4 (15–16), ad3 of tarsus IV (55–60). Collection of additional specimens is required for the exact identification of this species.

3.3.3. Melicharidae Hirschmann

***Proctolaelaps colombianus* sp. nov**. Figs (29–34)

Specimens examined. Holotype female and four paratype females from soil of a fragment of Andean forest (pH 4.7; organic matter 54%; humidity 77%; soil temperature 10°C); collected by D. Rueda-Ramirez in June, 2010. Holotype and three paratype females deposited at ESALQ-USP. One paratype female deposited at MJHN-PUJ.

Diagnosis. Anterior region of epistome with three similar projections, truncate and distally denticulate; deutosternal groove with lateral lines slightly divergent posteriorly but constricted between sixth and seventh and at level of eighth lines; dorsal shield almost completely covering the idiosoma, reticulate and with delineate strip along lateral margins; anterolateral margins of shield deeply incised between s1 and s2, with 38 pairs of setae; with one pair of metapodal plates; opisthogaster with ten pairs of setae on unsclerotised cuticle (Jv1–Jv5, Zv1–Zv5); peritreme extending anteriorly almost to the level of z1; peritrematic plate wide, fused to dorsal shield at level of j3.

Description (Female, five specimens measured).

Gnathosoma. Fixed cheliceral digit 34 (34–35) long, with 15–16 teeth and a membranous lobe instead of a *pilus dentilis*; movable digit 31 (30–32) long, with two teeth;

dorsal seta stout, dorsal and antiaxial lyrifissures distinct (Fig. 29). Numbers of setae on palp trochanter–tarsus: 2, 5, 6, 14, 15; palp tarsal apotele bifurcate. Anterior region of epistome with three similar projections, truncate and distally denticulate (Fig. 30); Deutosternal groove moderately wide (Fig. 31), with eight transverse lines, the most distal smooth, the most proximal with about six denticles and others with 15–26 denticles each; delimited by lateral lines which are slightly divergent posteriorly but constricted between sixth and seventh and at level of eighth line. Internal malae broad, distinctly separated from each other; lateral margins fimbriate. Corniculi horn-shaped, about twice as long as their basal width, well separated from each other, subparallel. Seta h3 about in longitudinal line with h1 and posteriad of h2. Measurements of setae: h1 28 (27–30), h2 21 (20–22), h3 32 (30–35), pc 31 (30–33), palp trochanter av 31 (28-33), palp trochanter pv 20 (17-22); setae aciculate and smooth.

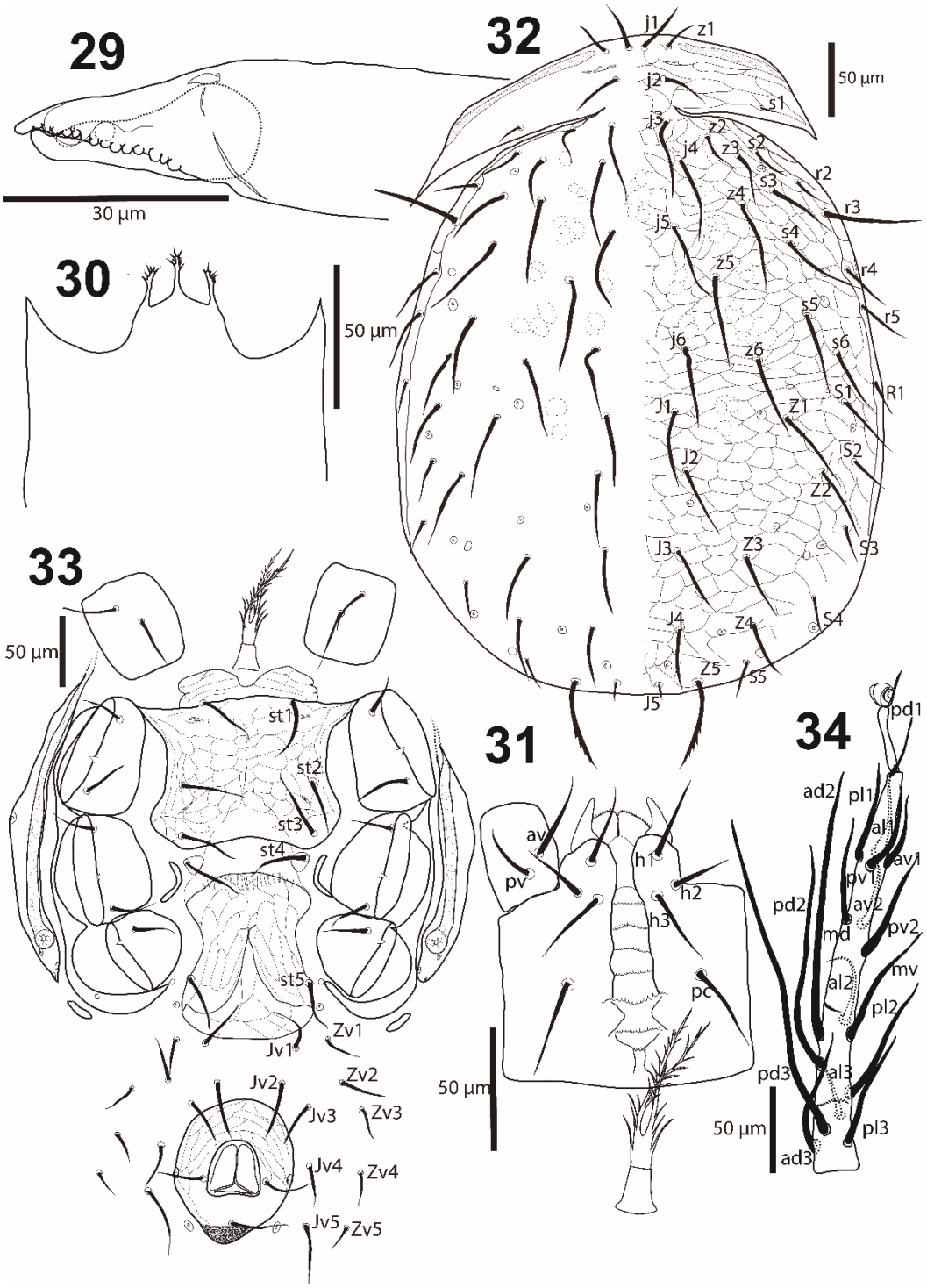
Dorsal idiosoma (Fig. 32). Idiosoma 410 (390–439) long and 271 (240–291) wide at the widest level. Podonotal and opisthonotal shields fused, 408 (384–431) long and 268 (237–280) wide at the widest level, almost completely covering dorsal surface of idiosoma, reticulate; antero-lateral margins of dorsal shield deeply incised between s1 and s2; with delineate strip along lateral margins. Podonotal region with 22 pairs of setae (including r2–r5, and s1; the latter inserted on distal part of fused dorsal and peritrematic shields), three pairs of lyrifissures and a pair of pores; seta z3 absent on the right side of three specimens examined. Opisthonotal region with 16–17 pairs of setae (including R1; one specimen with R2), nine pairs of lyrifissures and three pairs of pores. Setal measurements: j1 29 (28–30), j2 30 (28–31), j3 49 (47–50), j4 49 (47–52), j5 52 (50–53), j6 50 (49–51), J1 42 (41–44), J2 43 (41–45), J3 44 (43–45), J4 37 (35–39), J5 11 (10–13), z1 17 (14–19), z2 26 (25–27), z3 32 (31–33), z4 52 (47–56), z5 56 (56–57), z6 51 (49–54), Z1 53 (51–55), Z2 46 (43–50), Z3 42 (40–43), Z4 37 (35–38), Z5 58 (55–62), s1 14 (13–15), s2 25 (23–26), s3 41 (38–43), s4 55 (55–56), s5 52 (50–55), s6 40 (40–41), S1 38 (35–40), S2 26 (25–27), S3 21 (20–21), S4 22 (22–23), S5 23 (20–25), r2 26 (25–26), r3 55 (52–57), r4 35 (33–37), r5 35 (34–37), R1 18 (14–20), R2 15. Most dorsal shield setae smooth and longer than distance between their bases and the bases of the subsequent setae of the same series; Z5 very lightly serrate.

Ventral idiosoma (Fig. 33). Base of tritosternum 15 (15–16) long and 14 (14–15) wide proximally; laciniae 64 (61–66), separated for about 80% of their total length, pilose. Pre-sternal plates lightly sclerotised, fused with each other and with sternal shield, transversely reticulate. Sternal shield mostly reticulate and with posterior margin slightly concave; 91 (88–95) long and 122 (116–126) wide at widest level, with three pairs of setae and two pairs of lyrifissures; distances st1–st3 82 (80–83), st2–st2 81 (80–83). Fourth pair of

sternal setae (st4) on metasternal plates; third pair of lyrifissures (iv3) indistinct. Genital shield reticulate, with a moderate constriction at level of coxae IV; hyaline anterior section acuminate, overlapping posterior margin of sternal shield; posterior margin convex, 136 (127–150) long (including hyaline section) and 78 (72–84) wide at the widest level; distance st5–st5 72 (68–75); seta st5 inserted on the margin of the shield and lyrifissure iv5 on unsclerotised cuticle, posterolaterad of st5. With one pair of ellipsoidal metapodal plates. Opisthogaster with ten pairs of setae on unsclerotised cuticle (Jv1–Jv5, Zv1–Zv5); Jv3 absent on the left side and an extra opisthogastric seta present between Jv4 and Zv4 of the right side in specimen paratype. Anal shield pear-shaped and reticulate; 90 (83–100) long and 67 (64–70) wide, with a pair of marginal pores about in transverse line with para-anal setae, the latter slightly shorter than post-anal seta and inserted between posterior margin and mid-length of anal opening; anal opening almost 1/2 as long as shield, located at the center of the shield; 35 (34–38) long. Anterior section of endopodal plate fused with sternal shield; section behind sternal shield slender and curved. Exopodal plate a strip extending from the region between coxae I–II to region behind coxa IV. Peritrematic plate wide, fused with dorsal shield at level of j3 and extending posteriorly at level of posterior margin of coxa IV, apparently fused with exopodal plate by a narrow bridge, with a pore and two lyrifissures behind each stigma. Peritreme extending anteriorly almost to level of z1. Setal measurements: st1 39 (37–42), st2 41 (40–42), st3 40 (39–41), st4 42 (40–43), st5 33 (30–35), Jv1 31 (30–32), Jv2 39 (35–42), Jv3 29 (28–30), Jv4 27 (25–28), Jv5 37 (35–40), Zv1 21 (20–23), Zv2 28 (26–30), Zv3 23 (21–25), Zv4 20 (18–20), Zv5 18 (16–18) para-anal 31 (30–32), post-anal 34 (32–35); setae aciculate and smooth.

Spermathecal apparatus. Not distinguishable.

Legs. Lengths: I: 487 (479–494); II: 346 (335–356); III: 392 (366–409); IV: IV 629 (597–660). Setation (legs I–IV): coxae: 2, 2, 2, 1; trochanters: 6, 5, 5, 5; femora: 12, 10, 6, 6; genua: 13, 11, 9, 9; tibiae: 13, 9, 8, 10; tarsi: I not counted, 18, 18, 18. All legs with pretarsi and with a pair of strongly sclerotised claws (Fig. 34). Median section of pulvilli of legs I–IV rounded. Legs II–IV with a spine-like structure rising ventrally at the base of each claw. Most setae of tarsus IV wipe-like; Setae pd3 (ca. 190) of basitarsus IV and ad2 (ca. 150) and pd2 (ca. 125) of telotarsus IV (ca. 85) longer than other setae of the same segment (Fig. 34).



Figures 29–34. *Proctolaelaps colombianus* sp. nov. Female. 29. Chelicera; 30. Epistome; 31. Hypostome and proximal palp segment; 32. Dorsal idiosoma; 33. Ventral idiosoma; 34. Tarsus IV.

Adult male. Not found.

Etymology. The specific name "*colombianus*" refers to "from Colombia", country where the type specimens were collected.

Remarks. This species is most similar to *Proctolaelaps reticulatus* Chant, 1963 by the general shape of the dorsal shield, relative length of most setae and the lateral position of

the Z setae, especially Z2. However, *P. reticulatus* differs from the new species by having the tectum convex and smooth and dorsal shield with one more pair of R setae. The ventral spine-like structure at the base of each claw is reported for the first time in this genus, which may be due to its difficult visualization.

3.4. Discussion

Species of *Arctoseius*, *Gamasellodes* and *Protogamasellus* (Ascidae) as well as *Cheiroseius* (Blattisociidae) are reported for the first time from Colombia (Florez & Sanchez, 1995; Moraes *et al.*, 2016).

The species found in highest numbers in this study, *A. semiscissus*, has been reported from northern Europe and Australia (Moraes *et al.*, 2016). Other species of this genus have been reported almost exclusively from temperate regions of the Northern Hemisphere (Makarova, 1999; Lindquist & Makarova, 2012; Moraes *et al.*, 2015). The exceptions are *Arctoseius euventralis* Karg, 1998 and *Arctoseius latoanalis* Karg, 1998, both described from the region between Pifo and Papallacta, in Pichincha province, Ecuador, and Arctoseius bilinear Nasr, 1986 (in Zaher, 1986), described from Egypt. Similar to the region where the present study was conducted, the type localities of the species from Ecuador are also in the Andes Cordillera, at high elevation (4100 m above sea level). *Arctoseius semiscissus* as well as other species of this genus, as *Arctoseius cetratus* (Sellnick, 1940), has been reported as phoretic on adults and as predator of eggs and larvae of flies in the family Sciaridae (Moraes *et al.*, 2015). Most of the specimens collected in this study were attached to the insect's body by their chelicerae and were difficult to remove.

The occurrence of the three *Cheiroseius* species in samples from the Andean forest fragment but not in samples from the grassland is consistent with our present knowledge about the species of this genus, which is abundant mainly in wet forest litter, where they possibly feed on nematodes (Moraes *et al.*, 2015). In this study, *Cheiroseius* species were found in soil samples with moisture content of 46 to 78%. Many species of this genus have been described from the Western Hemisphere, namely seven species from the USA, six from Jamaica, four from Argentina, one from Brazil, five from Chile, one from Cuba, 23 from Ecuador and two from Venezuela (Moraes *et al.*, 2016). These species have been reported in soil, moss and leaves, at altitudes ranging from a few meters to over 4000 m above sea level. The presence of these species exclusively in the Andean forest fragment anticipates a major impact on their distribution caused by the removal of the natural vegetation.

Arctoseius semiscissus, *Cheiroseius* spp., *Gamasellodes andinus* sp. nov. and *Proctolaelaps colombianus* sp. nov. seem to be species of preserved environments, where pH is low (4.3 ± 0.1), characteristic of the forest fragment. Conversely, *Gamasellodes intermedius* sp. nov. was found exclusively in the grassland, characterized by a higher edaphic pH (5.4 ± 0.1). The higher pH of soil grassland is the result of the reduced content of organic matter, with the consequent decreased release of organic acids during decomposition (Coyne, 2000). Other authors have found significant relationships between pH and mite densities. Chikoski *et al.* (2006), Manu (2011), Birkhofer *et al.* (2012) found a positive relation between mite density and low pH, while Bedano *et al.* (2005) found a tendency of Mesostigmata mites to prefer neutral pH. Manu *et al.* (2016) found relationship between pH and the presence of some Mesostigmata species, including a *Gamasellodes* species.

Acknowledgements

Financial support to this project was provided by "Vicerrectoria Academica" of "Pontificia Universidad Javeriana (Project No. 3423).

References

Álvarez, L., Rueda, A., López, R., Ramos, P., Vásquez, D. & Mesa-Cobo, N.C. (2013) Estudio de la diversidad de ácaros asociados a hojarasca y suelo en el alto de la línea (Calarca, Cajamarca). In: D. M. Rueda-Ramírez (Ed), *Resúmenes Congreso Colombiano de Entomología. 40 Congreso Socolen.* Sociedad Colombiana de Entomología-Socolen, Bogotá, D.C., pp. 140.

Athias-Henriot, C. (1961) Mésostigmates (Urop. Excl.) Édaphiques Méditerranéens (Acaromorpha, Anactinotrichida) (collect. Prof. H. Franz et C. Athias-Henriot). Première Série. Acarologia, 3, 381–509.

Bedano, J.C., Cantu, M.P. & Doucet, M.E. (2005) Abundance of soil mites (Arachnida: Acari) in a natural soil of central Argentina. *Zoological Studies*, 44, 505–512.

Berlese, A. (1892) *Acari, Myriopoda et Scorpiones hucusque in Italia reperta*. Padova, Tipografia del Seminario, fasc. LXVII (7).

Bernhard, F. (1963) Die Familie Ascaidae (Oudemans 1905) Bernhard nov. comb. Abschnitt III. In: Stammer, H.-J. (Ed.), *Beiträge zur Systematik und Ökologie mitteleuropäischer Acarina. Band II. Mesostigmata I*. Akademische Verlagsgesellschaft Geest & Portig K.-G.: Leipzig. pp. 33–177.

Binns, E.S. (1972) *Arctoseius cetratus* (Sellnick) (Acarina: Ascidae) phoretic on mushroom sciarid flies. *Acarologia*, 14, 350–356.

Binns, E.S. (1974) Notes on the biology of *Arctoseius cetratus* (Sellnick) (Mesostigmata: Ascidae). *Acarologia*, 16 (4), 577–582.

Birkhofer, K., Schoning, I., Alt, F., Herold, N., Klarner, B., Maraun, M., Marhan, S., Oelmann, Y., Wubet, T., Yurkov, A., Begerow, D., Berner, D., Buscot, F., Daniel, R., Diekötter, T., Ehnes, R.B., Erdmann, G., Fischer, C., Foesel, B., Groh, J., Gutknecht, J., Kandeler, E., Lang, C., Lohaus, G., Meyer, A., Nacke, H., Näther, A., Overmann, J., Polle, A., Pollierer, M.M., Scheu, S., Schloter, M., Schulze, E.D., Schulze, W., Weinert, J., Weisser, W.W., Wolters, V. & Schrumpf, M. (2012) General relationships between abiotic soil properties and soil biota across spatial scales and different land-use types. *PLoS ONE*, 7, 1–8. http://dx.doi.org/10.1371/journal.pone.0043292

Britto, E.P.J., Lopes, P.C. & Moraes, G.J. de (2012) *Blattisocius* (Acari, Blattisociidae) species from Brazil, with description of a new species, redescription of *Blattisocius keegani* and a key for the separation of the world species of the genus. *Zootaxa*, 3479, 33–51.

Chant, D.A. (1963) The subfamily Blattisocinae Garman (Aceosejinae Evans) (Acarina: Blattisocidae Garman) (Aceosejidae Baker and Wharton) in North America, with descriptions of a new species. *Canadian Journal of Zoology*, 41, 243–305. http://dx.doi.org/10.1139/z63-025

Chikoski, J.M., Ferguson, S.H. & Meyer, L. (2006) Effects of water addition on soil arthropods and soil characteristics in a precipitation-limited environment. *Acta Oecologica*, 30, 203–211. http://dx.doi.org/10.1016/j.actao.2006.04.005

Coyne, M. (2000) *Microbiología del Suelo: un Enfoque Exploratorio*. Parainfo, Madrid , 416 pp.

Evans, G.O. (1958) A revision of the British Aceosejinae (Acarina: Mesostigmata). *Proceedings of the Zoological Society of London*, 131, 177–229. http://dx.doi.org/10.1111/j.1096-3642.1958.tb00685.x

Evans, G.O. (1963) Observations on the chaetotaxy of the legs in the free-living Gamasina (Acari: Mesostigmata). *Bulletin of the British Museum (Natural History). Zoology* 10, 275–303.

Florez, E. & Sanchez, H. (1995) La diversidad de los arácnidos en Colombia. Aproximación inicial. In: *Colombia diversidad Biotica I.* Instituto de Ciencias Naturales, Universidad Nacional de Colombia, Bogotá, pp. 327–372.

Fox, I. (1947) Seven new mites from rats in Puerto Rico. *Annals of the Entomological Society of America*, 40, 598–603. http://dx.doi.org/10.1093/aesa/40.4.598

Gerson, U., Smiley, R.L. & Ochoa, R. (2003) Mites (Acari) for pest control. Blackwell Publishing, Oxford, 539 pp. http://dx.doi.org/10.1002/9780470750995

Haines, C.P. (1978) A revision of the genus *Blattisocius* Keegan (Mesostigmata: Ascidae) with special reference to *B. tarsalis* (Berlese) and the description of a new species. Acarologia, 20, 19–38.

Halliday, R.B., Walter, D.E. & Lindquist, E.E. (1998) Revision of the Australian Ascidae (Acarina: Mesostigmata). *Invertebrate Systematics* 12, 1–54.

Hirschmann, W. (1962) Gangsystematik der Parasitiformes. Teil 5. Gamasiden Rückenhaarbesttimmungstafeln von 260 Typhlodromus–arten der Erde. Gänge´ Chaetotaxie Porotaxie, Mundwerkzeuge von *Typhlodromus* und verwandten Gattungen von *Proctolaelaps*, *Melichares*, *Lasioseius*, *Iphidozercon*, *Sejus*, *Rhodacarellus*, *Rhodacarus*, *Gamasellus*, *Veigaia*, *Macrocheles ivanovi*. Erstversuch der Aufstellung eines Gangsystems der Gamasiden auf grund der Gnathosoma–unterseite. *Acarologie. Schriftenreihe für Vergleichende Milbenkunde*, 5, 1–56.

IDEAM - Instituto De Hidrología Meteorología y Estudios Ambientales de Colombia (2011) *Proyecto Nacional Piloto de Adaptación–INAP: Componente B "Alta Montaña" Monitoreo a los ciclos de agua y carbono en ecosistemas de Alta montaña*. Bogotá, D.C.

Imbachi-López, K., Mesa-Cobo, N.C., López, R., Álvarez-Ríos, L. & Guerra, W.A. (2012) Cría de Lasioseius near meridionalis (Mesostigmata: Ascidae), como potencial controlador biológico de plagas del suelo. In: *Resúmenes 39 Congreso Socolen*. Sociedad Colombiana de Entomología, Ibague, pp. 22.

Kalúz, S. & Fenďa, P. (2005) *Mites (Acari: Mesostigmata) of the family Ascidae of Slovakia*. Slovak Academy of Sciences, Bratislava, 167 pp.

Karg, W. (1962) Zur Systematik und postembryonalen Entwicklung der Gamasiden (Acarina, Parasitiformes) landwirtschaftlich genutzter Boden. *Mitteilungen aus dem Zoologischen Museum in Berlin*, 38, 23–119.

Karg, W. (1981) The predatory mite genus *Cheiroseius* Berlese, 1916. *Zoologische Jahrbücher Abteilung für Systematik, Ökologie und Geographie der Tiere*, 108, 51–69.

Karg, W. (1998) Neue Raubmilbenarten der Ascidae Oudemans, 1905 im tropischen Regenwald von Ecuador (Acarina, Parasitiformes). *Zoosystematics and Evolution*, 74, 49–64. http://dx.doi.org/10.1002/mmnz.19980740107

Lindquist, E.E. & Evans, G.O. (1965) Taxonomic Concepts in the Ascidae, with a Modified Setal Nomenclature for the Idiosoma of the Gamasina (Acarina: Mesostigmata). *Memoirs of the Entomological Society of Canada* 97, 5–66.

Lindquist, E.E., Krantz, G.W. & Walter, D.E. (2009) Order Mesostigmata. In: G. W. Krantz and D. E. Walter (Eds), *A Manual of Acarology*. Texas Tech University Press, Lubbock, Texas, pp. 124–232.

Lindquist, E.E. & Moraza, M.L. (2008) A new genus of flower-dwelling melicharid mites (Acari: Mesostigmata: Ascoidea) phoretic on bats and insects in Costa Rica and Brazil. *Zootaxa*, 1685, 1–37.

Lindquist, E.E. & Makarova, O.L. (2012) Review of the mite subfamily Arctoseiinae Evans with a key to its genera and description of a new genus and species from Siberia (Parasitiformes, Mesostigmata, Ascidae). *ZooKeys*, 233, 1–20. http://dx.doi.org/10.3897/zookeys.233.3862

Makarova, O.L. (1999) Mesostigmatic mites (Parasitiformes, Mesostigmata) of polar deserts in Severnaya Zemlya. *Entomological Review*, 79, 982–990.

Malagón, D.C. (2003) Los Suelos de Colombia. Instituto Geográfico Agustín Codazzi (IGAC). *IGAC*. Available from: http:// www.sogeocol.edu.co/documentos/05loss.pdf (Accessed 1 May 2016)

Manu, M. (2011) The influence of some environmental factors on the species diversity of the predator mites (Acari: Gamasina) from natural forest ecosystems in Bucegi massif. *Travaux du Museum D'Histoire Naturelle"Grigore Antipa"*, 54, 9–20. http://dx.doi.org/10.2478/v10191-011-0001-7

Manu, M., Iordache, V., Băncilă, R. I., Bodescu, F. & Onete, M. (2016) The influence of environmental variables on soil mite communities (Acari: Mesostigmata) from overgrazed grassland ecosystems–Romania. *Italian Journal of Zoology*, 83, 1–9. http://dx.doi.org/10.1080/11250003.2015.1091897

Mineiro, J.L.C., Lindquist, E.E., & Moraes, G.J. de. (2009) Edaphic ascid mites (Acari: Mesostigmata: Ascidae) from the state of São Paulo, Brazil, with description of five new species. *Zootaxa*, 2024, 1–32.

Moraes, G.J. de, Venancio, R., Santos, V.L.V. dos & Paschoal, A.D. (2015) Potential of Ascidae, Blattisociidae and Melicharidae (Acari: Mesostigmata) as Biological Control Agents of Pest Organisms. In: D. Carrillo, G. J. de Moraes, and J. E. Peña (Eds), *Prospects for Biological Control of Plant Feeding Mites and Other Harmful Organisms*. Springer International Publishing, Switzerland, pp. 33–75.

Moraes, G.J. de, Britto, E.P.J., Mineiro, J.C. de & Halliday, B. (2016) Catalogue of the mite families Ascidae Voigts & Oudemans, Blattisociidae Garman and Melicharidae Hirschmann (Acari: Mesostigmata). *Zootaxa*, 4112 (1), 1–299. http://doi.org/10.11646/zootaxa.4112.1.1

Nesbitt, H.H.J. (1954) Some random notes on the mite fauna of Limburg with the description of two new species. *Natuurhistorisch Maandblad*, 43, 19–24.

Rangel-Ch., J.O. & Ariza-N, C. (2000) La vegetación del Parque Nacional Natural Chingaza. In: J. O. Rangel-Ch. (Ed), *Colombia diversidad biótica III: la región de vida paramuna*. Universidad Nacional de Colombia, Bogotá, D.C., pp. 720–753.

Rudzińska, M. (1998) Life history of the phoretic predatory mite Arctoseius semiscissus (Acari: Ascidae) on a diet of sciarid fly eggs. Experimental & Applied Acarology, 22, 643–648. http://dx.doi.org/10.1023/A:1006050020450

Rueda-Ramírez, D., Varela, A. & Moraes, G.J. de (2016) Soil mites of the families Ascidae, Blattisociidae and Melicharidae (Acari: Mesostigmata) from mountainous areas of Colombia. Zootaxa 4127, 493–514.

Ruf, A. (1998) A maturity index for predatory soil mites (Mesostigmata: Gamasina) as an indicator of environmental impacts of pollution on forest soils. *Applied Soil Ecology* 9, 447–452. http://dx.doi.org/10.1016/S0929-1393(98)00103-6

Ruf, A. & Beck, L. (2005) The use of predatory soil mites in ecological soil classification and assessment concepts, with perspectives for oribatid mites. *Ecotoxicology and Environmental Safety* 62, 290–299. http://dx.doi.org/10.1016/j.ecoenv.2005.03.029

Ruf, A., Beck, L., Dreher, P., Hund-Rinke, K., Römbke, J. & Spelda, J. (2003) A biological classification concept for the assessment of soil quality: "Biological soil classification scheme" (BBSK). *Agriculture, Ecosystems and Environment* 98, 263–271. http://dx.doi.org/10.1016/S0167-8809(03)00086-0

Sellnick, M. (1940) Die Milbenfauna Islands. *Göteborgs Kunglich Vetenkaps och vitterhets–Samhälles Handlingar*, Ser. B, 6 (14). Meddelanden Från Göteborgs Musei Zoologiska Avdelning, 83, 1–129.

Shcherbak, G.I. (1976) On studying mites of the genus Protogamasellus Karg, 1962 (sensu Karg, 1971) (Gamasoidea, Rhodacaridae). *Vestnik Zoologii*, 5, 81–83.

Sinha, R.N., Liscombe, E.A.R. & Wallace, H.A.H. (1962) Infestation of mites, insects and microorganisms in a large wheat bulk after prolonged storage. *The Canadian Entomologist*, 94, 542–555. http://dx.doi.org/10.4039/Ent94542-5

Treat, A.E. (1975) *Mites of Moths and Butterflies*. New York, Comstock University Press, 362 pp.

United States Department of Agriculture (1999). *Guía para la evaluación de la calidad y salud del suelo*. Departamento de Agricultura, Buenos Aires, 82 pp.

Vásquez, D.F., Ramos, P.A., Pinchao, E.C., Mesa-Cobo, N.C., López, R., Rueda, A. & Álvarez-Ríos, L. (2013) Diversidad de ácaros Mesostigmata y Prostigmata, asociada a hojarasca de un corredor ecológico en Palmira, Valle del Cauca. In: D. M. Rueda-Ramírez (Ed), *Resúmenes Congreso Colombiano de Entomología. 40 Congreso Socolen*. Sociedad Colombiana de Entomología-Socolen, Bogotá, D.C., pp. 139.

Walter, D.E. (2003) The genus Gamasellodes (Acari: Mesostigmata: Ascidae): New Australian and North American species. *Systematic & Applied Acarology Special Publications*, 15, 1–10. http://dx.doi.org/10.11158/saasp.15.1.1

Weis-Fogh, T. (1948) Ecological investigations on mites and collemboles in the soil. *Natura Jutlandica*, 1, 135–270.

Willmann, C. (1949) Das genus Arctoseius Sig Thor, 1930 (Acari). *Abhandlungen des Naturwissenschaftlichen Verein zu Bremen*, 32, 349–358.

Zaher, M.A. (1986) *Predaceous & nonphytophagous mites in Egypt*. Pl. 480 Programme U.S.A., Project nr. EG_ARS_30. Grant nr. FG_EG_139, 567 pp.

Zuluaga, I. (1970) *Resultados del reconocimiento e identificacion de la acarofauna del Valle del Cauca*. Universidad Nacional de Colombia, Palmira.

Zuluaga, I. (1971) Lista preliminar de ácaros de importancia en Colombia. *Acta Agronomica* XXI, 119–132.

4. EDAPHIC LAELAPID MITES (ACARI: MESOSTIGMATA: LAELAPIDAE) IN ROSE CROPS AND SURROUNDING VEGETATION OF THE BOGOTA PLATEU (COLOMBIA)

ABSTRACT

Soil mites of Laelapidae Berlese (Acari: Mesostigmata) are poorly known in Colombia. This family contains species with diverse feeding habits, among which the predatory habit stands out. Many of the predatory species of this family are found in soil and some of these are well known and commercially used as biological controllers. The aim of this study was to identify species of this family from different *Rosa* sp. greenhouses and surrounding vegetation at the Bogota plateu, Cundinamarca Department, Colombia, at about 2400–2800 m of elevation. Seven laelapid species were found, including *Gaeolaelaps aculeifer*, *Gaeolaelaps brevipellis*, *Gaeolaelaps queenslandicus*, *Cosmolaelaps claviger*, *Stratiolaelaps scimitus* and two new species. Morphological characterization of all the species and relevant soil characteristics of the sites where the mites were collected are presented.

Keywords: *Gaeolaelaps*; *Cosmolaelaps*; *Stratiolaelaps*; *Gymnolaelaps*; Greenhouse; Andean forest

4.1. Introduction

Rose cultivation is one of the main economic activities in Colombia, with a reveneu of about 1300 million dollars each year (Reyes 2016, 2017). About 95% of the annual production is exported (Fenalco 2017). One of the main problems in rose cultivation is the attack of pest arthropods, whose control is extremely difficult by means of chemical products. Consequently, there is a great interest of growers on the establishment of alternative control methods.

Applied biological control is among methods to be evaluated as alternatives. Some of the main pests on rose cultivation in the Bogotá plateau are immature thrips (Thysanoptera) and flies (Diptera). Given that those pests might spend at least part of their lives in the edaphic environment, they could potentially be controlled by predatory mites living in this type of microhabitat. Some of these predators are mites of the order Mesostigmata. Members of this group have been extensively studied and are presently used for pest control, especially of pests of aerial plant parts (Carrillo *et al.* 2015), but also of immature thrips and flies (Carrillo *et al.* 2015; Zhang 2003). Predatory mites commercially produced for the control of edaphic pests include species of Laelapidae (Moreira & Moraes 2015) and Macrochelidae (Azevedo *et al.* 2015), but mites of other families are also potential candidates (Carrillo *et al.* 2015).

Edaphic mites are poorly known in Colombia (Jimeno & Sierra 2008; López-Bermúdez 2014; Marín-Beitia *et al.* 2015; Rueda-Ramírez *et al.* 2013, 2016), but it is possible that effective species could be found in that country for the control of edaphic pests, including immature thrips and flies. The first step in the evaluation of that hypothesis is the determination of the main taxa of edaphic predatory mites in rose cultivation areas and in areas of the surrounding vegetation. The objective of this study was to determine the edaphic laelapid mites from four rose cultivations in the Bogotá plateu, Cundinamarca District, where about 76% of the Colombian commercial rose production takes place (Fenalco 2017; Solano 2009), and in surrounding (mostly natural) vegetation.

4.2. Material and methods

4.2.1. Study sites and collection dates

The rose cultivation considered in this study was done in greenhouses, as usual in Colombia, using soil as substrate. Samples from FV and FR (see Table 1 for code explanation) were collected every two months from August to December 2016, whereas samples from CR, CV, NR, TR, GR and GV were collected in January and February 2015, and every two months from August 2015 to December 2016. Samples from most conserved vegetation were collected in SV in February 2015 and July 2016, and in LV in January 2015 and January 2017. Samples were also taken from a pasture land, in LG, in June and August 2010.

Soil fertilization in rose cultivation areas was done weekly, through the irrigation system (ferti-irrigation). Pests are controlled chemically, as judged necessary by growers, but usually involving at least two applications a week. Evaluations were also done in the vegetation next to the greenhouses for comparison of the faunistic compositions. Additional details of each collection site are indicated under "Specimens measured" for each species.

4.2.2. Sample collection, mite extraction, identification and description

Each sample was collected with a cylinder (10 cm in diameter and 5 cm in length) totally inserted in the soil. The samples were placed in plastic bags and transported to a laboratory where mites were extracted using modified Berlese funnels. Extracted mesostigmatid mites were mounted in Hoyer’s medium and first identified to family, based

mainly on Lindquist *et al.* (2009). Adult laelapid females were identified to genera, based mainly on Krantz & Ainscough (1990) and unpublished keys of the Acarology Summer Program (Soil Acarology, Ohio State University, 2014), and to species, based on the original descriptions and complementary descriptions.

Specimens used in the description of the new species and complementary descriptions were illustrated and measured. Illustrations of taxonomically important structures were done with a camera lucida attached to a phase contrast microscope and a digital camera connected to an interference contrast microscope; photos and illustrations were processed with a digital tablet, using the Adobe Illustrator® program. Measurements were taken with a graded ocular. Measurements of each structure are given in micrometres, with the average measurement for the specimens examined followed (in parentheses) by the respective ranges, for variable structures. Minimum and maximum measurements of the paratypes of *Gaeolaelaps brevipellis* Karg are given in square brackets after the measurements of the specimens collected on Colombia.

The lengths of each structure corresponded to the maximum length between the anterior and the posterior margins. The width of each structure corresponded to its maximum width, except the sternal shield, whose reported width was the distance between the lateral margins at the level of the extensions between coxae II–III (not including the extensions); length of epigynial shield included the anterior lightly hyaline region; leg length did not include the pretarsus; length of the fixed cheliceral digit referred to the distance between the dorsal lyrifisure and the apex.

Setal nomenclature is based on Lindquist & Evans (1965), leg chaetotaxy is based on Evans (1963) and pore notation is based on and Lindquist & Moraza (2008). The number of teeth of each cheliceral digit does not include the respective terminal tooth.

Voucher specimens of previously described species were deposited in the Mite Reference Collection of Departamento de Entomologia e Acarologia, Escola Superior de Agricultura “Luiz de Queiroz”, Universidade de São Paulo, Piracicaba, State of São Paulo, Brazil (ESALQ-USP), and Museo Javeriano de Historia Natural, Pontificia Universidad Javeriana, Bogotá, Colombia (MJHN-PUJ). Type depositories of the new species are indicated in "Specimens measured" under each species. All specimens were collected by the first author of this publication.

Table 1. Location and characteristics of the collection of soil Laelapidae species in the Bogotá plateu (Cundinamarca, Colombia).

Municipality	Vereda	Farm	Coordinates DMS	Elevation (m)	Vegetation cover	Vegetation details	Code*
Cogua	El Mortiño	Agua Clara	05°03'23.3"N 073°55'44.4"W	2584–2589	Roses	Greenhouse with *Rosa* sp. Freedom var.	CR
Nemocón	Checua	Flores el Futuro	05°07'03.1–03.2"N 073°51'31.7–31.9"W	2584–2591	Roses	Greenhouse with *Rosa* sp. Freedom, Green Tea, Ocean Song and Sophie var.	NR
Facatativa	El Corzo	San Pedro	04°46'39.4–40.7"N 074°19'23.9–24.8"W	2572–2575	Roses	Greenhouse with *Rosa* sp. Freedom var.	FR
Tocancipa	El Porvenir	El Placer	04°59'19.3"N 073°54'15.9"W	2581–2601	Roses	Greenhouse with *Rosa* sp. Freedom var.	TR
Guasca	San José	La Toma	04°50'38.3"N 073°53'07.9"W	2572–2575	Roses	Greenhouse with *Rosa* sp. Freedom, Isabel, Matilda and Tiffany var.	GR
Cogua	El Mortiño	Agua Clara	05°03'19.00–23.4"N 073°55'42.4–44.3"W	2584–2609	Secondary vegetation	Patch of secondary vegetation of about 920 m^2 between greenhouses with rose cultivation. Shrubby vegetation mainly composed of *Pyracantha coccinea* M. Roem. and *Rubus glaucus* Benth. (both Rosaceae) and *Abutilon striatum* Dicks. ex Lindl. (Malvaceae)	CV
Facatativa	El Corzo	La Esmeralda	04°59'53.6–56.6"N 074°19'13.9–17.5"W	2576–2583	Secondary vegetation	Patch of secondary vegetation of about 7900 m^2 between greenhouses with rose cultivation. Arboreal and shrubby vegetation with *Agapanthus* sp. (Amaryllidaceae), *Sambucus perubiana* Kunth (Adoxaceae), *Solanum quitoense* Lam., *Solanum betaceum* Cav. (both Solanaceae), *Abutilon* spp. (Malvaceae), *Salix humboldtiana* Willd. (Salicaceae), *Ligustrum lucidum* W.T.Aiton (Oleaceae), *Acacia baileyana* F.Muell. (Leguminosae), *Eugenia* sp. (Myrtaceae), *Cotoneaster pannosus* Franch. (Rosaceae), *Lafoensia acuminata* (Ruiz & Pav.) DC. (Lythraceae),	FV
Guasca	San José	La Toma	04°50´50.5–54.6"N	2676–2681	Secondary	Patch of secondary vegetation of about 4900	GV

Municipality	Vereda	Farm	Coordinates DMS	Elevation (m)	Vegetation cover	Vegetation details	Code*
			073°53´03.98-5.8"W		vegetation	m^2 between greenhouses with rose cultivation. Arboreal and shrubby vegetation dominated by *Sambucus peruviana* Kunth (Adoxaceae), *Acacia* sp. (Fabaceae) and *Cucurbita* sp. (Cucurbitaceae)	
Soacha	San Francisco	Granja El Porvenir	04°34´31.9–33.7"N 074°17´50.87"W	2460–2508	Secondary vegetation	Patch of forest of about 58780 m^2 with most conserved arboreal vegetation including *Cedrela* sp. (Meliaceae), *Juglans* sp. (Juglandaceae), *Cyathea* sp. (Cyatheaceae) and ferns	SV
La Calera	Mundo Nuevo	San José del Palmar	04°39´0.21"N 73°51´0.07"W	2736–2764	Secondary vegetation	Patch of forest of about 12420 m^2 with most conserved arboreal vegetation dominated mainly by *Weinmannia* spp. (Cunoniaceae), *Drymis granadensis* L. (Winteraceae), *Clusia multiflora* Kunth (Clusiaceae), *Ageratina tinifolia* (Kunth) R. M. King & H. Rob. (Asteraceae), as well as by species of Brunelliaceae, Lauraceae, Melastomataceae and Rubiaceae (Rangel-Ch & Ariza-N, 2000; IDEAM, 2011)	LV
La Calera	Mundo Nuevo	San José del Palmar	4°38'49.03"N–73°51'12.37"W	2607–2626	Grassland	Grassland used mainly for dairy cows, dominated by *Pennisetum clandestinun* Hochstetter ex Chiovenda and *Lolium* sp. (both Poaceae)	LG

* The first letter of each code indicates the municipality where the sampling was conducted, and the last, the vegetation cover: C = Cogua, Agua Clara farm; N = Nemocón, Flores el Futuro farm; T = Tocancipa, El Placer farm; G = Guasca, La Toma farm; R = rose fields; V = patches of secondary vegetation.

4.2.3. Soil physicochemical analyses

A fraction of soil sample of each site was separated and stored at 4°C until the analyses were done. The following parameters were determined: pH (with potentiometer of a 1:1 v/v in distilled water), soil moisture (by gravimetric method, with precision of 0.01 g), percentage of organic matter (by calcination), texture (Bouyucos method) and electrical conductivity (conductivity measured in a suspension with 1:1 v/v in distilled water). The soils of all samples were classified as either sandy loam or silt loam (low clay content), and as non-saline (electrical conductivity lower than 0.98 dS/m, United States Department of Agriculture 1999).

4.3. Results

Seven laelapid species were found. Morphological information about these is subsequently provided.

***Gaeolaelaps aculeifer* (Canestrini)**

Laelaps aculeifer Canestrini, 1884: 698.

Hypoaspis aculeifer.— Canestrini, 1885: 84

Laelaps (*Iphis*) *aculeifer*.— Berlese 1892: LXIII, 10; Halbert, 1923: 367.

Androlaelaps concisus Womersley, 1956: 579 [Junior synonymy of H. aculeifer by Strong & Halliday, 1994: 87].

Laelaps aculeifer; non *Laelaps*.— Tipton, 1960: 286.

Hypoaspis (Hypoapis) *aculeifer*.— Karg, 1962: 61.

Geolaelaps concisus.— Ryke 1963: 11.

Gaeolaelaps aculeifer.— Hyatt, 1964: 472; Beaulieu, 2009: 36; Bahrami et al., 2011: 351Kavianpour et al., 2013: 8; ; Kavianpour & Nemati, 2014: 322.

Hypoaspis (Gaeolaelaps) *aculeifer*.— Evans & Till, 1966: 166; Teng, 1982: 162; Luxton, 1998: 20; Faraji et al., 2008: 207.

Hypoaspis (Geolaelaps) *consisa* [sic].— Karg 1979, 84; 1982: 242, 1989: 116.

Geolaelalps aculeifer.— Walter & Oliver, 1989: 295; Farrier & Hennessey, 1993: 72.

Material measured: three ♀, three ♂ and one protonymph from soil (pH 5.5 ± 0.1; organic matter 21 ± 1.6%; humidity 29 ± 1.3%; temperature 17.4 ± 0.1°C) at CR; collected on

January 21 and August 14, 2015; one ♀, one ♂, four deutonymphs and two protonymphs from soil (pH 5.7 ± 0.1; organic matter 16 ± 1.3%; humidity 31 ± 1.6%; temperature 18.6 ± 0.4°C) at GR, collected on January 21 and February 19, 2015; one ♀ from soil (pH 5.3 ± 0.1; organic matter 18 ± 1.8%; humidity 28 ± 1.1%; temperature 17.1 ± 0.3°C) at TR collected on January 29, 2015; one ♀, two ♂, one deutonymph from soil (pH 4.0 ± 0.1; organic matter 85 ± 3%; humidity 70 ± 2%; temperature 15.3 ± 0.2°C) at SV, collected on February 11, 2015; one protonymph from soil (pH 5.8 ± 0.1; organic matter 35 ± 4.3%; humidity 34 ± 3.5%; temperature 16.2 ± 0.2°C) at GV collected on February 19, 2015.

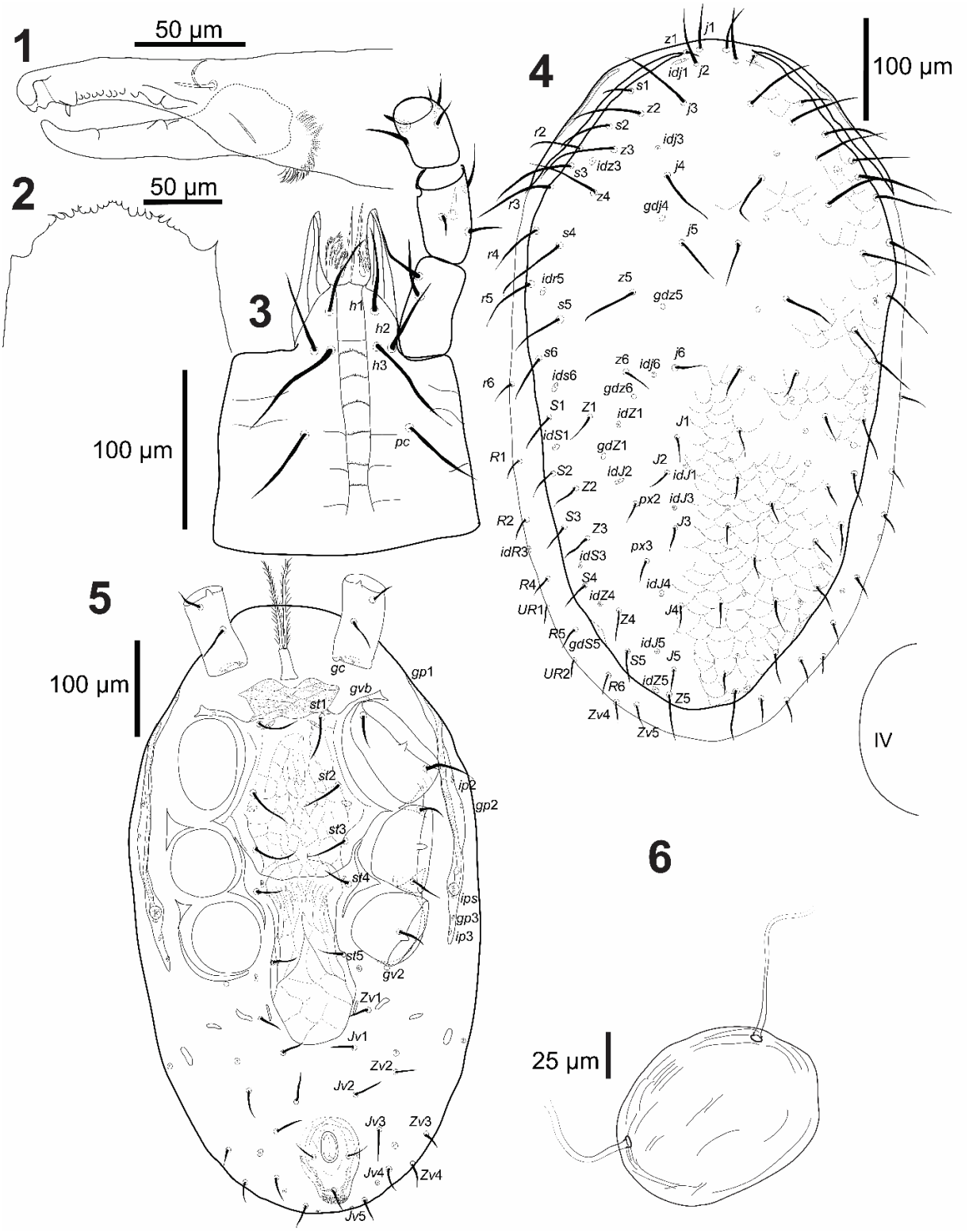
Additional material examined: 698 ♀ (319 in rose crops and 379 in natural vegetation), 325 ♂ (147 in rose crops and 178 in natural vegetation), 475 deutonymphs (194 in rose crops and 281 in natural vegetation) and 135 protonymphs (54 in rose crops and 81 in natural vegetation) from CR, CV, FV, NR, SV, FR, TR, GR and GV.

Diagnosis: female with anterior region of epistome rounded, with margin denticulate; fixed cheliceral with 1–2 small subapical teeth, followed by a large (lobe-like) tooth at the level of the thorne-shaped *pilus dentilis*, a row of 8–10 small teeth and two large adjacent teeth; deutosternal groove delimited by subparallel lateral lines, with seven transverse lines, the most distal smooth and others with 15-25 denticles; dorsal shield slightly tapered posteriad of *r*3–4, brownish, reticulate, partly covering the idiosoma, with 39 pairs of setae (including *px*2–3), elongate on the podonotal shield, shorter on the opisthonotal shield, except *Z*5, almost as long as *z*5; pre-sternal platelets punctate and with transverse lines; opisthogaster with ten pairs of aciculate setae (*Jv*1–*Jv*5; *Zv*1–*Zv*5) on unsclerotised cuticle; three pairs of metapodal platelets; a pair platelets next to edge of epigynial shield, which bears only *st*5. Male spermadactyl curved upward, extending slightly beyond tip of movable digit and tapering slightly to a blunt tip; holoventral shield reticulate, with distinct extension between coxae I–II. Deutonymph dorsal shield with deep, curved lateral incisions almost reaching level between j6 and *J*1 (schizodorsal shield); sternal shield lightly sclerotized, tapering posteriad of *st*3. Unsclerotized cuticle between podonotal and opisthonotal shields of protonymph with three pairs of lightly sclerotized and rounded sigillar platelets; sternal shield lightly sclerotized.

Adult female (Figs. 1–10, six specimens measured).

Gnathosoma. Chelicera with arthrodial process shaped as a coronet-like fringe; fixed cheliceral digit 96 (88–105) long, with a deep axial subapical pocket to receive apex of movable digit, with 1–2 small subapical teeth, followed by a large (lobe-like) tooth at the level of the thorne-shaped *pilus dentilis*, a row of 8–10 small teeth and two large adjacent

teeth; movable digit 89 (85–93) long, with two teeth; dorsal seta stout, dorsal and antiaxial lyrifissures distinct (Fig. 1).



Figures 1–6. *Gaeolaelaps aculeifer* (Canestrini, 1884). Colombian female. 1. Chelicera; 2. Epistome; 3. Hypostome and proximal palp segments; 4. Dorsal idiosoma; 5. Ventral idiosoma; 6. Spermathecal apparatus.

Numbers of setae on palp trochanter–tarsus: 2, 5, 6, 14, 15; palp apotele bifurcate. Anterior region of epistome rounded, with margin denticulate (Fig. 2); deutosternal groove delimited by subparallel lateral lines (Fig. 3), with seven transverse lines, the most distal smooth and others with 15-25 denticles; with three pairs of smooth, transverse lines external to deutosternum, at level or posteriad of third most proximal line of denticles. Internal malae distinctly separated from each other and ventrally fimbriate, flanked by up to three pairs of curved, fimbriate structures. Corniculi horn-shaped, more than twice as long as their largest width, well separated from each other, subparallel. Hypostomal seta *h*3 about in longitudinal line with *h*1 and mediad and slightly posteriad of *h*2. Measurements of setae: *h*1 39 (35–45), *h*2 37 (33–40), *h*3 57 (50–63), *pc* 42 (38–53); setae aciculate and smooth.

Idiosoma (Figs. 4, 5). Oval, 773 (725–825) long and 474 (450–500) wide.

Dorsal idiosoma (Fig. 4). Podonotal and opisthonotal shields fused, 658 (625–688) long and 401 (375–415) wide, partly covering dorsal surface of idiosoma, slightly tapered posteriad of *r*3–4, brownish, reticulate. Podonotal region with 22 pairs of setae (including *r*2–*r*5), six pairs of lyrifissures and three pairs of pores. Opisthonotal region with 17 pairs of setae (including *px*2 and *px*3 between *J* and *Z* series), ten pairs of lyrifissures and two pairs of pores. Dorsal setae elongate on the podonotal and shorter on the opisthonotal regions, except *Z*5, almost as long as *z*5. Setae *r*6, *R*1, *R*2, *R*4–*R*6, and *UR*2 (some specimens with an additional *UR* between *R*4 and *R*5; *R*3 absent) and lyrifissure *idR*3 on unsclerotized lateral cuticle. All setae aciculate. Setal measurements shown in Table 2.

Table 2. Length (µm) of dorsal idiosomal setae of Colombian specimens of ***Gaeolaelaps aculeifer* (Canestrini, 1884)**; mean (minimum–maximum). - = seta absent.

Seta	Female (n = 6)	Male (n = 6)	Deutonymph (n = 5)	Protonymph (n = 4)
*j*1	41 (33–45)	35 (30–38)	41 (35–55)	31 (28–35)
*j*2	62 (50–68)	48 (40–58)	41 (35–45)	28 (25–30)
*j*3	75 (73–75)	52 (43–58)	52 (45–58)	42 (35–50)
*j*4	56 (53–63)	37 (33–40)	40 (35–45)	34 (28–43)
*j*5	42 (38–45)	30 (25–33)	31 (28–38)	29 (23–38)
*j*6	32 (30–35)	24 (23–28)	23 (18–28)	23 (18–28)
*J*1	25 (20–30)	20 (18–23)	18 (15–20)	17 (15–20)
*J*2	23 (20–25)	17 (15–18)	16 (15–18)	15 (13–20)
*J*3	19 (18–20)	15 (13–18)	13 (10–15)	13 (10–15)
*J*4	24 (20–25)	14 (13–15)	13 (10–15)	14 (13–15)
*J*5	24 (20–28)	20 (15–23)	17 (15–20)	14 (13–15)

Seta	Female (n = 6)	Male (n = 6)	Deutonymph (n = 5)	Protonymph (n = 4)
*J*2–*J*3	52 (38–63)	25 (20–33)	32 (30–35)	34 (23–45)
*J*3–*J*4	73 (70–75)	42 (33–50)	45 (40–50)	37 (35–38)
*j*2–*j*3	49 (38–58)	38 (33–43)	33 (30–38)	21 (20–23)
*z*1	65 (63–75)	13 (10–20)	11 (10–13)	-
*z*2	65 (50–75)	52 (50–53)	48 (40–55)	44 (38–53)
*z*3	71 (63–88)	51 (48–55)	38 (33–48)	-
*z*4	68 (63–75)	55 (48–63)	54 (45–63)	43 (38–50)
*z*5	54 (43–68)	34 (28–40)	31 (18–38)	33 (28–38)
*z*6	32 (25–50)	18 (18–20)	18 (15–20)	
*Z*1	28 (25–30)	18 (15–20)	17 (15–20)	16 (15–18)
*Z*2	21 (18–23)	17 (13–23)	17 (15–18)	17 (13–23)
*Z*3	24 (20–28)	19 (18–20)	19 (15–23)	16 (13–18)
*Z*4	27 (23–30)	20 (18–20)	35 (33–38)	16 (15–18)
*Z*5	44 (40–50)	22 (20–25)	25 (23–33)	35 (28–45)
*s*1	47 (43–55)	30 (28–30)	33 (28–40)	-
*s*2	58 (53–63)	39 (33–43)	58 (50–63)	-
*s*3	65 (55–80)	57 (48–65)	51 (45–55)	-
*s*4	68 (55–80)	55 (50–58)	37 (33–40)	44 (38–55)
*s*5	51 (48–55)	39 (30–53)	29 (25–30)	34 (28–38)
*s*6	57 (50–63)	24 (15–30)	23 (18–28)	28 (23–30)
*S*1	44 (38–53)	20 (15–25)	19 (15–23)	-
*S*2	33 (28–40)	20 (15–23)	17 (13–20)	18 (15–23)
*S*3	27 (18–33)	18 (18–20)	16 (15–18)	14 (13–18)
*S*4	29 (25–33)	20 (18–23)	20 (18–23)	16 (15–18)
*S*5	27 (20–30)	23 (18–28)	13 (10–15)	25 (20–38)
*px*2	20 (18–23)	15 (13–18)	14 (10–18)	-
*px*3	18 (15–23)	14 (13–18)	39 (35–43)	-
*r*2	70 (63–75)	37 (33–43)	59 (50–65)	34 (30–43)
*r*3	55 (50–63)	44 (38–53)	30 (25–35)	32 (28–38)
*r*4	53 (50–63)	36 (28–40)	34 (25–40)	-
*r*5	43 (38–55)	31 (18–40)	14 (13–15)	27 (23–33)
*r*6	24 (20–25)	18 (13–23)	14 (10–15)	
*R*1	20 (18–25)	16 (13–18)	11 (10–13)	14 (10–15)
*R*2	18 (15–20)		12 (10–13)	-
*R*4	18 (15–20)	15 (13–15)	13 (10–15)	-
*R*5	21 (18–25)	15 (10–18)	15 (13–15)	-
*R*6	21 (18–23)	14 (13–15)	18 (15–20)	-
*UR*1	21	-	-	-
*UR*2	23 (20–25)	-	-	-

Ventral idiosoma (Fig. 5). Base of tritosternum 36 (35–37) long and 14 (13–18) wide proximally; laciniae 90 (88–95), totally separated, pilose. Pre-sternal area weakly sclerotized, represented by two lobes fused with sternal shield, punctate and striate. Sternal shield reticulate, with posterior margin slightly concave, anterolateral corners extending between coxae I–II, distally bearing pores *gvb*; 191 (185–200) long and 193 (188–200) wide, with three pairs of setae (*st*1–3) and two pairs of lyrifissures (*iv*1 and *iv*2); distances *st*1–3 142 (138–150), *st*2–*st*2 100 (95–103). Fourth pair of sternal setae (*st*4) and third pair of lyrifissure (*iv*3) on unsclerotized cuticle. Epigynial shield tongue-shaped, reticulate; anterior hyaline region irregularly convex and slightly overlapping posterior margin of sternal shield; 185 (178–190) long and 98 (93–105) wide; distance *st*5–*st*5 80 (70–88); seta *st*5 inserted on shield margin and lyrifissure *iv*5 on unsclerotised cuticle posterolaterad of *st*5. Distance between epigynial and anal shields exceeding length of anal shield. A pair of rod-shaped platelets next to edge of epigynial shield. With three pairs of bacilate metapodal platelets. Opisthogaster with eight pairs of setae on unsclerotised cuticle (*Jv*1–*Jv*5, *Zv*1–*Zv*5) and five pairs of lyrifissures. Anterior section of endopodal plate fused with sternal shield; section behind sternal shield represented by an elongate v-shaped platelet between coxae III–IV (in some specimens, anterior tip of the plate apparently fused to sternal shield). Exopodal plate represented by triangular sections between coxae II–III and III–IV, and a curved fragment partially surrounding external margin of coxa IV, in some specimens fused with triangular plate between coxae III-IV; *gv*2 on unsclerotized cuticle. Anal shield small, inversely pear-shaped, reticulate; 90 (85–100) long and 68 (63–90) wide, with a pair of marginal pores about in transverse line with para-anal setae, the latter about as long as or slightly shorter than post-anal seta and inserted between mid-length and posterior margin of anal opening; anal opening almost 1/4 as long as shield, 30 (25–33) long, anteriad of shield center. All ventral setae aciculate. Setal measurements shown in Table 3.

Table 3. Length of ventral idiosomal and ventral gnathosomal setae of Colombian specimens of ***Gaeolaelaps aculeifer*** **(Canestrini, 1884)**; mean (minimum–maximum). - = seta absent.

Seta	Female (n = 6)	Male (n = 6)	Deutonymph (n = 5)	Protonymph (n = 4)
*st*1	50 (43–55)	31 (23–38)	36 (33–38)	31 (28–33)
*st*2	52 (50–55)	37 (33–40)	34 (30–38)	28 (25–30)
*st*3	50 (43–55)	34 (30–38)	31 (30–33)	26 (25–28)
*st*4	31 (25–38)	22 (15–25)	18 (15–20)	-
*st*5	30 (28–33)	22 (20–25)	18 (15–20)	12 (10–13)
*Jv*1	34 (30–38)	24 (23–28)	18 (18–20)	19 (18–20)

Seta	Female (n = 6)	Male (n = 6)	Deutonymph (n = 5)	Protonymph (n = 4)
*Jv*2	36 (30–40)	26 (23–30)	21 (18–23)	18 (18–20)
*Jv*3	29 (25–35)	24 (20–30)	19 (15–23)	-
*Jv*4	26 (23–28)	20 (15–28)	17 (13–18)	-
*Jv*5	26 (20–28)	20 (13–23)	18 (13–25)	22 (18–28)
*Zv*1	25 (23–30)	20 (18–23)	13 (10–15)	-
*Zv*2	30 (25–33)	23 (23–25)	17 (15–20)	16 (15–18)
*Zv*3	20 (15–23)	-	13 (10–15)	-
*Zv*4	19 (18–23)	-	17 (16–20)	
*Zv*5	23 (20–28)	16 (13–18)	18 (15–20)	
Para–anal	22 (20–25)	17 (15–20)	17 (15–20)	16 (15–18)
post–anal	29 (28–30)	21 (18–25)	25 (23–28)	19 (18–20)

Peritreme and peritrematic plate. Peritreme extending anteriorly to level slightly beyond *s*1. Peritrematic plate fused with dorsal shield near *z*1; with a pore (*gp*1) between coxae I–II, with a lyrifissure (*ip*2) and a pore (*gp*2) between coxae II–III, and with two lyrifissures (*ip*s and *ip*3) and a pore (*gp*3) posteriad of stigma. Post-stigmatic extension of peritrematic plate free, about straight, tapering posteriorly and almost reaching median level of coxa IV (Fig. 5).

Spermathecal apparatus (Fig. 6). Laelapid-type. Insemination pore apparently located at anterior margin at base of coxa IV; infundibulum indistinct; tubulus elongate; ramus barely distinguishable, attached to the globular sacculus; sperm duct indistinct.

Legs (Figs. 7–10). Lengths: I: 679 (663–700); II: 553 (533–575); III: 524 (513–538); IV: 788 (750–825). Chaetotaxy (legs I–IV): coxae: $0-\frac{0\,0}{2\,0}-0$, $0-\frac{0\,0}{1\,1}-0$, $0-\frac{0\,0}{1\,1}-0$, $0-\frac{0\,0}{1\,0}-0$; trochanters: $1-\frac{1\,0}{2\,1}-1$, $1-\frac{0\,1}{1\,1}-1$, $1-\frac{1\,0}{1\,1}-1$, $2-\frac{1\,0}{1\,1}-0$; femora: $2-\frac{2\,3}{1\,3}-2$, $2-\frac{3\,2}{1\,2}-1$,$1-\frac{2\,1}{1\,0}-1$, $1-\frac{2\,1}{1\,0}-1$; genua: $2-\frac{3\,3}{2\,1}-2$,$2-\frac{3\,2}{1\,1}-2$, $2-\frac{2\,2}{1\,1}-1$, $2-\frac{2\,3}{1\,0}-1$; tibiae: $2-\frac{3\,3}{2\,1}-2$, $2-\frac{2\,2}{1\,1}-2$, $2-\frac{1\,2}{1\,1}-1$, $2-\frac{1\,3}{1\,1}-2$; tarsal setation: I not counted, 18, 18, 18. All legs with pretarsi containing a pair of strongly scletorized claws; median section of pulvilli of legs I–IV rounded. Setae *av*1 of femur II, *av*1 of genu II, *av*1 and *pv*1 of tibia II, *av*1–2, *pv*1–2, *al*1, *pl*1, *md*, *mv* and *ad*2 of tarsus II, *av*1 and *pv*1 of genu III, *av*1 and *pv*1 of tibia III, most setae of tarsus III (except *al*2, *al*2, *ad*1, *ad*3, *pd*1 and *pd*3), *av*1 of genu IV, *av*1, *pv*1 and *pl*1 of tibia IV, and most setae of tarsus IV (except *ad*1, *ad*3, *pd*1 and *pd*3) stout and spine-like.

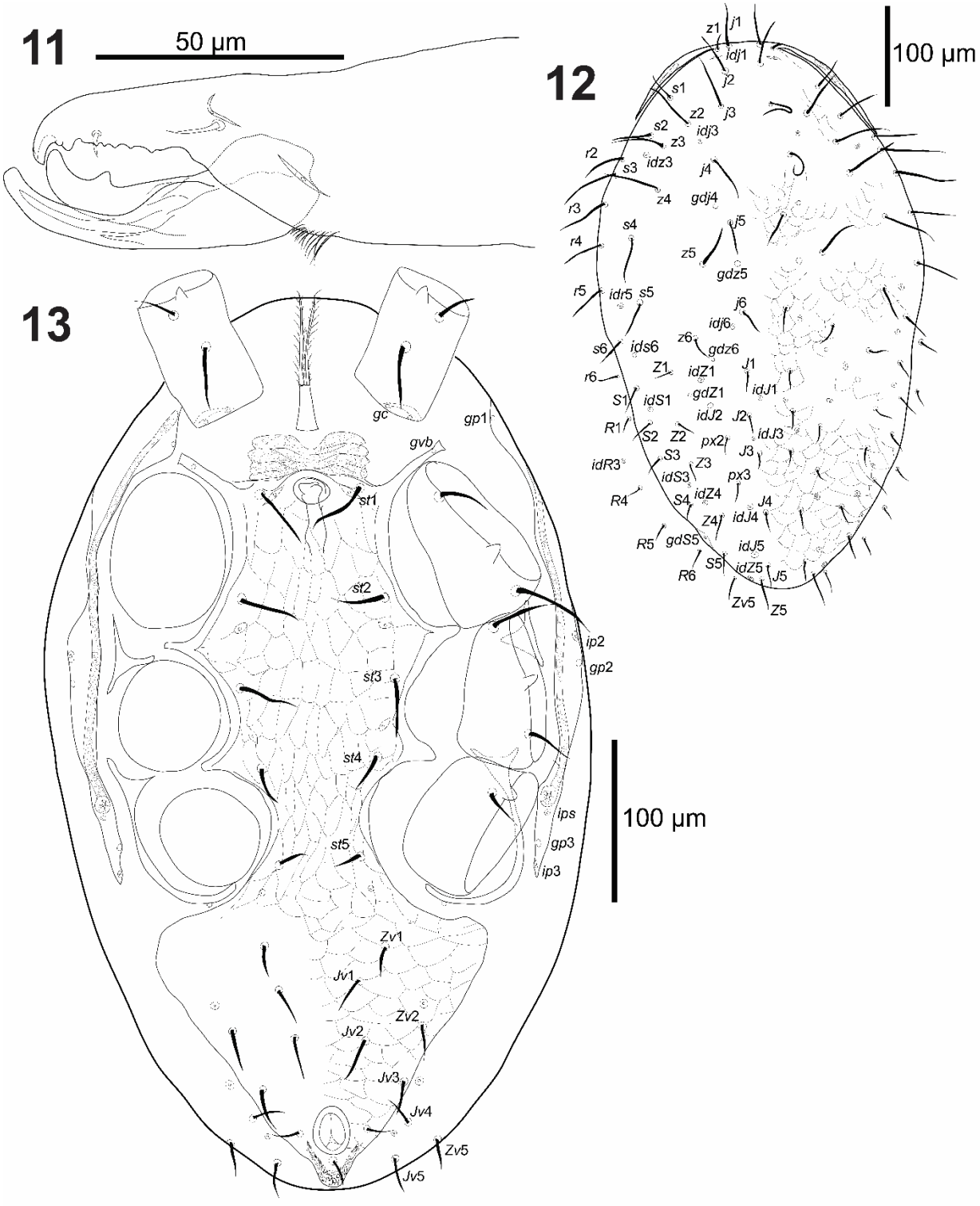
Figure 7–10. *Gaeolaelaps aculeifer* (Canestrini, 1884). Colombian female. 7. Leg I; 8. Leg II; 9. Leg III; 10. Leg IV.

Adult male (Figure 11–13, six specimens measured).

Gnathosoma. Fixed cheliceral digit 55 (53–58) long, with a small tooth, followed by a large tooth and then by a series of 6–8 irregular and small teeth; movable digit 52 (50–53) long, with one large tooth; spermadactyl ca. 63 long, curved upward, extending slightly beyond tip of movable digit and tapering to a blunt tip; dorsal seta stout, dorsal lyrifissure distinct, but antiaxial lyrifissure indistinct (Fig. 11). Arthrodial process of chelicera, palp chaetotaxy, apotele, epistome, deutosternum, corniculus and position of hypostomal setae as in adult female. Measurements of setae: *h*1 29 (18–38), *h*2 30 (28–33), *h*3 37 (33–40), *pc* 33 (30–38); setae aciculate and smooth.

Idiosoma (Figs. 12, 13). Tapering slightly posteriorly, 533 (513–550) long and 335 (288–375) wide.

Dorsal idiosoma (Fig. 12). Podonotal and opisthonotal shields fused, 506 (488–513) long and 323 (300–350) wide, completely covering dorsal surface of idiosoma, brownish, reticulate. Podonotal region with the same setae of adult female, six pairs of distinct lyrifissures and three pairs of pores.



Figures 11–13. *Gaeolaelaps aculeifer* (Canestrini, 1884). Colombian male. 11. Chelicera; 12. Dorsal idiosoma; 13. Ventral idiosoma.

Opisthonotal region with the same setae, lyrifissures and pores as adult female. Setae *r*6 and *R*1, *R*4–*R*6 (*R*2, *UR*1 and *UR*2 absent) on unsclerotized lateral cuticle, not visible dorsally in most of the specimens. Other features similar adult female. Setal measurements shown in Table 2.

Ventral idiosoma (Fig. 13). Base of tritosternum 24 (26–22) long and 12 (10–13) wide proximally; laciniae 73 (68–83) long, totally separated, pilose. Pre-sternal area similar to female. Sternogenital and ventrianal shields fused in a holoventral shield, reticulate, anterolateral corners extending between coxae I–II, distally bearing pores *gvb*; 430 (413–450) long and 155 (138–163) wide at the level of coxae IV; with ten pairs of setae (*st1–5*, *Jv*1–*Jv*3, *Zv*1 and *Zv*2) in addition to circumanal setae, five pairs of distinguishable lyrifissures and a pair of marginal pores about in transverse line with or slightly posteriad of para-anal setae. Unsclerotised cuticle posterolaterad of ventrianal region with three pairs of setae (*Jv*4, *Jv*5 and *Zv*5; *Zv*3 and *Zv*4 absents) and two pairs of distinguishable lyrifissures; *gv*2 on unsclerotized cuticle. Shape of ventral idiosomal setae as in adult female. Setal measurements shown in Table 3.

Peritreme and peritrematic plate. As in adult female.

Legs. Lengths: I: 540 (525–563); II: 471 (438–500); III: 449 (425–463); IV: 608 (575–638). Shape of setae as in adult female.

Deutonymph (Figs. 14–16, five specimens measured).

Gnathosoma. Fixed cheliceral digit 65 (60–70) long, with a small subapical tooth, followed by a large (lobe-like) tooth at the level of the thorne-shaped *pilus dentilis*, a row of 5–6 irregular teeth and a large tooth; movable digit 61 (55–65) long, with two large teeth; dorsal seta stout, dorsal and antiaxial lyrifissures distinct (Fig. 14). Arthrodial process of chelicera, palp chaetotaxy, apotele, epistome, deutosternum, corniculus and position of hypostomal setae as in adult female. Measurements of setae: *h*1 36 (30–38), *h*2 33 (25–35), *h*3 47 (40–55), *pc* 33 (30–38); setae aciculate and smooth.

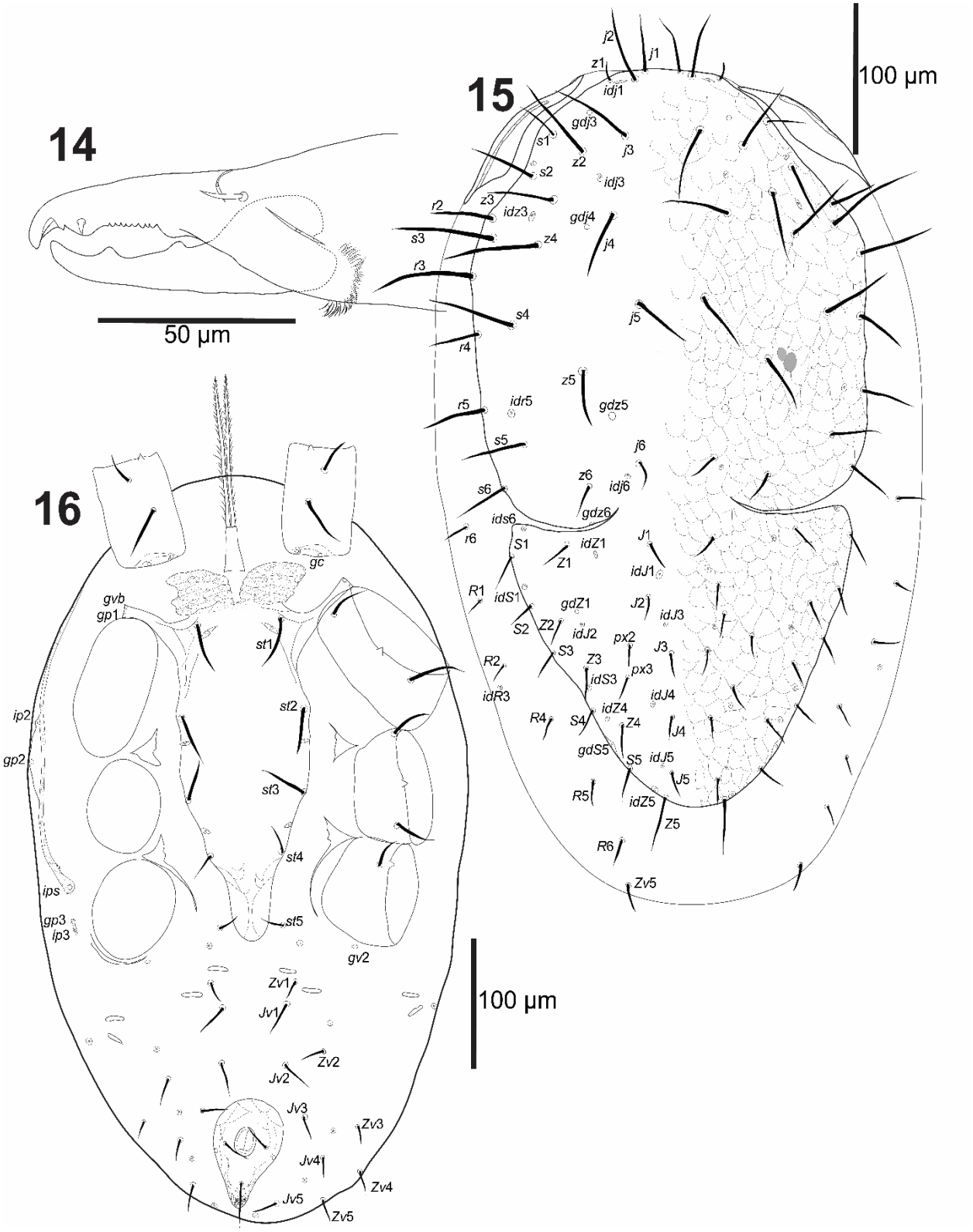
Idiosoma (Figs., 15, 16). Oval, whitish, 535 (513–575) long and 342 (313–375) wide.

Dorsal idiosoma (Fig. 15). Dorsal shield with deep, curved lateral incisions almost reaching level between j6 and *J*1 (schizodorsal shield), 458 (438–488) long and 258 (238–275) wide, partly covering dorsal surface of idiosoma, tapered posteriad of *r*3–4, whitish, reticulate. Podonotal region with 22 pairs of setae (including *r*2–5), six pairs of lyrifissures (*ids*6 posteriad of lateral incision) and four pairs of pores. Opisthonotal region with 17 pairs of setae (including *px*2–3), ten pairs of lyrifissures and a pair of pores. Setae *r*6 and *R*1, *R*2 and *R*4–6 (*R*3, *UR*1 and *UR*2 absent) on unsclerotized lateral cuticle. Other features similar to adult female. Setal measurements shown in Table 2.

Ventral idiosoma (Fig. 16). Base of tritosternum 31 (36–27) long and 15 (13–18) wide proximally; laciniae 68 (65–75), totally separated, pilose. Pre-sternal area similar to adult female. Sternal shield lightly sclerotized, smooth except for a slight reticulation laterad of *st*1 and on epigynial area, tapering posteriad of *st*3, anterolateral corners extending between coxae I–II, distally bearing pores *gvb* and *gp*1, 262 (243–280) long and 110 (88–135) wide, with four pairs of setae (*st*1–*st*4) and three pairs of lyrifissures (*iv*1–*iv*3); distances *st*1–3 129 (110–155), *st*2–*st*2 93 (85–100). Seta *st*5 and lyrifissure *iv*5 on unsclerotized cuticle, the latter posterolaterad of *st*5. A pair of bacillate metapodal platelets. Opisthogaster with ten pairs of setae on unsclerotised cuticle (*Jv*1–5, *Zv*1–5), five pairs of lyrifissures. Endopodal elements represented by a triangular section between coxae II–III and by a triangular section with an elongate posterior extension between coxae III–IV. Exopodal plate reduced to some fragments behind coxa IV; *gv*2 on unsclerotized cuticle. Anal shield small, inversely pear-shaped, slightly reticulate, 62 (53–75) long and 53 (50–55) wide, with a pair of marginal pores about in transverse line with para-anal setae. Shape of ventral idiosomal setae as in adult female. Setal measurements shown in Table 3.

Peritreme and peritrematic plate. Peritreme as in adult female. Peritrematic plate lightly sclerotized, reduced to a small distal section between *z*1 and *r*2, not fused with dorsal shield, and a platelet between coxae II–III, bearing a lyrifissure (*ip*2) and a pore (*gp*2). Post-stigmatic peritrematic poroid (*gp*3) and lyrifissures (*ips* and *ip*3) on lightly sclerotized enlongated platelet, followed behind by a tiny rounded platelet.

Legs. Lengths: I: 513 (463–563); II: 451 (400–500); III: 357 (325–395); IV: 540 (488–588). Shape of setae as in adult female.



Figures 14–16. *Gaeolaelaps aculeifer* (Canestrini, 1884). Deutonymph. 14. Chelicera; 15. Dorsal idiosoma; 16. Ventral idiosoma.

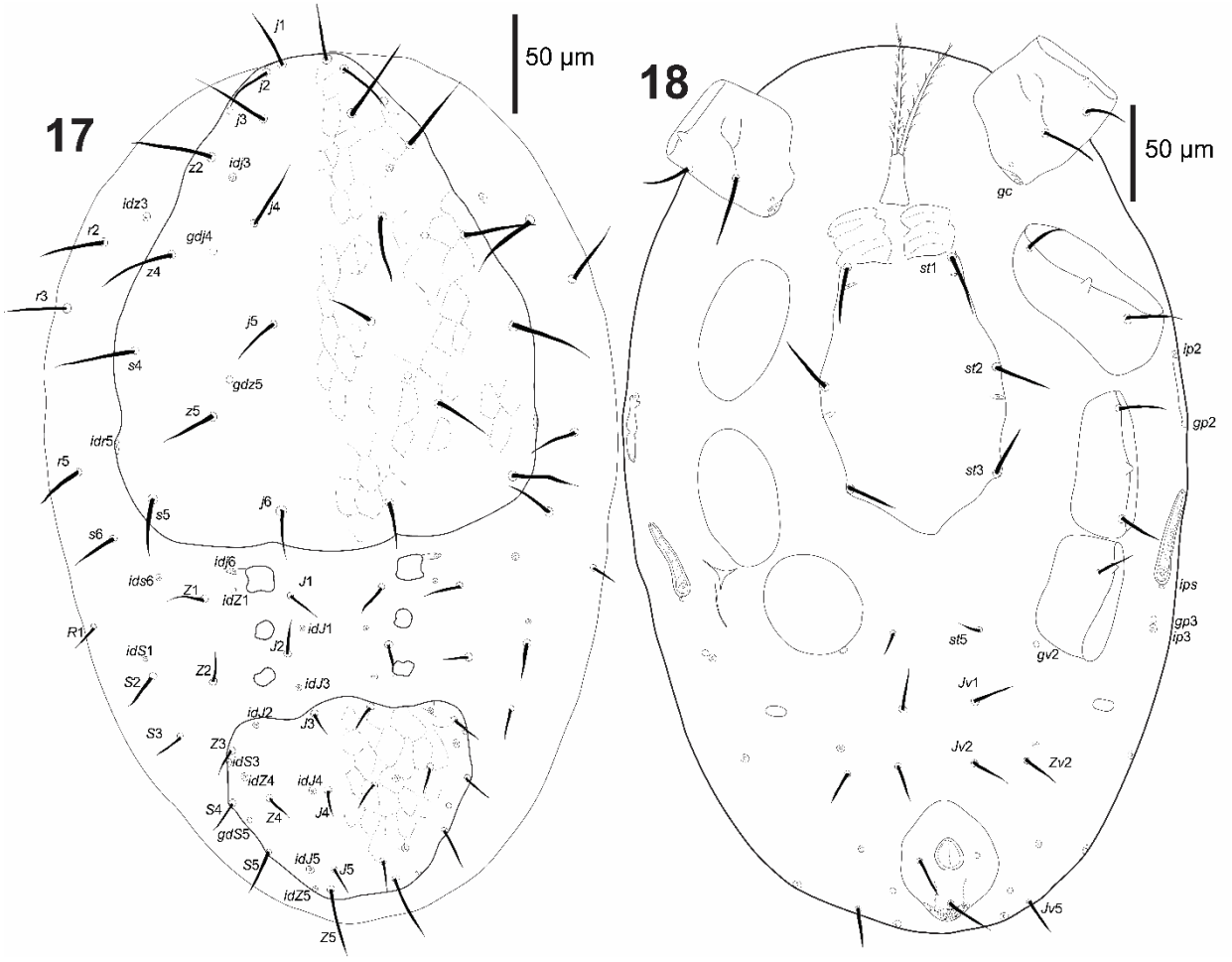
Protonymph (Figs. 17–18, four specimen measured).

Gnathosoma. Fixed cheliceral digit 54 (48–60) long, with a small subapical tooth, followed by a large (lobe-like) tooth at the level of the thorne-shaped *pilus dentilis*, a row of 5–7 irregular and small teeth and a large tooth; movable digit 49 (43–55) long, with two large teeth. Numbers of setae on palp trochanter–tarsus: 1, 4, 5, 12, 15; arthrodial process of chelicera, apotele, epistome, deutosternum, corniculus and position of hypostomal setae as in adult female. Measurements of setae: *h*1 32 (30–33), *h*2 26 (20–30), *h*3 36 (33–40), *pc* 27 (25–28); setae aciculate and smooth.

Idiosoma (Figs. 17, 18). Oval, 447 (375–513) long and 291 (225–350) wide.

Dorsal idiosoma (Fig. 17). Podonotal and opisthonotal shields separate. Podonotal shield 247 (218–275) long and 206 (173–250) wide, whitish, lightly reticulate, with 11 pairs of setae (*j*1–6, *z*2, *z*4, *z*5, *s*4, *s*5), two pairs of lyrifissures and three pairs of pores; unsclerotized cuticule laterad of podonotal shield with four pairs of setae (*s*6, *r*2, *r*3, *r*5) and a pair of lyrifissures. Opisthonotal shield 108 (90–123) long and 119 (105–150) wide, lightly reticulate, with eight pairs of setae (*J*3–5, *Z*3–5, *S*4, *S*5), four pairs of lyrifissures and a pair of pores. Unsclerotized cuticle between podonotal and opisthonotal shields with three pairs of lightly sclerotized and rounded sigillar platelets, seven pairs of setae (*J*1, *J*2, *Z*1, *Z*2, *S*2, *S*3, *R*1) and six pairs of lyrifissures. Shape and proportion of setae as in adult female. All setae aciculate. Setal measurements shown in Table 2.

Ventral idiosoma (Fig. 18). Base of tritosternum 26 (24–30) long and 14 (13–15) wide proximally; laciniae 63 (58–70), totally separated, pilose. Pre-sternal area similar to female. Sternal shield lightly sclerotized, smooth; 133 (125–138) long and 93 (88–100), with three pairs of setae (*st*1–3) and two pairs of lyrifissures (*iv*1–*iv*2); distances *st*1–3 109 (100–125), *st*2–*st*2 87 (80–90); setae *st*4 absent. Seta *st*5 on unsclerotized cuticle. A pair of bacillate metapodal platelets. Opisthogaster with four pairs of setae on unsclerotised cuticle (*Jv*1, *Jv*2, *Jv*5, *Zv*2), five pairs of lyrifissures and a pair of pores. Endopodal and exopodal plates indistinguishable; *gv*2 on unsclerotized cuticle. Anal shield small, ovoid, 54 (50–58) long and 55 (50–70) wide. Shape of ventral idiosomal setae as in adult female. Setal measurements shown in Table 3.



Figures 17–18. *Gaeolaelaps aculeifer* (Canestrini, 1884). Protonymph. 17. Dorsal idiosoma; 18. Ventral idiosoma.

Peritreme and peritrematic plate. Peritreme short, reaching area next to middle of coxa III. Peritrematic shield lightly sclerotized, reduced to a small fragment between coxae II–III, bearing a lyrifissure (*ip*2) and a pore (*gp*2), and a barely distinguishable platelet bearing the peritreme. Post-stigmatic peritrematic poroid (*gp*3) and lyrifissures (*ips* and *ip*3) on soft cuticle.

Legs. Lengths: I: 375 (338–438); II: 306 (275–333); III: 294 (263–338); IV: 419 (363–475). Chaetotaxy (legs I–IV): coxae: $0-\frac{0\,0}{2\,0}-0$, $0-\frac{0\,0}{1\,1}-0$, $0-\frac{0\,0}{1\,1}-0$, $0-\frac{0\,0}{1\,0}-0$; trochanters: $1-\frac{0\,0}{1\,1}-1$, $1-\frac{0\,0}{1\,1}-1$, $1-\frac{1\,0}{1\,1}-1$, $1-\frac{1\,0}{1\,1}-0$; femora: $2-\frac{2\,2}{1\,1}-2$, $1-\frac{2\,2}{1\,1}-1{,}1-\frac{2\,1}{1\,0}-0$, $1-\frac{2\,1}{0\,0}-0$; genua: $1-\frac{2\,2}{1\,1}-1{,}1-\frac{2\,2}{0\,0}-1$, $1-\frac{2\,2}{0\,0}-1$, $1-\frac{2\,2}{0\,0}-0$; tibiae: $1-\frac{2\,2}{1\,1}-1$, $1-\frac{1\,2}{1\,1}-1$, $1-\frac{1\,2}{1\,1}-1$, $1-\frac{1\,2}{1\,1}-1$; tarsal setation: I not counted, 17, 17, 17. Shape of setae as in adult female.

Remarks. This species was originally described from Italy, from unspecified substrate. The specimens examined are larger than reported by Evans & Till (1966) in a complementary description based on mites collected from nest of *Riparia riparia* in Gloucestershire in Britain (female dorsal shield 684 long 360 wide, male dorsal shield 540 long and 276 wide, deutonymph dorsal shield 450 long and 216 wide, and protonymph dorsal shield 258 long and 190 wide). Concurrently, other measurements are also larger, especially the cheliceral digits.

The present complementary description provides additional information not given in the original description and in the complementary description by Evans & Till (1966), including measurements of all dorsal and ventral idiosomal setae, leg chaetotaxy, and characteristics of the spermatheca.

***Gaeolaelaps brevipellis* Karg**

Hypoaspis (*Geolaelaps*) *brevipellis* Karg, 1979: 87.
Hypoaspis (*Geolaelaps*) *brevipellis*.— Karg, 1982: 243; 1989: 117; 2000: 247.
Gaeolaelaps brevipellis.— Nemati & Mohseni, 2013: 75.

Material measured: two ♀, and two deutonymphs from soil (pH 4.0 ± 0.1; organic matter 85 ± 3%; humidity 70 ± 2%; temperature 10.5 ± 0.1°C) at LV collected on January 17, 2015; three ♀ from soil (pH 4.0 ± 0.1; organic matter 85 ± 3%; humidity 70 ± 2%; temperature 15.3 ± 0.2°C) at SV collected on February 11, 2015; three ♀ paratypes from litter, near El Bolsón, [Rio Negro], Argentina (Museum für Naturkunde collection numbers ZMB Kat Nr 39974, 39975 and 39977); two ♀ from unknown substrate in Venezuela (Museum für Naturkunde collection numbers ZMB Kat Nr 39980 and 39982).

Additional material examined: 25 ♀ and six deutonymphs from SV and LV.

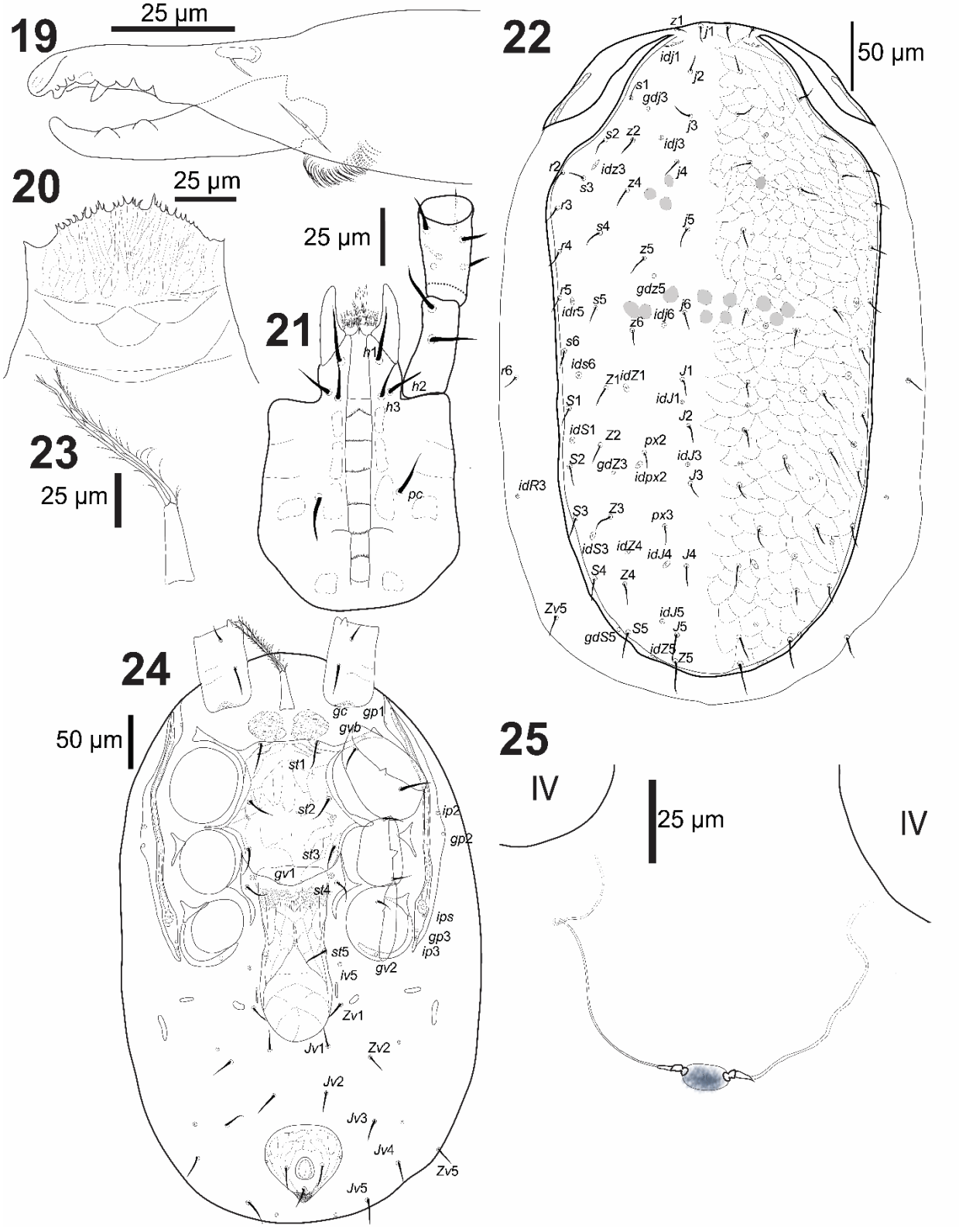
Diagnosis: female with anterior region of epistome slightly convex, with with irregular dorsal lines and margin irregularly denticulate; fixed cheliceral digit with a large offset subapical tooth followed by 2–3 small subapical teeth and a row of five teeth; with stout *pilus dentilis*; deutosternal groove delimited by subparallel lateral lines, with eight transverse lines, the most distal and the most proximal smooth and others with 10-28 denticles; second most distal line v-shaped; dorsal shield covering most dorsal surface of idiosoma, ellipsoidal, brownish, reticulate, with 38 pairs of setae (including *px*2–3); pre-sternal area weakly sclerotized, represented by a pair of slightly sclerotised granulated ovoid plates; opisthogaster with eight pairs of setae (*Jv*1–5, *Zv*1, *Zv*2, *Zv*5) on unsclerotised cuticle;

two pairs of metapodal platelets; a pair of slender platelets next to edge of epigynial shield, which bears only *st*5. Deutonymph dorsal shield with straight lateral incisions reaching slightly beyond level of *z*6 (schizodorsal shield); sternal shield lightly sclerotized, reticulate, tapering posteriad of *st*3, anterolateral corners extending as a slender strip between coxae I–II.

Adult female (Figs. 19–29, five Colombian specimens measured, in addition to three paratypes and two Venezuelan specimens identified by Karg and deposited in the Museum für Naturkunde, Leibniz Institute for Evolution and Biodiversity Science).

Gnathosoma. Chelicera with arthrodial process shaped as a coronet-like fringe; fixed cheliceral digit 60 (57–62) [58–62] long, with a large offset subapical tooth followed by two small subapical teeth, four large teeth and a basel ridge-like structure; with stout *pilus dentilis*; movable digit 54 (50–58) long [57–60], with two large teeth; dorsal seta cylindrical, with round tip; dorsal and antiaxial lyrifissures distinct (Fig. 19). Numbers of setae on palp trochanter–tarsus: 2, 5, 6, 14, 15; palp apotele bifurcate. Anterior region of epistome slightly convex, with irregular dorsal lines and with margin irregularly denticulate (Fig. 20); Deutosternal groove (Fig. 21) delimited by subparallel lateral lines, with eight transverse lines, the most distal and the most proximal smooth, and others with 10-28 denticles; second most distal v-shaped; with a pair of smooth, transverse and curved lines external to deutosternum, at the level of third most proximal line of denticles. Internal malae distinctly separated from each other and ventrally fimbriate, consisting of a pair of elongate projections flanked by a dense series of parallel fimbriae. Corniculi horn-shaped, more than twice as long as their largest width, well separated from each other, subparallel. Hypostomal seta *h*3 about in longitudinal line with *h*1 and mediad and slightly posteriad of *h*2. Measurements of setae: *h*1 23 (20–30) [26], *h*2 20 (17–22) [14–16], *h*3 19 (15–23) [15–20], *pc* 16 (15–20) [20]; setae aciculate and smooth.

Idiosoma (Figs. 22, 24). Ellipsoidal, 445 (400–512) [427–481] long and 282 (233–338) [248–293] wide.



Figures 19–25. *Gaeolaelaps brevipellis* Karg, 1979. Colombian female. 19. Chelicera; 20. Epistome; 21. Hypostome and proximal palp segments; 22. Dorsal idiosoma; 23. Tritosternum; 24. Ventral idiosoma; 25. Spermathecal apparatus.

Dorsal idiosoma (Fig. 22). Podonotal and opisthonotal shields fused, 423 (382–487) [455–470] long and 244 (225–275) [248–256] wide, covering most of dorsal surface of idiosoma, ellipsoidal, reticulate. Podonotal region with 21 pairs of setae (including *r*2–5), six pairs of lyrifissures and two pairs of pores. Opisthonotal region with 17 pairs of setae (including *px*2–3 between *J* and *Z* series), ten pairs of lyrifissures and two pairs of pores. Seta *r*6 and lyrifissure *idR*3 on unsclerotized lateral cuticle. All setae aciculate; setae of about uniform lengths, except *Z*5, slightly longer. Setal measurements shown in Table 4.

Table 4. Length of dorsal idiosomal setae of Colombian specimens of ***Gaeolaelaps brevipellis*** **Karg, 1979**; mean (minimum–maximum). - = seta absent.

Seta	Female (n = 5)	Argentina paratypes and Venezuelan specimens (n = 5)	Deutonymph (n = 2)
*j*1	15 (12–17)	[13–14]	14 (10–18)
*j*2	14 (12–17)	[12–14]	15 (13–18)
*j*3	16 (15–18)	[15–19]	18 (15–20)
*j*4	14 (10–17)	[18–19]	18 (15–20)
*j*5	15 (12–17)	[18–20]	16 (15–18)
*j*6	14 (12–15)	[16–20]	16 (15–18)
*J*1	15 (13–18)	[14–16]	14 (13–15)
*J*2	13 (12–15)	[15–16]	13 (10–15)
*J*3	11 (10–13)	[13–14]	11 (10–13)
*J*4	13 (10–15)	[14–18]	11 (10–13)
*J*5	16 (15–17)	[16–17]	13 (13–13)
*J*2–*J*3	36 (25–43)	[50–66]	28 (25–30)
*J*3–*J*4	53 (38–63)	[50–65]	41 (38–45)
*j*2–*j*3	31 (30–35)	[26–34]	28 (25–30)
*z*1	12 (8–18)	Broken or not visible	10
*z*2	15 (13–18)	[16–19]	16 (15–18)
*z*4	14 (13–15)	[19–19]	16 (15–18)
*z*5	14 (12–20)	[18–19]	16 (15–18)
*z*6	13 (10–15)	[17–18]	15
*Z*1	14 (12–15)	[16–20]	15
*Z*2	14 (13–15)	[13–17]	13 (10–15)
*Z*3	13 (12–15)	[14–15.5]	13
*Z*4	15 (12–17)	[16–17]	14 (13–15)
*Z*5	20 (18–23)	[18–23]	24 (23–25)
*s*1	11 (10–13)	[10–13]	15
*s*2	12 (10–15)	[15–16]	15 (13–18)

Seta	Female (n = 5)	Argentina paratypes and Venezuelan specimens (n = 5)	Deutonymph (n = 2)
*s*3	15 (12–17)	[14–17]	14 (13–15)
*s*4	14 (13–18)	[18–19]	16 (15–18)
*s*5	14 (13–15)	[17–18]	14 (13–15)
*s*6	12 (10–15)	[18–18]	14 (13–15)
*S*1	12 (10–15)	[16–17]	10
*S*2	12 (10–15)	[15–15.5]	14 (13–15)
*S*3	14 (12–17)	[15–17]	14 (13–15)
*S*4	15 (12–17)	[16]	13
*S*5	16 (15–17)	[16–18]	16 (15–18)
*px*2	13 (11–14)	[14–15]	15
*px*3	14 (10–15)	[13–16]	11 (10–13)
*r*2	14 (10–18)	[16–17]	14 (13–15)
*r*3	13 (10–15)	[15–18]	13
*r*4	12 (10–15)	[15–18]	14 (13–15)
*r*5	13 (10–18)	[16–18]	15
*r*6	10 (10–10)	[12]	12 (12–13)

Ventral idiosoma (Figs. 23–24). Base of tritosternum 25 (23–30) [24–33] long and 12 (10–12) [11–15] wide proximally; laciniae 64 (58–75) [85] totally separated from each other, pilose (Fig. 23). Pre-sternal area weakly sclerotized, represented by a pair of slightly sclerotised granulated ovoid plates. Sternal shield reticulate, with posterior margin convex, anterolateral corners extending between coxae I–II, distally bearing pores *gvb*; 118 (113–130) [118–125] long and 122 (113–138) [113–127] wide, with three pairs of setae (*st*1–3), two pairs of lyrifissures (*iv*1 and *iv*2) and and a pair of pores near posterior margin (*gv*1); distances *st*1–3 87 (80–98) [93], *st*2–*st*2 69 (65–75) [77]. Fourth pair of sternal setae (*st*4) and third pair of lyrifissure (*iv*3) on unsclerotized cuticle. Epigynial shield tongue-shaped, reticulate; anterior hyaline region irregularly convex and slightly overlapping posterior margin of sternal shield; 118 (110–128) [140–163] long and 62 (58–70) [64–71] wide; distance *st*5–*st*5 53 (45–63) [60]; seta *st*5 inserted on shield margin and lyrifissure *iv*5 on unsclerotised cuticle, posterolaterad of *st*5. Distance between epigynial and anal shields almost same as length of anal shield. A pair of elongate platelets next to edge of epigynial shield, posterolaterad to *st*5. With two pairs of metapodal platelets, the inner ovoid and the outer bacillate. Opisthogaster with eight pairs of setae on unsclerotised cuticle (*Jv*1–5, *Zv*1, *Zv*2 and *Zv*5), two pair of lyrifissures and a pair of pores. Anterior section of endopodal plate

fused with sternal shield; section behind sternal shield represented to an elongate v-shaped platelet between coxae III–IV. Exopodal plate represented by triangular sections between coxae II–III and III–IV, and an curved fragment partially surrounding external margin of coxa IV, bearing *gv*2. Anal shield small, curvilinear subtriangular, reticulate; 63 (58–70) [62–72] long and 66 (63–75) [68–88] wide, with a pair of marginal pores in about transverse line with para-anal setae, the latter about as long as or slightly shorter than post-anal seta and inserted between mid-length and posterior margin of anal opening; anal opening almost 1/4 as long as shield, 19 (18–23) [21–22] long, located slightly behind shield center. All ventral setae aciculate. Setal measurements shown in Table 5.

Table 5. Length of ventral idiosomal and ventral gnathosomal setae of Colombian specimens of ***Gaeolaelaps brevipellis*** **Karg, 1979**; mean (minimum–maximum). - = seta absent.

Seta	Female (n = 5)	Argentina paratypes and Venezuelan specimens (n = 5)	Deutonymph (n = 2)
*st*1	22 (20–23)	[24–27]	21 (20–23)
*st*2	21 (17–22)	[24–30]	19 (18–20)
*st*3	19 (15–25)	[23–26]	19 (18–20)
*st*4	17 (15–20)	[23–23]	13 (10–15)
*st*5	17 (15–18)	[23–23]	14 (13–15)
*Jv*1	15 (13–18)	[18–20]	12 (12–13)
*Jv*2	18 (15–23)	[20–22]	14 (13–15)
*Jv*3	17 (15–23)	[19–21]	15
*Jv*4	17 (15–18)	[21–22]	16 (13–20)
*Jv*5	24 (23–25)	[24–27]	21 (20–23)
*Zv*1	15 (13–18)	[18–19]	11 (10–13)
*Zv*2	18 (17–20)	[17–20]	15
*Zv*5	16 (12–20)	[18]	17 (17–18)
Para–anal	18 (15–20)	[16–20]	16 (15–18)
post–anal	16 (15–18)	[15–20]	15 (13–18)

Peritreme and peritrematic plate. Peritreme extending anteriorly to level of *s*1. Peritrematic shield fused with dorsal shield near z1; with a pore (*gp*1) between coxae I–II, with a lyrifissure (*ip*2) and a pore (*gp*2) between coxae II–III, and with two lyrifissures (*ip*s and *ip*3) and a pore (*gp*3) posteriad of stigma. Post-stigmatic area of peritrematic plate free, with a distinct suture separating the more sclerotized inner section and the adjacent thin, lightly sclerotized band, about straight and tapering posteriorly, extending slightly beyond posterior margin of coxa IV (Fig. 24).

Spermathecal apparatus (Fig. 25). Laelapid-type. Insemination pore and infundibulum indistinct; tubulus elongate, connected to small globular sacculus by distint ramus, which has a median constriction; sperm duct indistinct.

Legs (Figs. 26–29). Lengths: I: 409 (387–457) [409–432]; II: 341 (325–362) [270–298]; III: 272 (233–300) [235–274]; IV: 391 (375–442) [235–274]. Chaetotaxy (legs I–IV): coxae: $0-\frac{0\,0}{2\,0}-0$, $0-\frac{0\,0}{1\,1}-0$, $0-\frac{0\,0}{1\,1}-0$, $0-\frac{0\,0}{1\,0}-0$; trochanters: $1-\frac{1\,0}{2\,1}-1$, $1-\frac{0\,1}{1\,1}-1$, $1-\frac{1\,0}{1\,1}-1$, $2-\frac{1\,0}{1\,1}-0$; femora: $2-\frac{2\,3}{1\,3}-2$, $2-\frac{3\,2}{1\,2}-1{,}1-\frac{2\,1}{1\,0}-1$, $1-\frac{2\,1}{1\,0}-1$; genua: $2-\frac{3\,3}{2\,1}-2{,}2-\frac{3\,2}{1\,1}-2$, $2-\frac{2\,2}{1\,1}-1$, $2-\frac{2\,3}{1\,0}-1$; tibiae: $2-\frac{3\,3}{2\,1}-2$, $2-\frac{2\,2}{1\,1}-2$, $2-\frac{1\,2}{1\,1}-1$, $2-\frac{1\,3}{1\,1}-2$; tarsal setation: I not counted, 18, 18, 18. All legs with pretarsi containing a pair of strongly scletorized claws; median section of pulvilli of legs I–IV rounded. Leg setae of about uniform length and shape.

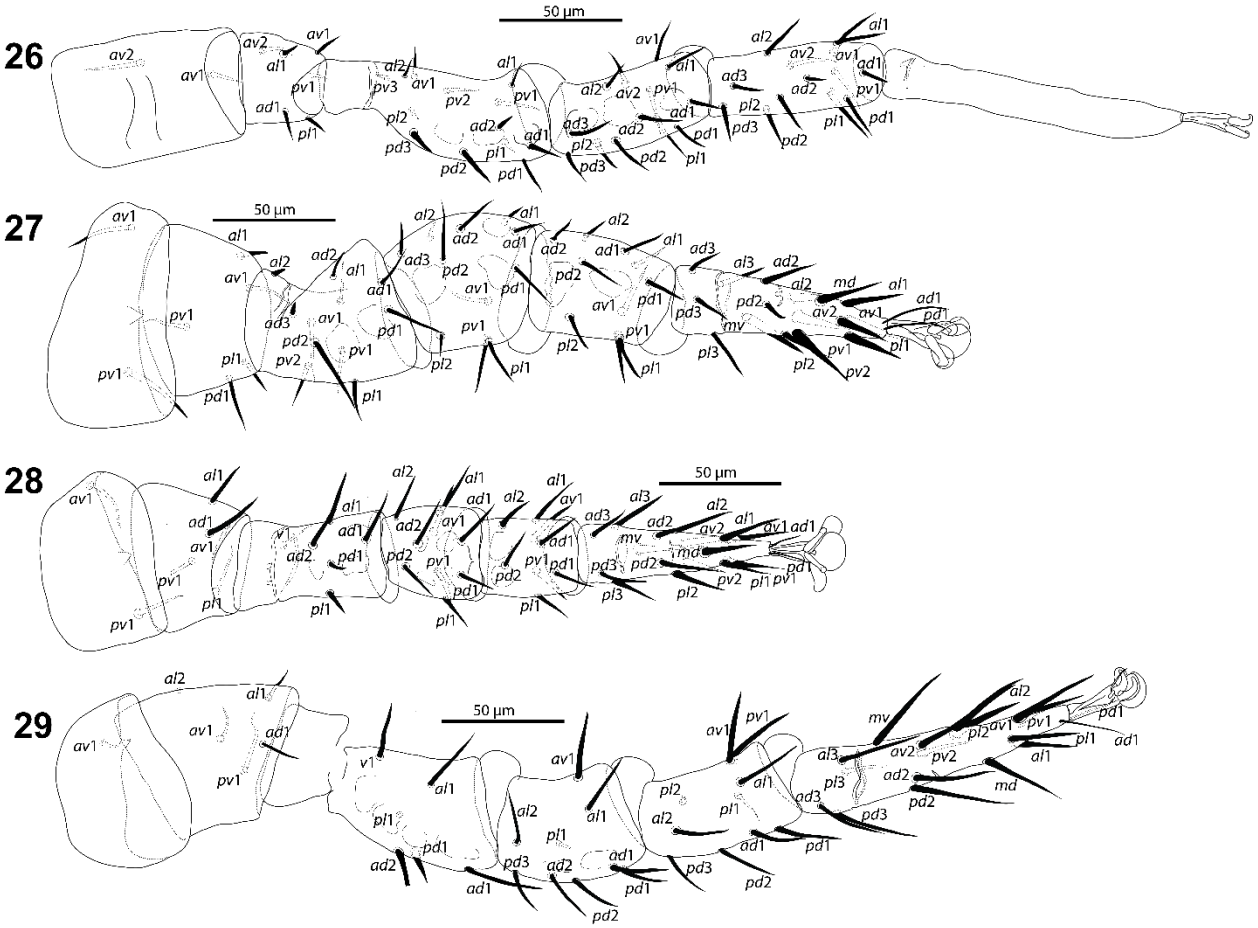


Figure 26–29. *Gaeolaelaps brevipellis* Karg, 1979. Colombian female. 26. Leg I; 27. Leg II; 28. Leg III; 29. Leg IV.

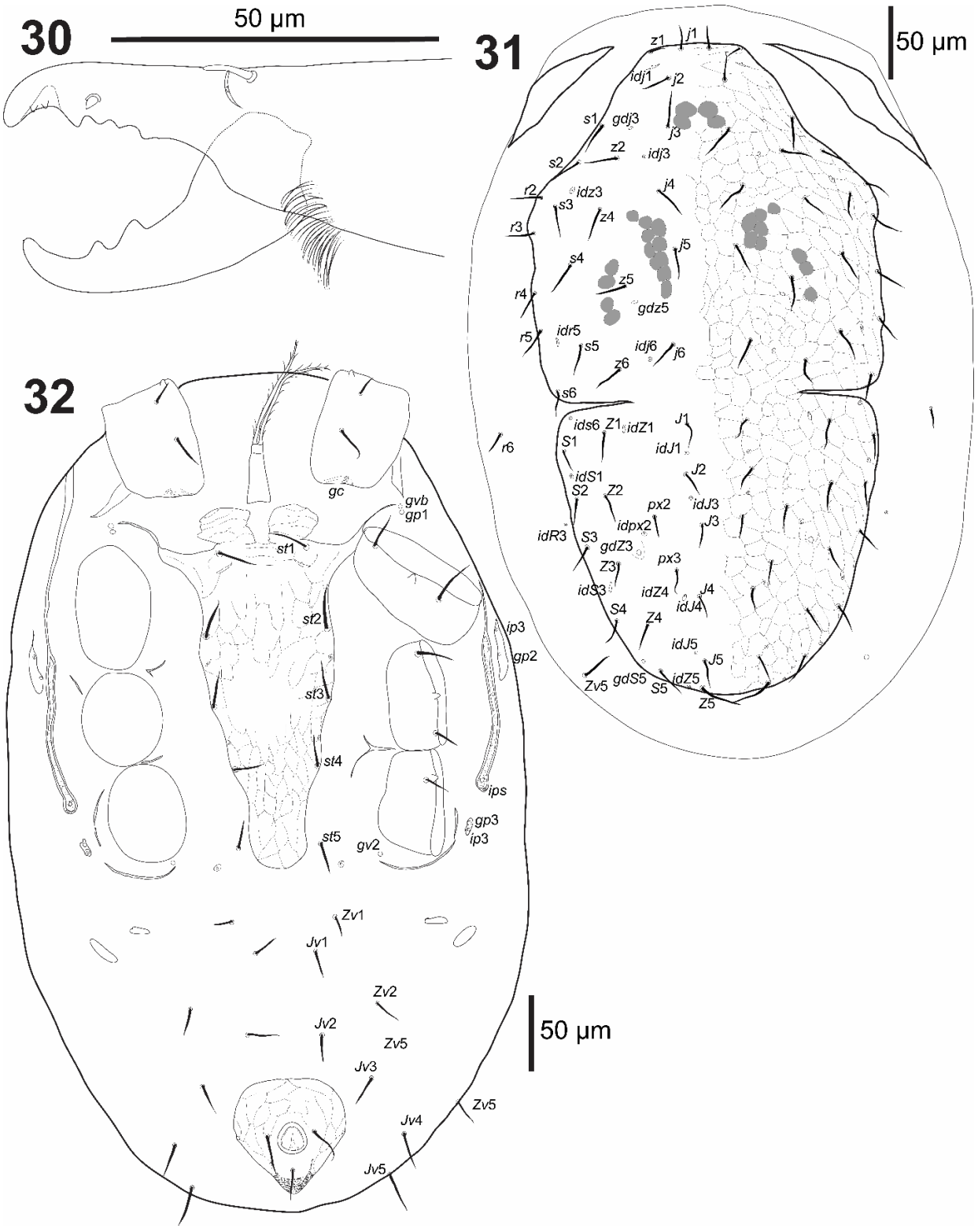
Deutonymph (Figs. 30–32, two specimens measured).

Gnathosoma. Fixed cheliceral digit 51 (50–53) long, with a large offset subapical tooth, followed by two small subapical teeth, a large tooth, two small teeth and another large tooth; with stout *pilus dentilis*; movable digit 48 long, with two large teeth; dorsal seta cylindrical and with rounded tip, dorsal lyrifissure distinct, antiaxial lyrifissure indistinct (Fig. 30). Arthrodial process of chelicera, palp chaetotaxy, apotele, epistome, deutosternum, corniculus and position of hypostomal setae as in adult female. Measurements of setae: *h*1 20 (18–23), *h*2 14 (13–15), *h*3 13, *pc* 15 (13–18); setae aciculate and smooth.

Idiosoma (Figs. 31, 32). Ellipsoidal, 400 (350–450) long and 270 (233–308) wide.

Dorsal idiosoma (Fig. 31). Dorsal shield with straight lateral incisions reaching slightly beyond level of *z*6 (schizodorsal shield), 323 (225–420) long and 231 (175–288) wide, partly covering dorsal surface of idiosoma, ovoid, whitish, reticulate. Podonotal region with 21 pairs of setae (including *r*2–5), six pairs of lyrifissures (*ids*6 posteriad of lateral incision) and two pairs of pores. Opisthonotal region with 17 pairs of setae (including *px*2–3), nine pairs of lyrifissures and a pair of pores. Setae *r*6 and lyrifissure *idR*3 on unsclerotized lateral cuticle. Other features similar to adult female. Setal measurements shown in Table 4.

Ventral idiosoma (Fig. 32). Base of tritosternum 30 long and 13 (10–15) wide proximally; laciniae 60 (58–63), almost totally separated, pilose. Pre-sternal area similar to adult female. Sternal shield lightly sclerotized, reticulate, anterolateral corners extending as a slender strip between coxae I–II; pores *gvb* and *gp*1 on unsclerotized cuticle; 178 (163–193) long and 71 (68–75) wide, with four pairs of setae (*st*1–*st*4) and three pairs of lyrifissures (*iv*1–*iv*3); distances *st*1–3 85 (80–90), *st*2–*st*2 65 (60–70). Seta *st*5 and lyrifissure *iv*5 on unsclerotized cuticle, the latter posterolaterad of *st*5. A pair of bacillate to rounded metapodal platelets. Opisthogaster with seven pairs of setae on unsclerotised cuticle (*Jv*1–5, *Zv*1, *Zv*2, *Zv*5) and a pair of lyrifissures. Anterior section of endopodal plate fused with sternal shield; section behind sternal shield represented by a subtriangular platelet between coxae III–IV. Exopodal plate indistinguishable, except for slender, curved fragments partially surrounding external margin of coxa IV; *gv*2 on unsclerotized cuticle. Anal shield small, curvilinear subtriangular, reticulate; 60 (53–68) long and 61 (55–68) wide, with a pair of marginal pores about in transverse line with para-anal setae, the latter about as long as post-anal seta and inserted between mid-length and posterior margin of anal opening; anal opening almost 1/4 as long as shield, 14 (13–15) long, located slightly behind shield center. All ventral setae aciculate. Setal measurements shown in Table 5.



Figures 30–32. *Gaeolaelaps brevipellis* Karg, 1979. Deutonymph. 30. Chelicera; 31. Dorsal idiosoma; 32. Ventral idiosoma

Peritreme and peritrematic plate. Peritreme short, extending anteriorly to the level between coxae II–III. Peritrematic plate lightly sclerotized, anteriad of peritreme as a narrow

strip widening progressively anteriorly, not fused with dorsal shield; lyrifissure *ip*2 and pore *gp*2 on a separate lightly sclerotized platelet between coxae II–III; lyrifissure *ip*2 at the posterior margin of stigma; post-stigmatic poroid (*gp*3) and lyrifissure (*ip*3) on a separate platelet (Fig. 32).

Legs. Lengths: I: 369 (338–400); II: 281 (250–313); III: 238 (213–263); IV: 344 (313–375). Shape of setae as in adult female.

Remarks. This species was described based on specimens collected in Argentina. The Colombian specimens are similar in size to the paratypes and to the Venezuelan specimens. The only measurements provided for the female in the original description are the length (380–490) and width (219) of the idiosoma, average lengths of dorsal setae (10–12, except *Z*5, 20) and lengths of legs I (360), II (270), III (220) and IV (360).

***Gaeolaelaps queenslandicus* (Womersley)**

Androlaelaps queenslandicus Womersley, 1956: 577

Geolaelaps queenslandicus – Ryke, 1963:13; Walter & Oliver, 1989: 295; Farrier & Hennessey, 1993: 73.

Gaeolaelaps queenslandicus.— Hyatt, 1964: 472; Beaulieu, 2009: 37; Kavianpour et al., 2013: 8; Nemati & Kavianpour, 2013: 71; Kavianpour & Nemati, 2014: 321.

Hypoaspis queenslandicus.— Costa, 1966: 141; Spain & Luxton, 1971: 186

Material measured: four ♀ and four ♂ from soil (pH 5.5 ± 0.1; organic matter 22 ± 1.6%; humidity 28 ± 1.3%; temperature 17.4 ± 0.2°C) at CR collected on January 21 and August 14, 2015; one ♀ from soil (pH 5.7 ± 0.1; organic matter 16.3 ± 1.3%; humidity 31 ± 1.6%; temperature 18.6 ± 0.4°C) at GR, collected on February 19, 2015.

Additional material examined: 64 ♀ (61 in rose crops and 3 in natural vegetation) and 20 ♂ (in rose cultivation) from CR, CV, NR, SV, TR, GR and GV.

Diagnosis: female with anterior region of epistome slightly convex, with margin denticulate; fixed cheliceral digit with a large offset tooth, followed by a small tooth and large tooth at the level of a stout *plus dentilis*, a row of 7–8 small teeth and a large tooth; palp apotele three-tined; deutosternal groove with eight transverse lines, the most distal smooth and others with 17–23 denticles; delimited by lateral deutosternal lines, which converge posteriorly between the fourth and the seventh rows; dorsal shield tapered posteriad of *r*3, exposing a great part of the idiosoma, brownish, reticulate, with 37–38 pairs of setae (including *px*2 in most specimens); pre-sternal area represented by two lobes fused to each

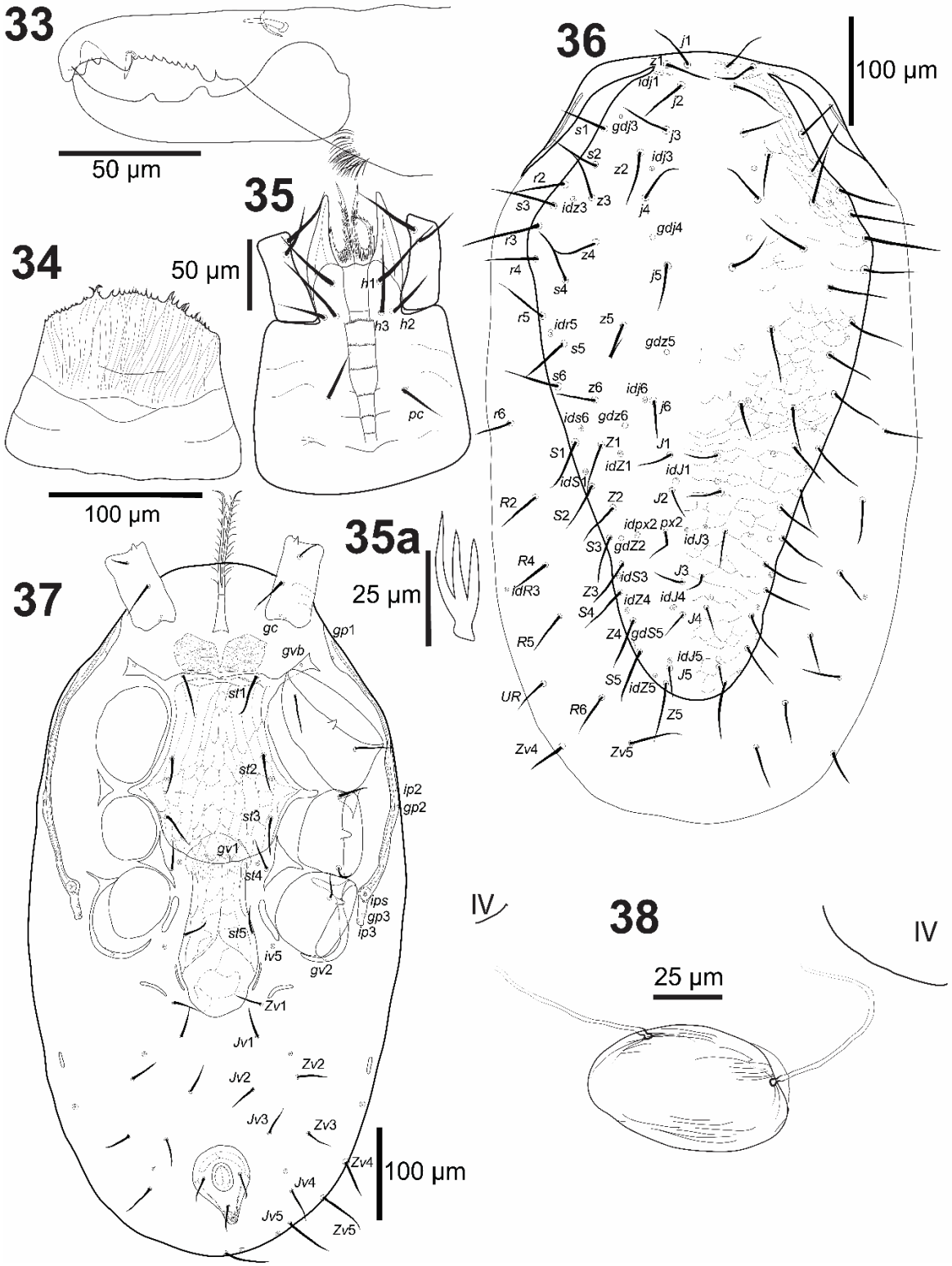
other posteriorly, punctate and with transverse lines; opisthogaster with ten pairs of aciculate setae (*Jv*1–5; *Zv*1–5) on unsclerotised cuticle; two pairs of metapodal platelets; with a pair of elongate platelets next to edge of epigynial shield, which bears only *st*5; tarsus II with distal strong spine-like setae. Male spermadactyl curved upward, of about uniform diameter, extending slightly beyond tip of movable digit; holoventral shield reticulate, anterolateral corners extending between coxae I–II.

Adult female (Figs. 33–42, five specimens measured).

Gnathosoma. Chelicera with arthrodial process shaped as a coronet-like fringe; fixed cheliceral digit 89 (80–93) long, with an offset large tooth, followed by a small tooth and large tooth at the level of a stout *plus dentilis*, a row of 7–8 small teeth and a large tooth; movable digit 82 (73–85) long, with two large teeth; dorsal seta aciculate, dorsal lyrifissure distinct but antiaxial lyrifissure indistinct (Fig. 33). Numbers of setae on palp trochanter–tarsus: 2, 5, 6, 14, 15; palp apotele three-tined (Fig. 35a). Anterior region of epistome slightly convex, with margin denticulate, sometimes with 2 teeth slightly larger than others (Fig. 34); deutosternal groove delimited by the lateral deutosternal lines, which converge posteriorly between the fourth and the seventh rows; with a smooth transverse line at the level of *h*3, followed by seven transverse rows of denticles; the three most anterior with 17–23 denticles and others with 8–12 denticles; with two pairs of smooth, transverse lines external to deutosternum, at the level of first and third most proximal lines of denticles. Internal malae distinctly separated from eah other and ventrally fimbriate, flanked by a pair of curved, fimbriate structures. Corniculi horn-shaped, more than three times as long as their largest width, well separated from each other, subparallel. Hypostomal seta *h*3 about in longitudinal line with *h*1 and mediad and about in transverse line with *h*2. Measurements of setae: *h*1 38 (35–40), *h*2 26 (25–28), *h*3 38 (30–43), *pc* 23 (20–25); setae aciculate and smooth.

Idiosoma (Figs. 36, 37). Ellipsoidal, 627 (583–663) long and 343 (313–368) wide.

Dorsal idiosoma (Fig. 36). Podonotal and opisthonotal shields fused, 532 (500–563) long and 289 (250–313) wide, tapered posteriad of *r*3, exposing a great part of the idiosoma, brownish, reticulate, except for smooth central area of podonotal region, with a slightly constriction laterally between setae *S*3-4 (evident in some specimens). Podonotal region with 22 pairs of setae (including *r*2–5), six pairs of lyrifissures and four pairs of pores. Opisthonotal region with 16 pairs of setae; 9% of the specimens with only 15 pairs (without *J*3; one specimen also missing one *J*4), ten pairs of lyrifissures and a two of pores. All setae aciculate. Setal measurements shown in Table 6.



Figures 33–38. *Gaeolaelaps queenslandicus* (Womersley, 1956). Colombian female. 33. Chelicera; 34. Epistome; 35. Hypostome and proximal palp segments; 36. Dorsal idiosoma; 37. Ventral idiosoma; 38. Spermathecal apparatus.

Ventral idiosoma (Fig. 37). Base of tritosternum 34 (31–37) long and 16 (15–18) wide proximally; laciniae 85 (75–100), separated for about 94% of their total length, pilose.

Pre-sternal area weakly sclerotized, represented by two lobes fused to each other posteriorly, punctate and with transverse lines. Sternal shield reticulate, with posterior margin of shield convex, anterolateral corners extending between coxae I–II, distally bearing pores gvb; 177 (160–188) long and 173 (150–188) wide, with three pairs of setae (st1–3), two pairs of lyrifissures (iv1 and iv2) and a pair of pores near posterior margin (gv1, not distinguishable in most specimens); distances st1–3 129 (113–138), st2–st2 86 (83–88). Fourth pair of sternal setae (st4) and third pair of lyrifissure (iv3) on unsclerotized cuticle. Epigynial shield tongue-shaped, reticulate; anterior hyaline region irregularly convex and slightly overlapping posterior margin of sternal shield; 144 (138–150) long and 75 (63–80) wide; distance st5–st5 69 (63–73); seta st5 inserted on shield margin and lyrifissure iv5 on unsclerotised cuticle, posterolaterad of st5. Distance between epigynial and anal shields about twice length of anal shield. A pair of elongate platelets next to edge of epigynial shield. With two pairs of metapodal platelets, the inner elongate and curved, the outer bacillate.

Table 6. Length of dorsal idiosomal setae of Colombian specimens of ***Gaeolaelaps queenslandicus* (Womersley, 1956)**; mean (minimum–maximum). - = seta absent.

Seta	Female (n = 5)	Male (n = 4)
*j*1	34 (30–38)	27 (25–28)
*j*2	38 (33–40)	36 (30–38)
*j*3	44 (40–45)	36 (30–40)
*j*4	40 (38–43)	38 (35–40)
*j*5	39 (38–40)	32 (30–35)
*j*6	34 (30–38)	32 (28–38)
*J*1	29 (28–33)	28 (25–30)
*J*2	28 (25–30)	26 (25–28)
*J*3	25 (23–28)	27 (25–30)
*J*4	24 (20–28)	25
*J*5	27 (25–30)	21 (20–25)
*J*2–*J*3	73 (63–78)	60 (50–65)
*J*3–*J*4	26 (25–28)	25
*j*2–*j*3	37 (33–40)	24 (18–30)
*z*1	37 (35–38)	38 (35–40)
*z*2	41 (38–43)	38
*z*3	44 (40–50)	38 (38–40)
*z*4	43 (40–45)	39 (38–40)
*z*5	40 (38–43)	37 (30–43)
*z*6	33 (30–38)	34 (33–38)
*Z*1	42 (40–45)	41 (35–45)

Seta	Female (n = 5)	Male (n = 4)
*Z*2	37 (33–43)	42 (38–45)
*Z*3	39 (38–40)	44 (40–50)
*Z*4	42 (40–43)	47 (43–50)
*Z*5	49 (45–50)	53 (50–58)
*s*1	39 (35–43)	33 (30–35)
*s*2	41 (40–43)	38 (38–40)
*s*3	51 (45–58)	44 (40–48)
*s*4	45 (43–50)	43 (38–50)
*s*5	42 (40–45)	43 (40–48)
*s*6	42 (38–45)	44 (43–48)
*S*1	41 (38–45)	38
*S*2	38 (35–40)	39 (38–43)
*S*3	37 (33–40)	40 (38–43)
*S*4	38	41 (38–43)
*S*5	42 (38–45)	49 (45–50)
*px*2	30 (25–38)	28 (25–30)
*r*2	37 (30–40)	37 (35–40)
*r*3	61 (45–70)	54 (50–63)
*r*4	41 (38–43)	43 (38–50)
*r*5	43 (40–45)	45 (40–50)
*r*6	30 (28–30)	20 (18–23)
*R*1	32 (30–35)	21 (20–25)
*R*2	33 (30–38)	25 (23–28)
*R*3	30 (25–33)	25
*R*4	35 (30–38)	25 (23–28)
UR	29 (25–33)	-

Opisthogaster with ten pairs of setae on unsclerotised cuticle (*Jv*1–5, *Zv*1–5) and four pair of lyrifissures. Anterior section of endopodal plate fused with sternal shield; section behind sternal shield represented by a triangular section between coxae III–IV, followed by an elongate section next to coxa IV. Exopodal plate represented by triangular sections between coxae II–III, and another between coxae III–IV, fused to a curved fragment partially surrounding external margin of coxa IV, bearing *gv*2. Anal shield small, inversely pear-shaped, rounded anteriorly, reticulate; 70 (63–75) long and 57 (55–60) wide, with a pair of marginal pores about in transverse line with para-anal setae, the latter about as long as or slightly shorter than post-anal seta and inserted between mid-length and posterior margin of anal opening; anal opening almost 1/3 as long as shield, 25 (20–30) long, located at shield center. All ventral setae aciculate. Setal measurements shown in Table 7.

Table 7. Length of ventral idiosomal and ventral gnathosomal setae of Colombian specimens of ***Gaeolaelaps queenslandicus* (Womersley, 1956)**; mean (minimum–maximum). - = seta absent.

Seta	Female (n = 5)	Male (n = 4)
*st*1	36 (28–40)	30 (25–35)
*st*2	35 (30–38)	30 (28–33)
*st*3	33 (30–35)	29 (28–30)
*st*4	26 (23–30)	23 (20–25)
*st*5	25 (23–25)	21 (20–23)
*Jv*1	27 (25–28)	28 (25–30)
*Jv*2	25 (23–28)	25 (23–28)
*Jv*3	26 (25–28)	24 (23–25)
*Jv*4	26 (25–28)	20 (18–23)
*Jv*5	45 (30–50)	37 (33–43)
*Zv*1	23 (20–25)	20 (18–23)
*Zv*2	28 (25–30)	23 (20–28)
*Zv*3	26 (23–30)	-
*Zv*4	31 (28–38)	-
*Zv*5	42 (38–45)	26 (23–30)
Para–anal	23 (20–25)	17 (15–18)
post–anal	25 (23–28)	19 (18–20)

Peritreme and peritrematic plate. Peritreme extending anteriorly to level slightly beyond *s*1. Peritrematic shield fused with dorsal shield near *z*1; with a pore (*gp*1) between coxae I–II; with a lyrifissure (*ip*2) and a pore (*gp*2) between coxae II–III, and with two lyrifissures (*ip*s and *ip*3) and a pore (*gp*3) posteriad of stigma. Post-stigmatic area of peritrematic plate free, about straight and of uniform width, terminating bluntly near median level of coxa IV (Fig. 37).

Spermathecal apparatus (Fig. 38). Laelapid-type. Insemination pore and infundibulum indistinct; tubulus elongate, connected to small globular sacculus by a barely distinguishable ramus, which has a median constriction; sperm duct indistinct.

Legs (Figs. 39–42). Lengths: I: 559 (513–600); II: 428 (350–475); III: 394 (353–438); IV: 601 (543–663). Chaetotaxy (legs I–IV): coxae: $0-\frac{0\,0}{2\,0}-0$, $0-\frac{0\,0}{1\,1}-0$, $0-\frac{0\,0}{1\,1}-0$, $0-\frac{0\,0}{1\,0}-0$; trochanters: $1-\frac{1\,0}{2\,1}-1$, $1-\frac{0\,1}{1\,1}-1$, $1-\frac{1\,0}{1\,1}-1$, $2-\frac{1\,0}{1\,1}-0$; femora: $2-\frac{2\,3}{1\,3}-2$, $2-\frac{3\,2}{1\,2}-1{,}1-\frac{2\,1}{1\,0}-1$, $1-\frac{2\,1}{1\,0}-1$; genua: $2-\frac{3\,3}{2\,1}-2{,}2-\frac{3\,2}{1\,1}-2$, $2-\frac{2\,2}{1\,1}-1$, $2-\frac{2\,3}{1\,0}-1$; tibiae: $2-\frac{3\,3}{2\,1}-2$, $2-\frac{2\,2}{1\,1}-2$, $2-\frac{1\,2}{1\,1}-1$, $2-\frac{1\,3}{1\,1}-2$; tarsal setation: I not counted, 18,

18, 18. All legs with pretarsi containing a pair of strongly scletorized claws; median section of pulvilli of legs I–IV rounded. Setae *av*1 of femur II and *md*, *pv*2, *al*1, *pl*1, *av*1 of tarsus II distinctly stout and spine-like. Setae *av*1 of genu II, *av*1 and *pv*1 of tibia II, *av*2, and *mv* of tarsus II, most setae of tarsus III (except *al*2, *al*2, *ad*1, *ad*3, *pd*1 and *pd*3), *av*1 of genu IV, *av*1, *pv*1 and *pl*1 of tibia IV, and most setae of tarsus IV (except *ad*1, *ad*3, *pd*1 and *pd*3) thicker than other leg setae.

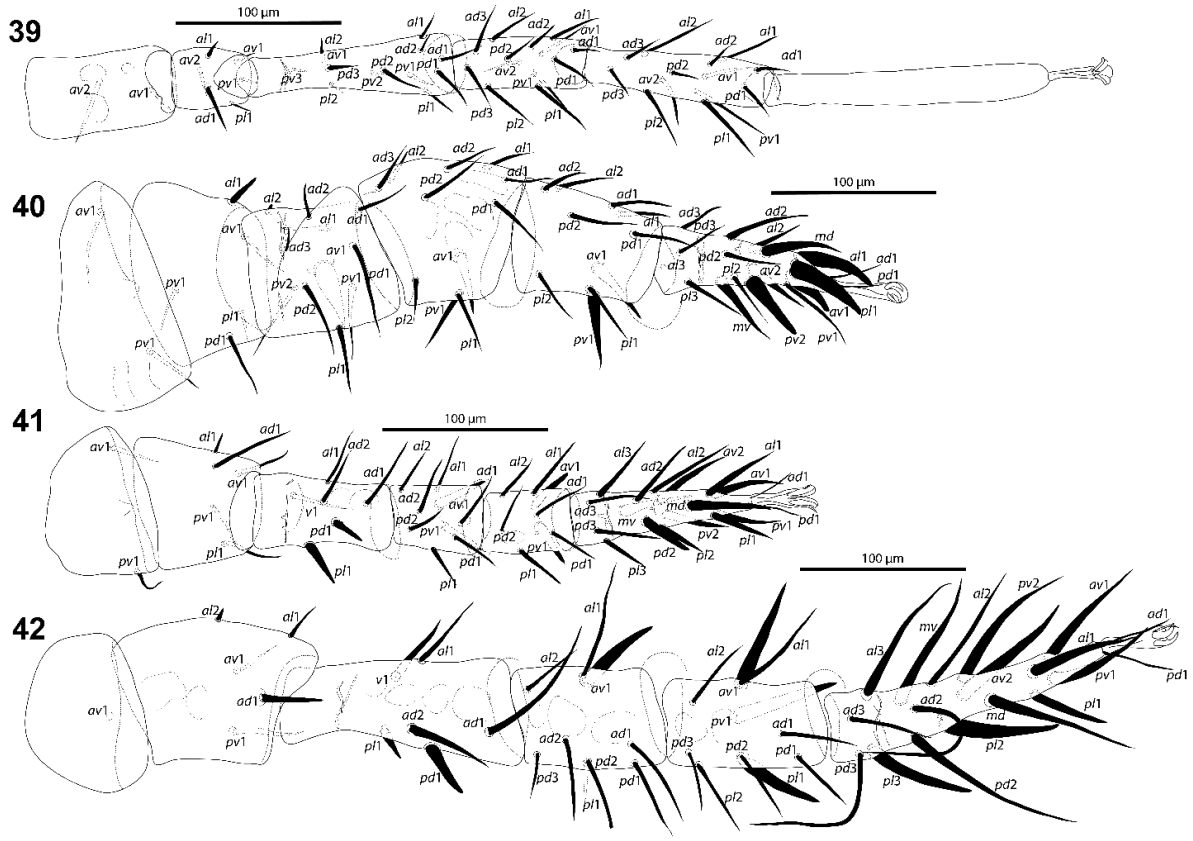


Figure 39–42. *Gaeolaelaps queenslandicus* (Womersley, 1956). Colombian female. 62. Leg I; 63. Leg II; 64. Leg III; 65. Leg IV.

Adult male (Figs. 43–45, four specimens measured).

Gnathosoma. Fixed cheliceral digit 58 (53–63) long, with a large offset subapical tooth followed by three teeth, a stout *pelis dentilis* and another four teeth; movable digit 54 (50–55) long, with one large tooth; spermadactyl 63 (63–65) long, curved upward, of about uniform diameter, extending slightly beyond tip of movable digit; dorsal seta stout and acuminate, dorsal lyrifissure distinct, but antiaxial lyrifissure indistinct because of the position of the chelicerae (Fig. 43). Arthrodial process, palp chaetotaxy, apotele, epistome, deutosternum, corniculus and position of hypostomal setae as in adult female. Measurements of setae: *h*1 25 (20–30), *h*2 16 (15–18), *h*3 30, *pc* 19 (15–23); setae aciculate and smooth.

Idiosoma (Figs. 44, 45). Oval, tapering posteriorly, 454 (450–463) long and 262 (235–275) wide.

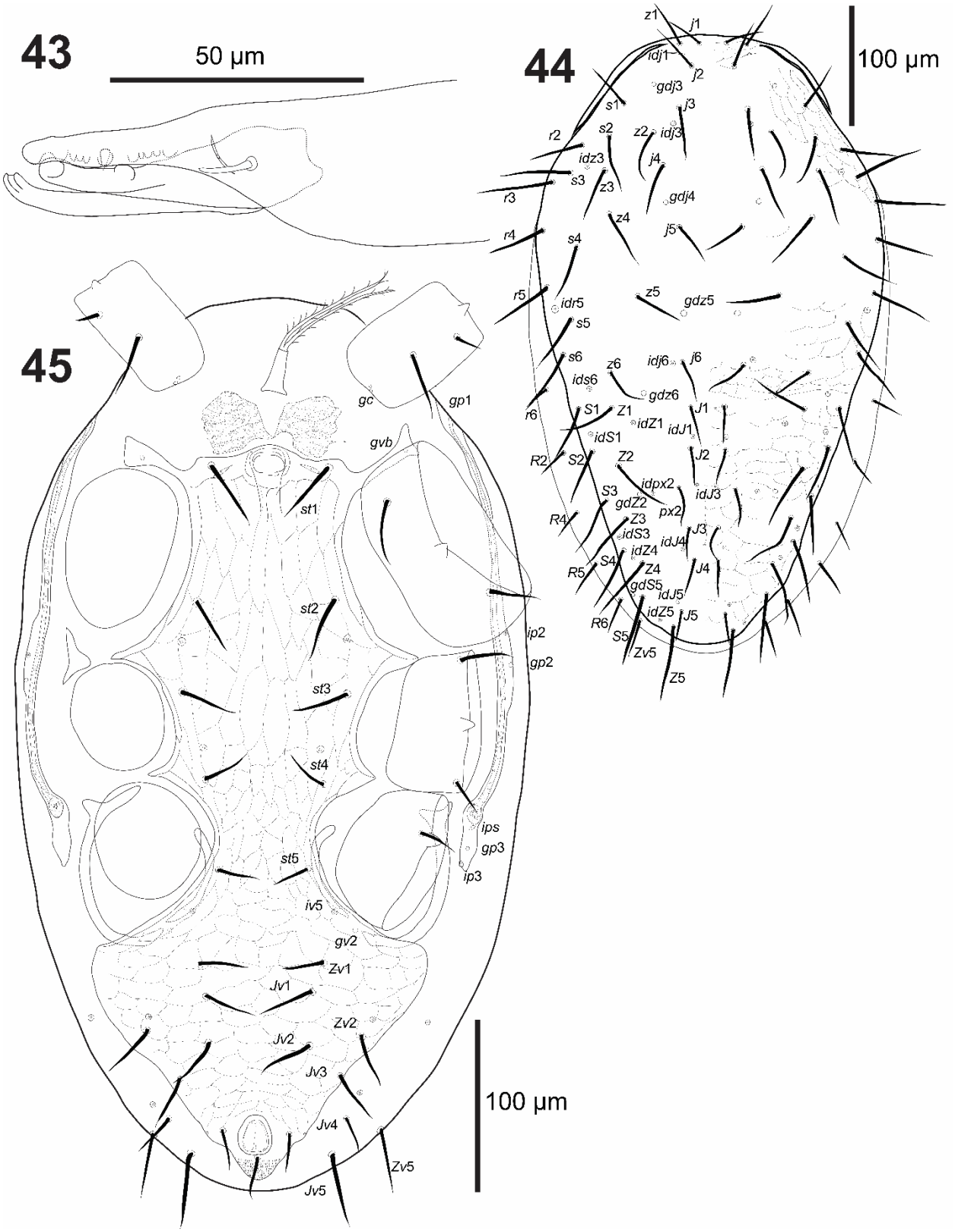
Dorsal idiosoma (Fig. 44). Podonotal and opisthonotal shields fused, 442 (425–450) long and 259 (225–275) wide, tapered posteriad of *r*3, exposing a part of the idiosoma, brownish, reticulate, except for smooth central area of podonotal region. Podonotal and opisthonotal regions with same setae, lyrifissures and pores as adult female. Setae *r*6 and *R*2, *R*4–6 (*UR*1 and *UR*2 absent) on unsclerotized lateral cuticle, not visible dorsally in most specimens. Other features similar to adult female. Setal measurements shown in Table 6.

Ventral idiosoma (Fig. 45). Base of tritosternum 23 (21–25) long and 12 (10–13) wide proximally; laciniae 75 (63–88), almost totally separated from each other, pilose. Presternal area similar to female. Sternogenital and ventrianal shields fused in a holoventral shield, reticulate, anterolateral corners extending between coxae I–II, distally bearing pores *gvb*; 378 (375–388) long and 148 (140–150) wide at the level of coxae IV; with ten pairs of setae (*st1–5*, *Jv*1–3, *Zv*1 and *Zv*2) in addition to circumanal setae, five pairs of distinguishable lyrifissures and a pair of marginal pores about in transverse line with or slightly posteriad of para-anal setae. Unsclerotised cuticle posterolaterad of ventrianal region with three pairs of setae (*Jv*4, *Jv*5 and *Zv*5; *Zv*3 and *Zv*4 absent) and two pairs of distinguishable lyrifissures; *gv*2 on unsclerotized cuticle. Shape of ventral idiosomal setae as in adult female. Setal measurements shown in Table 7.

Peritreme and peritrematic plate. As in adult female.

Legs. Lengths: I: 559 (513–600); II: 428 (350–475); III: 394 (353–438); IV: 601 (543–663). Shape of setae as in adult female.

Remarks. *Gaeolaelaps angustus* (Karg, 1965) and *Gaeolaelaps queenslandicus* (Womersley, 1956) are similar species, described respectively from Germany and Australia, by having eight deutosternal rows delimited by the lateral deutosternal lines, which converge posteriorly between the fourth and the seventh rows; similar size (dorsal shield 610 long and 329 wide in a paratype female of *G. angustus* examined and 585 long and 325 in *G. queenslandicus*, as reported in the original description); dorsal shield tapered posteriad of *r*3, exposing a great part of the idiosoma; strong spine-like setae on femur and tarsus II (the same type of setae also observed on femur–tarsus of legs III–IV of Colombian specimens, but not referred to in the original description or the redescription of Costa (1966) of *G. queenslandicus*). *Gaeolaelaps angustus* and *G. queenslandicus* have dorsal shield with 37 pairs of setae, *J*3 or *J*4 being absent, which is also the case with part of the specimens collected in this work.



Figures 43–45. *Gaeolaelaps queenslandicus* (Womersley, 1956). Colombian male. 43. Chelicera; 44. Dorsal idiosoma; 45. Ventral idiosoma.

However, the opisthogaster of *G. angustus* lacks the pair of metapodal platelets anterolaterad of *Zv*1 (present in the Colombian specimens). In *G. queenslandicus* the dorsal shield has a pronounced constriction at the level of *Z*3, the chelicera is larger (movable digit 110 long) and the fixed cheliceral digit is mentioned to bear about twelve teeth (Costa 1966), but those differences could be related to the slightly larger size of *G. queenslandicus*.

According to Costa (1966), *G. angustus* differs of *G. queenslandicus* by having dorsal shield without pronounced constriction at the level of *Z*3 (laterally between setae *S*3-4), different distribution and relative length of setae, different relative length of hyposthomal setae and different format of deutosternal groove. Nemati & Kavianpour (2013), Kavianpour *et al.* (2013) and Kavianpour & Nemati, 2014 also stated that *G. angustus* differs from *G. queenslandicus* by having legs I shorter than the idiosoma and epistome with a row of equal denticles (instead of epistomal transverse lines each with two denticles longer than others in *G. queenslandicus*). The Colombian specimens have dorsal shield with a slight constriction at the level of *Z*3 (laterally between setae *S*3-4), leg I shorter than idiosoma, anterior margin of epistome usually with denticles larger than others (not in some specimens) and relative lengths of hyposthomal setae similar to the illustration of *G. queenslandicus* by Costa (1966). According to Khalesi & Kazemi (2018), *G. queenslandicus* has a slightly or distincs constriction laterally between setae *S*3-4; anterolateral edges of the sternal shield well-developed between coxae I-II, bearing gland pores *gvb*, and also *gv*1 in posterior region of the shield; and a pair of narrow parapodal plates bearing gland pores *gv*2. Colombian specimens are identified as *G. queenslandicus*; however, some characteristics seem intermediate to what has been reported for *G. angustus* and *G. queenslandicus*, suggesting the synonymization, which depends on the revision of the type material.

***Gymnolaelaps* sp. nov.**

Material measured: three ♀ from soil (pH 5.1 ± 0.3; organic matter 58 ± 9%; humidity 33 ± 7%; temperature 13.6 ± 1.2°C) of a grassland at LG collected on June and August, 2010. Holotype and one paratype deposited at MJHN-PUJ; one paratype ♀ deposited at ESALQ-USP.

Diagnosis: female with anterior region of epistome convex, with margin denticulate; fixed cheliceral digit with an offset large tooth followed by a row of about eight small teeth at the level of a thorne-like *pilus dentilis*, a large tooth and a basel ridge-like structure; palp

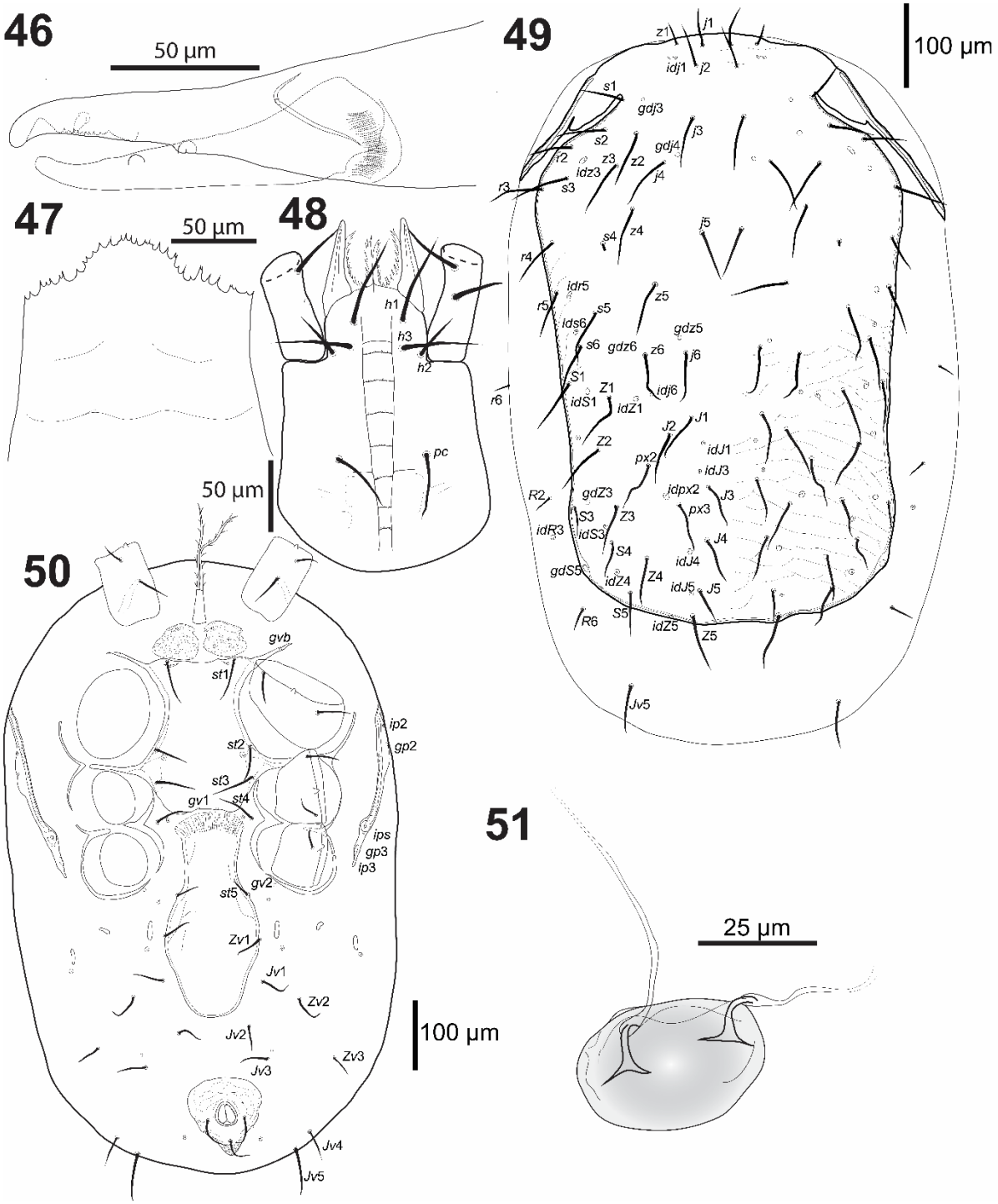
apotele three-tined; deutosternal groove delimited by subparallel lateral lines, with eight transverse lines, the most distal smooth and others with 22-25 denticles; dorsal shield posteriorly truncate, exposing part of the idiosoma, brownish, reticulate, with 38 pairs of setae (including *px*2–3; *S*2 absent); pre-sternal platelets ovoid to irregular, punctate and with transverse lines; setae *st*5 and *Zv*1 inserted at the lateral margin of the epigynial shield, which is not expanded posteriorly to abut anal shield; opisthogaster with six pairs of aciculate setae (*Jv*1–5; *Zv*2–3) on unsclerotised cuticle; two pairs of bacillate metapodal platelets; a pair of bacillate platelets next to epigynial shield; some leg setae disintictly stouter than others.

Adult female (Figs. 46–55, three specimens measured).

Gnathosoma. Chelicera with arthrodial process shaped as a coronet-like fringe; fixed cheliceral digit 119 (117 - 120) long, with a deep axial subapical pocket to receive apex of movable digit, with a large offset subapical tooth, followed by row of about eight small teeth at the level of a thorne-like *pilus dentilis*, a large tooth and a basel ridge-like structure; movable digit 105 (101 - 110), long, with two large teeth; dorsal lyrifissures distinct, dorsal seta and antiaxial lyrifissure indistinct (Fig. 46). Numbers of setae on palp trochanter–tarsus: 2, 5, 6, 14, 15; palp apotele three-tined. Anterior region of epistome irregularly convex, with margin denticulate (Fig. 47); deutosternal groove (Fig. 48) delimited by subparallel lateral lines, with eight transverse lines, the most distal smooth and others with 22-25 denticles; with a pair of smooth, transverse lines external to deutosternum, slightly anteriad of third most proximal line of denticles. Internal malae distinctly separated from each other and ventrally fimbriate, flanked by a pair of curved structures with internal surface and distal end coarsely fimbriate. Corniculi horn-shaped, more than three times as long as their largest width, well separated from each other, subparallel.

Hypostomal seta *h*3 about in longitudinal line with *h*1 and mediad and slightly anteriad of *h*2. Measurements of setae: *h*1 64 (63 - 65), *h*2 35 (34 - 35), *h*3 59 (57 - 60), *pc* 44 (43 - 44); setae aciculate and smooth.

Idiosoma (Figs. 49, 50). Ellipsoidal, 791 (788–795) long and 500 (485–525) wide.



Figures 46–51. *Gymnolaelaps* sp. nov. Colombian female. 46. Chelicera; 47. Epistome; 48. Hypostome and proximal palp segments; 49. Dorsal idiosoma; 50. Ventral idiosoma; 51. Spermathecal apparatus.

Dorsal idiosoma (Fig. 49). Podonotal and opisthonotal shields fused, 658 (640 - 684) long and 395 (390 - 400) wide, truncate posteriorly, exposing part of the idiosoma, brownish. Podonotal region mostly smooth, except for few marginal lines, with 22 pairs of setae (including *r*2–*r*5), four pairs of lyrifissures and four pairs of pores. Opisthonotal region

reticulate, with cells distinctly wider than long, with 16 pairs of setae (including *px*2 and *px*3 between *J* and *Z* series; *S*2 absent), eleven pairs of lyrifissures and a pair of large pores (*gdS*5) at posterior corner. Setae *R*1, *R*3, *R*1 and *R*6 and lyrifissure *idR*3 on unsclerotized lateral cuticle. Setal measurements shown in Table 8. All setae aciculate.

Table 8. Length of dorsal and ventral idiosomal setae of ***Gymnolaelaps* sp. nov.**; mean (minimum–maximum). - = seta absent.

Dorsal setae		**Ventral setae**	
Seta	**Female (n = 3)**	**Seta**	**Female (n = 3)**
*j*1	46 (42 - 49)	*st*1	54 (54 - 55)
*j*2	46 (45 - 48)	*st*2	51 (50 - 53)
*j*3	62 (62 - 63)	*st*3	59 (57 - 61)
*j*4	66 (63 - 70)	*st*4	50 (50 - 51)
*j*5	65 (63 - 67)	*st*5	36 (35 - 37)
*j*6	60 (58 - 60)	*Jv*1	41 (40 - 42)
*J*1	61 (60 - 61)	*Jv*2	42 (41 - 43)
*J*2	59 (55 - 60)	*Jv*3	42 (42 - 43)
*J*3	60 (57 - 63)	*Jv*4	44 (42 - 48)
*J*4	57 (53 - 60)	*Jv*5	56 (53 - 59)
*J*5	43	*Zv*1	43 (40 - 49)
*J*2–*J*3	63	*Zv*2	43 (42 - 45)
*J*3–*J*4	62	*Zv*3	37 (35 - 39)
*j*2–*j*3	54 (50 - 57)	Para–anal	42 (39–47)
*z*1	26 (25 - 27)	post–anal	44 (42–46)
*z*2	60 (60 - 61)		
*z*3	67 (63 - 70)		
*z*4	67 (66 - 67)		
*z*5	65 (64 - 65)		
*z*6	63		
*Z*1	65		
*Z*2	60		
*Z*3	59 (58 - 60)		
*Z*4	63		
*Z*5	62 (60 - 63)		
*s*1	48 (46 - 50)		
*s*2	53 (52 - 54)		
*s*3	70 (69 - 71)		
*s*4	64 (62 - 66)		
*s*5	67 (66 - 68)		
*s*6	62 (57 - 66)		

Dorsal setae		Ventral setae	
Seta	**Female (n = 3)**	**Seta**	**Female (n = 3)**
*S*1	62 (61 - 63)		
*S*3	30		
*S*4	45 (44 - 45)		
*S*5	49 (48 - 50)		
*px*2	60 (59 - 61)		
*px*3	59 (58 - 60)		
*r*2	53 (51 - 54)		
*r*3	61 (60 - 63)		
*r*4	59 (59 - 60)		
*r*5	60 (58 - 61)		
*r*6	19 (18 - 20)		
*R*2	19 (17 - 21)		
*R*6	30 (26 - 31)		

Ventral idiosoma (Fig. 50). Base of tritosternum 47 (45–48) long and 19 (18–20) wide proximally; laciniae 89 (87–94), totally separated, pilose. Pre-sternal area represented by pre-sternal ovoid to irregular platelets, punctate and with transverse lines. Sternal shield mostly smooth, with few lateral lines, with posterior margin slightly concave, anterolateral corners extending between coxae I–II, distally bearing pores *gvb*; 191 (185–202) long and 182 (175–190) wide, with three pairs of setae (*st*1–3) and two pairs of lyrifissures (*iv*1 and *iv*2); distances *st*1–3 159 (153–166), *st*2–*st*2 122 (120–124). Fourth pair of sternal setae (*st*4) and third pair of lyrifissure (*iv*3) on unsclerotized cuticle. Epigynial shield flask-shaped, with a constriction at level of posterior margin of coxa IV, with few irregular and longitudinal lines near lateral margins; anterior hyaline region irregularly convex and almost reaching posterior margin of sternal shield; 251 (244–258) long and 123 (122–123) wide; setae *st*5 and *Zv*1 inserted on the lateral margin of the shield, and lyrifissure *iv*5 on unsclerotised cuticle, posterolaterad of *st*5; distance *st*5–*st*5 87 (85–88), distance *Zv*1–*Zv*1 123 (122–124). Epigynial shield flask-shape, not expanded posteriorly to abut anal shield; distance between epigynial and anal shields almost same as length of anal shield. A pair of bacillate platelets next to epigynial shield. With two pairs of bacillate metapodal platelets. Opisthogaster with six pairs of setae on unsclerotised cuticle (*Jv*1–5, *Zv*2–3), a pair of lyrifissures and a pair of pores. Anterior section of endopodal plate fused with sternal shield; section behind sternal shield represented by an elongate v-shaped platelet between coxae III–IV. Exopodal plate represented by elongate v-shaped platelets between coxae II–III and III–IV, and a curved

fragment partially surrounding external margin of coxa IV, the anterior of of the latter abutting the closer triangular plate; *gv*2 on unclerotized cuticle. Anal shield small, inversely curvilinear subtriangular, reticulate; 101 (98–103) long and 95 (94–96) wide, with a pair of marginal pores about in transverse line with para-anal setae, the latter about as long as or slightly shorter than post-anal seta and inserted between mid-length and posterior margin of anal opening; anal opening almost 1/3 as long as shield, 32 (28–34) long, located at shield center. Setal measurements shown in Table 8. All ventral setae aciculate.

Peritreme and peritrematic plate. Peritreme extending anteriorly to level of *s*1. Peritrematic shield fused with dorsal shield near *s*1, forming a deep incision on antero-lateral margins of dorsal shield, laterad of *s*1; pore *gp*1 indistinct; with a lyrifissure (*ip*2) and a pore (*gp*2) between coxae II–III on a small expansion of the narrow plate, and with two lyrifissures (*ip*s and *ip*3) and a pore (*gp*3) posteriad of stigma. Post-stigmatic area of peritrematic plate free, about straight and tapering posteriorly, reaching median level of coxa IV (Fig. 50).

Spermathecal apparatus (Fig. 51). Laelapid-type. Insemination pore and infundibulum indistinct; tubulus elongate, connected globular sacculus by distinct funnel-shaped ramus; sperm duct indistinct.

Legs (Figs. 52–55). Lengths: I: 787–800; II: 620–658; III: 588–600; IV: 863. Chaetotaxy (legs I–IV): coxae: $0-\frac{0\,0}{2\,0}-0$, $0-\frac{0\,0}{1\,1}-0$, $0-\frac{0\,0}{1\,1}-0$, $0-\frac{0\,0}{1\,0}-0$; trochanters: $1-\frac{1\,0}{2\,1}-1$, $1-\frac{0\,1}{1\,1}-1$, $1-\frac{1\,0}{1\,1}-1$, $2-\frac{1\,0}{1\,1}-0$; femora: $2-\frac{2\,3}{1\,3}-2$, $2-\frac{3\,2}{1\,2}-1$,$1-\frac{2\,1}{1\,0}-1$, $1-\frac{2\,1}{1\,0}-1$; genua: $2-\frac{3\,3}{2\,1}-2$,$2-\frac{3\,2}{1\,1}-2$, $2-\frac{2\,2}{1\,1}-1$, $2-\frac{2\,3}{1\,0}-1$; tibiae: $2-\frac{3\,3}{2\,1}-2$, $2-\frac{2\,2}{1\,1}-2$, $2-\frac{1\,2}{1\,1}-1$, $2-\frac{1\,3}{1\,1}-2$; tarsal setation: I not counted, 18, 18, 18. All legs with pretarsi containing a pair of strongly scletorized claws, smaller in leg I; median section of pulvilli of legs I–IV rounded. Setae *al*1 and *ad*1 of trochanter I, *pd*3 of femur I, *al*1 of trochanter II, *al*2 and *av*1 of femur II, *av*1 of genu II, *pv*1 of tibia II, all ventral setae of tarsus II, *pd*1 of femur III, *av*1 and *pv*1 of genu III, *av*1 and *pv*1 of tibia III, most setae of tarsus III, *ad*1 of trochanter IV, *ad*1 and *ad*2 of femur IV, *av*1 and *pl*1 of genu IV, and *av*1, *pv*1 and *pl*1 of tibia IV thicker and spine-like. Setae of leg IV longer than of other legs.

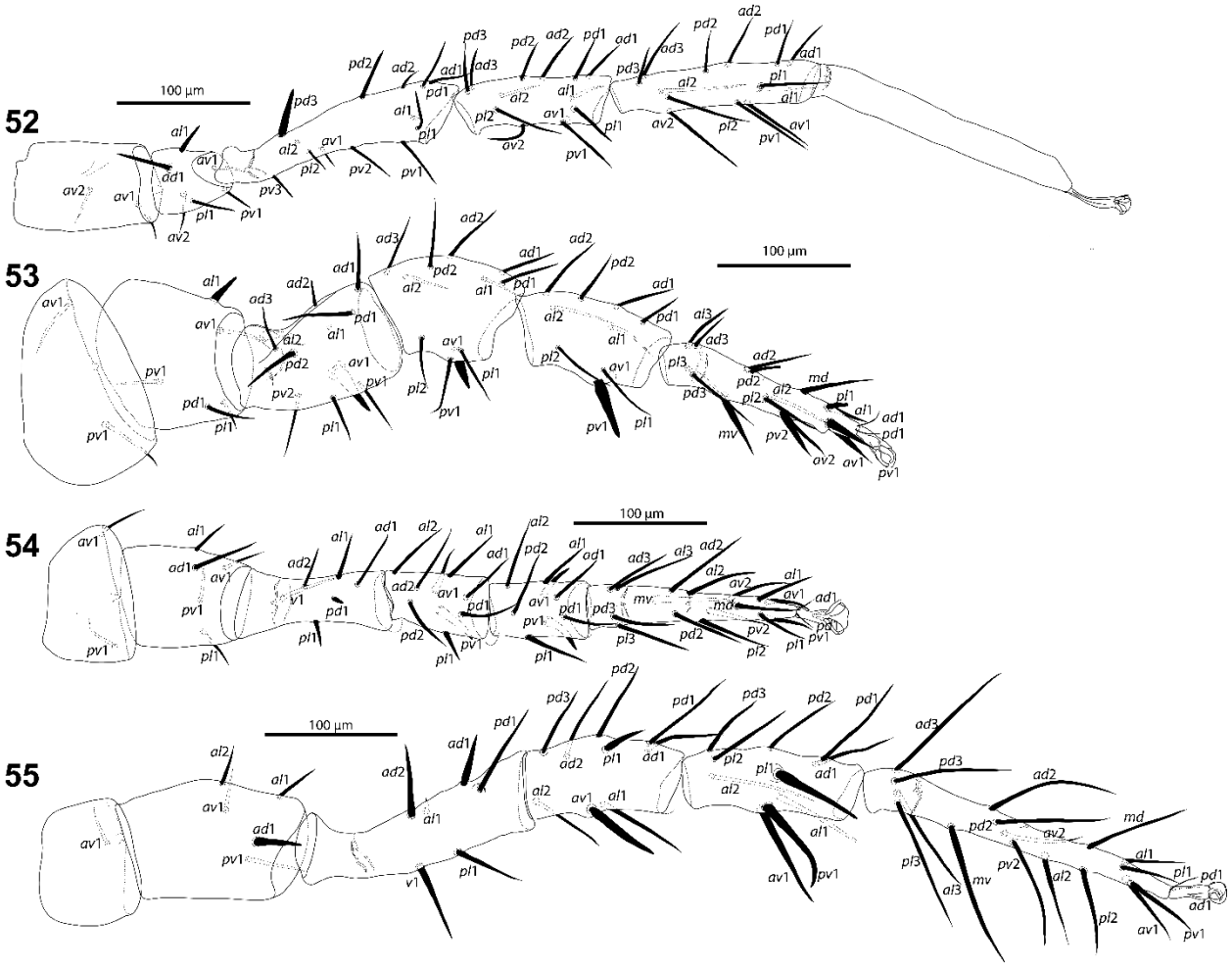


Figure 52–55. *Gymnolaelaps* sp. nov. Colombian female. 52. Leg I; 53. Leg II; 54. Leg III; 55. Leg IV.

Remarks. Some characteristics of this species are typical of *Gymnolaelaps*, namely epigynial shield with a pair (*Zv*1) of setae on the lateral margin in addition of *st*5 and apotele three-tined (also present in some *Gaeolaelaps*). Other characteristics are typical of *Gaeolaelaps*, namely the presence of extra setae (*px*2 and *px*3) between the series of setae *J* and *Z* (also present in some *Gymnolaelaps*, according to Joharchi & Halliday, 2013), epigynial shield not enlarged posteriorly to abut anal shield; anal shield small, peritrematic plate not extending posteriorly beyond coxa IV (also observed in *Gymnolaelaps unospinosus* (Karg, 1978), as discussed by Nemati & Gwiazdowicz (2016) and strong spine-like setae on the ventral side of legs II–IV (Beaulieu 2009; Kazemi *et al.* 2014). The main features that distinguish this new species from other *Gymnolaelaps* species are: dorsal shield truncate posteriorly; presence of a pair of deep incisions in the anterolateral region of the dorsal shield and a pair of large pores (*gdS*5) in the posterolateral corners of the dorsal shield, next to *S*4; absence of *S*2, epigynial shield not expanded posteriorly to abut anal shield (also observed in

Gymnolaelaps shealsi Hunter & Costa 1971, as dicussed by Nemati & Gwiazdowicz 2016) and exopodal plate not exapanded behind coxa IV (also observed in *Gymnolaelaps unospinosus* (Karg, 1978), as discussed by Nemati & Gwiazdowicz 2016). The classification of the new species here described in *Gymnolaelaps* requires de expansion of the concept of the genus given by Joharchi & Halliday (2013), to include species with epigynial shield not expanded posteriorly to abut a small anal shield.

Etymology. The specific name refers to the truncate posterior margin of the dorsal shield.

***Gaeolaelaps* sp. nov.**

Material measured: two ♀ and one deutonymph from soil (pH 5.5 ± 0.1; organic matter 22 ± 1.6%; humidity 28 ± 1.3%; temperature 17.4 ± 0.2°C) at CR, collected on January 21 and August 14, 2015; one ♀ from soil (pH 5.8 ± 0.1; organic matter 35 ± 4.3%; humidity 34 ± 3.5%; temperature 16.2 ± 0.2°C) at GV, collected on February 19, 2015; one ♀ and one deutonymph from soil (pH 5.4 ± 0.1; organic matter 18 ± 1.8%; humidity 27 ± 1.1%; temperature 17. ± 0.3°C) at TR, collected on January 28, 2015; one ♀ and one deutonymph from soil (pH 5.0 ± 0.1; organic matter 31 ± 2.2%; humidity 44 ± 1.0%; temperature 18.8 ± 0.2°C) at NR, collected on August 13, 2015; one ♂ and three protonymphs from soil (pH 5.6 ± 0.2; organic matter 31 ± 2.2%; humidity 47 ± 8.2%; temperature 15.6 ± 0.1°C) at CV, collected on August 14, 2015; three ♂ and two deutonymphs from soil (pH 5.6 ± 0.1; organic matter 23 ± 1.9%; humidity 31 ± 3.0%; temperature 16.4 ± 0.2°C) at FV, collected on August 25, 2016. Holotype ♀, two paratype ♀, two paratype ♂, three paratype deutonymphs and two paratype protonymphs deposited at MJHN-PUJ; two paratype ♀, two paratype ♂, two paratype deutonymphs and one paratype protonymph deposited at ESALQ-USP.

Additional material examined: 597 ♀ (312 in rose crops and 285 in natrual vegetation), 300 ♂ (167 in rose crops and 133 in natrual vegetation), 101 deutonymphs (40 in rose crops and 61 in natrual vegetation) and four protonymphs (three in rose crops and one in natrual vegetation), in samples from CR, CV, FV, NR, FR, TR, GR and GV.

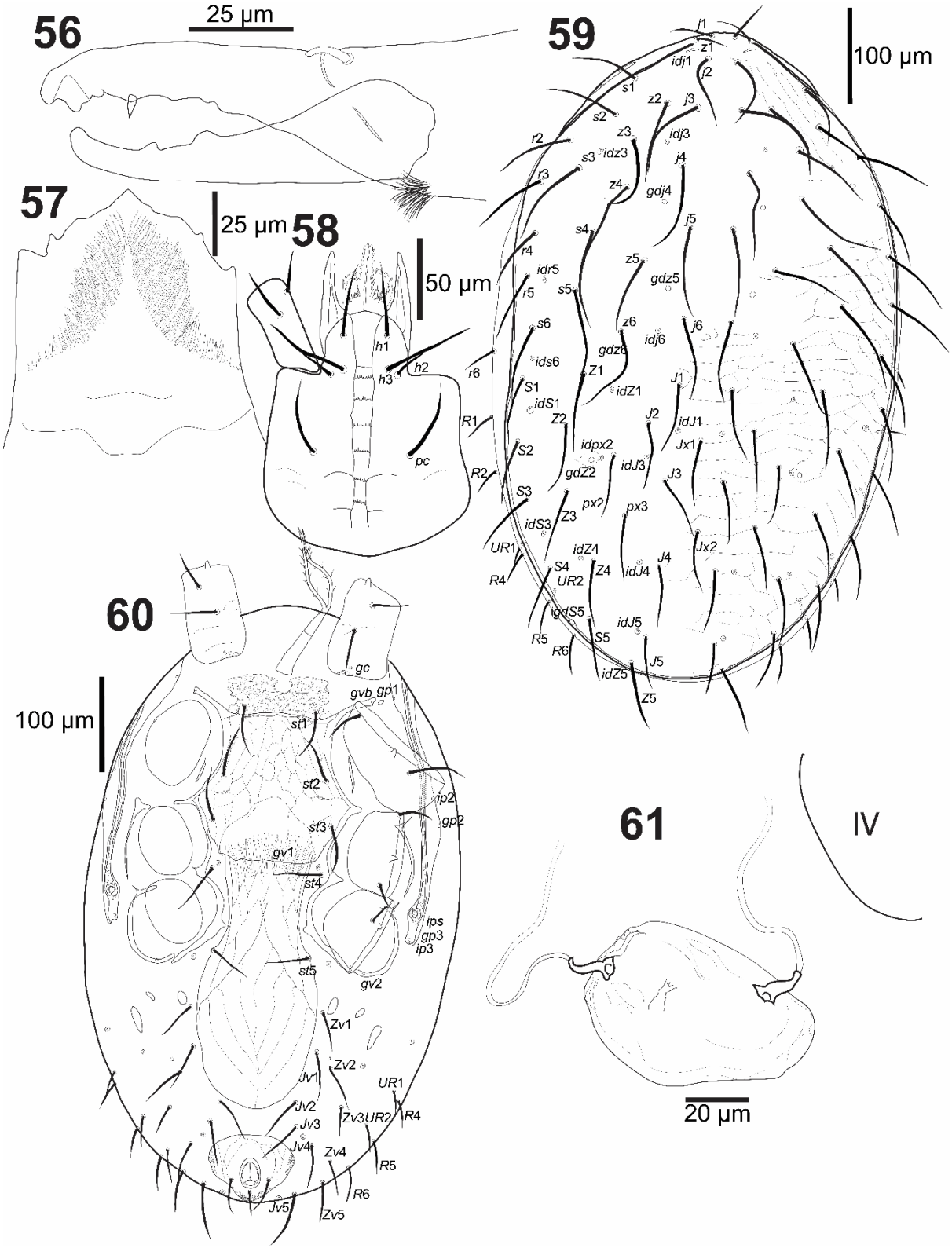
Diagnosis: female with epistome lightly sclerotized, acuminate, with distinct radial ornamentation; margin mostly smooth, usually with 1–2 pairs of short, triangular projections; fixed cheliceral digit with a large offset tooth followed by a row of four teeth, setiform *pilus dentilis* and a basel ridge-like structure; movable digit with two large teeth; deutosternal

groove delimited by subparallel lateral lines, with seven transverse lines, the most distal smooth and others with 6-10 denticles; dorsal shield almost completely covering dorsal surface of idiosoma, ellipsoidal, brownish, reticulate, except for smooth central area of podonotal region, with 39 pairs of setae (including *px*2–3); pre-sternal area weakly sclerotized, represented by a pair of irregular lobes fused posteriorly and abutting sternal shield, with *st*1; epigynial shield enlarged porteriorly, so that it is separated from anal shield by less than half length of anal shield; opisthogaster with ten pairs of aciculate setae (*Jv*1–*Jv*5 and *Zv*1–*Zv*5) on unsclerotised cuticle; two pairs of metapodal platelets; a pair of platelets next to edge of epigynial shield, which bears only *st*5. Male spermadactyl curved upward and extending slightly beyond tip of movable digit, of about uniform diameter; holoventral shield reticulate, anterolateral corners extending between coxae I–II.

Deutonymph dorsal shield with straight lateral incisions reaching well beyond bases of *z*6 (schizodorsal shield); sternal shield lightly sclerotized, smooth except for light reticulation laterad of *st*1 and posteriad of *st*4, tapering posteriad of *st*3. Unsclerotized cuticle between podonotal and opisthonotal shields of protonymph with three pairs of lightly sclerotized and rounded-irregular platelets, the anterior adjacent to a lightly sclerotized oval element; sternal shield lightly sclerotized, smooth.

Adult female (Figs. 56–61, five specimens measured).

Gnathosoma. Chelicera with arthrodial process shaped as a coronet-like fringe; fixed cheliceral digit 79 (75–85), with a deep axial subapical pocket to receive apex of movable digit, with a large offset tooth followed by a row of four teeth, setiform *pilus dentilis* and a basel ridge-like structure; movable digit 72 (68–78) long, with two large teeth; dorsal setae cylindrical, with rounded tip; dorsal and antiaxial lyrifissures distinct (Fig. 56). Numbers of setae on palp trochanter–tarsus: 2, 5, 6, 14, 15; palp apotele bifurcate. Anterior region of epistome lightly sclerotized, acuminate, with distinct radial ornamentation; margin mostly smooth, usually with 1–2 pairs of short, triangular projections (Fig. 57); deutosternal groove delimited by subparallel lateral lines (Fig. 58), with seven transverse lines, the most distal smooth and others with 6-10 denticles; with two pairs of smooth, transverse and curved lines external to deutosternum, at the level or posteriad of second most proximal line of denticles. Internal malae distinctly separated from each other and ventrally fimbriate, flanked by a pair of curved structures, fimbriate. Corniculi horn-shaped, more than twice as long as their largest width, well separated from each other, subparallel. Hypostomal seta *h*3 about in longitudinal line with *h*1 and mediad and slightly anteriorad of *h*2. Measurements of setae: *h*1 39 (38–43), *h*2 25 (23–28), *h*3 52 (48–60), *pc* 43 (38–50); setae aciculate and smooth.



Figures 56–61. *Gaeolaelaps* sp. nov. Colombian female. 38. Chelicera; 39. Epistome; 40. Hypostome and proximal palp segments; 41. Dorsal idiosoma; 42. Ventral idiosoma; 43. Spermathecal apparatus.

Idiosoma (Figs. 59, 60). Ellipsoidal, 633 (600–700) long and 401 (350–500) wide.

Dorsal idiosoma (Fig. 59). Podonotal and opisthonotal shields fused, 622 (595–663) long and 622 (595–663) wide, almost completely covering dorsal surface of idiosoma, ellipsoidal, brownish, reticulate, except for smooth central area of podonotal region. Podonotal region with 22 pairs of setae (including *r*2–5), six pairs of lyrifissures and two pairs of pores. Opisthonotal region with 17 pairs of setae (including *px*2 and *px*3 between *J* and *Z* series), two unpaired median setae *Jx* anteromediad of *J*3 and of *J*4, ten pairs of lyrifissures and two pairs of pores. Setae *r*6, *R*1, *R*2, *R*4–*R*6, *UR*1 and *UR*2 on unsclerotized lateral cuticle; lyrifissure *idR*3 indistinguishable. All setae aciculate. Setal measurements shown in Table 9.

Table 9. Length of dorsal idiosomal setae of Colombian specimens of ***Gaeolaelaps* sp. nov.**; mean (minimum–maximum). - = seta absent.

Seta	Female (n = 5)	Male (n = 5)	Deutonymph (n = 5)	Protonymph (n = 3)
*j*1	36 (33–40)	30 (23–35)	30 (25–33)	28 (23–33)
*j*2	65 (63–68)	47 (28–55)	47 (40–50)	35 (30–38)
*j*3	73 (68–75)	64 (50–75)	55 (50–63)	50 (45–53)
*j*4	76 (75–78)	65 (58–75)	57 (48–63)	52 (50–55)
*j*5	75 (70–80)	62 (53–78)	51 (43–58)	43 (38–48)
*j*6	74 (73–75)	60 (50–68)	52 (48–58)	38
*J*1	65 (55–70)	51 (45–55)	33 (30–35)	25 (23–28)
*J*2	49 (48–50)	44 (33–50)	31 (28–35)	23 (20–25)
*J*3	51 (50–53)	43 (38–50)	26 (20–30)	25 (20–30)
*J*4	55 (50–63)	43 (38–45)	25 (20–28)	24 (23–25)
*J*5	49 (45–53)	38 (33–43)	22 (18–28)	13 (13–15)
*Jx*1	57 (53–63)	43 (38–50)	30 (25–35)	-
*Jx*2	49 (45–50)	46 (43–50)	30 (25–33)	-
*J*2–*J*3	93 (88–100)	44 (38–50)	29 (25–33)	19 (13–25)
*J*3–*J*4	82 (75–88)	70 (58–75)	40 (38–43)	34 (30–40)
*j*2–*j*3	41 (38–45)	36 (28–40)	29 (25–33)	22 (15–25)
*z*1	23 (20–25)	30 (25–43)	18 (13–23)	-
*z*2	71 (63–75)	52 (38–63)	53 (50–60)	54 (50–58)
*z*3	68 (63–78)	46 (15–63)	49 (43–55)	-
*z*4	71 (68–75)	66 (53–80)	61 (53–63)	53 (50–60)
*z*5	72 (63–75)	64 (58–68)	50	48 (45–50)
*z*6	69 (65–73)	58 (53–63)	46 (40–50)	-
*Z*1	66 (60–75)	54 (45–63)	45 (43–50)	37 (35–38)
*Z*2	53 (50–58)	47 (40–58)	36 (30–40)	28 (25–30)
*Z*3	51 (48–55)	50 (43–55)	30 (28–33)	24 (20–28)
*Z*4	59 (53–65)	46 (43–50)	28 (25–33)	23 (23–25)

Seta	Female (n = 5)	Male (n = 5)	Deutonymph (n = 5)	Protonymph (n = 3)
*Z*5	64 (60–70)	49 (43–55)	49 (43–55)	42 (38–45)
*s*1	48 (38–58)	49 (45–55)	39 (38–40)	-
*s*2	61 (50–73)	62 (50–75)	48 (45–50)	-
*s*3	78 (75–83)	56 (40–70)	57 (53–63)	-
*s*4	77 (75–83)	59 (50–68)	68 (63–75)	58 (50–63)
*s*5	68 (63–80)	65 (50–75)	54 (50–63)	44 (43–45)
*s*6	55 (50–68)	58 (48–63)	42 (40–45)	36 (30–40)
*S*1	53 (43–63)	47 (38–60)	37 (33–38)	-
*S*2	50 (45–55)	47 (38–50)	39 (38–43)	32 (28–38)
*S*3	56 (50–63)	48 (43–53)	35 (30–38)	28 (20–35)
*S*4	58 (50–63)	47 (45–50)	33 (28–38)	23 (23–25)
*S*5	58 (55–63)	46 (38–53)	36 (30–38)	32 (30–33)
*px*2	54 (50–58)	43 (40–50)	29 (25–38)	-
*px*3	47 (40–53)	44 (38–48)	24 (20–25)	-
*r*2	58 (50–63)	53 (33–68)	51 (45–58)	48 (43–53)
*r*3	64 (55–75)	49 (38–55)	51 (45–58)	44 (43–45)
*r*4	62 (60–63)	60 (55–63)	42 (38–48)	-
*r*5	65 (60–68)	55 (43–63)	45 (43–50)	39 (38–43)
*r*6	28 (25–33)	27 (20–33)	24 (23–25)	-
*R*1	31 (25–38)	25 (23–25)	21 (18–25)	19 (18–20)
*R*2	30 (25–38)	21 (20–23)	22 (18–30)	-
*R*4	35 (30–40)	30 (25–38)	19 (15–20)	-
*R*5	37 (30–45)	22 (18–25)	18 (13–23)	-
*R*6	42 (38–50)	26 (20–33)	22 (20–25)	-
*UR*1	20 (15–25)	-	-	-
*UR*2	25 (20–30)	-	-	-

Ventral idiosoma (Fig. 60). Base of tritosternum 52 (50–55) long and 14 (13–18) wide proximally; laciniae 140 (139–142), separated for about 72% of their total length, pilose. Pre-sternal area weakly sclerotized, represented by a pair of irregular lobes fused posteriorly and abutting sternal shield, punctate and striate, with *st*1. Sternal shield reticulate, with posterior margin straight, anterolateral corners extending between coxae I–II and distally bearing pores *gvb*; 150 (143–158) long and 166 (145–183) wide, with two pairs of setae (*st*2–3), two pairs of lyrifissures (*iv*1 and *iv*2) and a pair of pores near posterior margin (*gv*1); distances *st*1–3 119 (113–125), *st*2–*st*2 105 (100–113). Fourth pair of sternal setae (*st*4) and third pair of lyrifissure (*iv*3) on unsclerotized cuticle. Epigynial shield tongue-shaped, posteriorly expanded, reticulate; anterior hyaline region irregularly convex and slightly overlapping posterior margin of sternal shield; 252 (235–275) long and 122 (113–133) wide;

distance *st*5–*st*5 102 (95–113); seta *st*5 inserted on shield margin and lyrifissure *iv*5 on unsclerotised cuticle posterolaterad of *st*5. Distance between epigynial and anal shields less than half length of anal shield. A pair of of oval platelets next to edge of epigynial shield. With two pairs of metapodal platelets, the inner oval to bacillate, the outer larger, oval to ellipsoidal. Opisthogaster with ten pairs of setae on unsclerotised cuticle (*Jv*1–5 and *Zv*1–5) and five pair of lyrifissures. Anterior section of endopodal plate fused with sternal shield; section behind sternal shield represented by an elongate v-shaped platelet between coxae III–IV, extended slightly behind coxa IV and sometimes fused with posterolateral corners of sterna shield. Exopodal plate represented by an elongate fragment laterad of coxa III and a curved fragment laterad of coxa IV, which bears *gv*2. Anal shield inversely curvilinear subtriangular, reticulate and with a pair of granulate marginal region, which contains a pair of pores anterolaterad of para-anal setae; 71 (63–88) long and 89 (83–100) wide; para-anal setae longer than post-anal seta and inserted between mid-length and posterior margin of anal opening; anal opening almost 1/3 as long as shield, 27 (25–33), slightly behind shield center. All ventral setae aciculate. Setal measurements shown in Table 10.

Table 10. Length of ventral idiosomal setae of Colombian specimens of ***Gaeolaelaps* sp. nov.**; mean (minimum–maximum). - = seta absent.

Seta	Female (n = 5)	Male (n = 5)	Deutonymph (n = 5)	Protonymph (n = 3)
*st*1	51 (45–55)	38 (35–40)	38 (35–40)	35 (33–38)
*st*2	53 (50–55)	43 (38–45)	45 (43–48)	38 (38–40)
*st*3	56 (43–60)	42 (40–45)	40 (38–43)	27 (20–30)
*st*4	51 (48–55)	37 (35–38)	29 (25–33)	-
*st*5	43 (38–50)	30 (28–33)	23 (20–25)	11 (10–13)
*Jv*1	46 (45–50)	37 (35–38)	29 (28–30)	27 (23–30)
*Jv*2	47 (40–50)	39 (33–43)	26 (25–28)	25
*Jv*3	43 (40–45)	38 (35–43)	28 (25–33)	-
*Jv*4	39 (33–45)	-	23 (20–25)	27 (25–30)
*Jv*5	54 (50–60)	46 (40–50)	43 (40–48)	-
*Zv*1	38 (38–40)	34 (28–40)	23 (20–25)	-
*Zv*2	43 (38–50)	33 (28–38)	24 (23–25)	18 (15–23)
*Zv*3	29 (25–30)	-	20 (18–23)	-
*Zv*4	36 (33–38)	-	23 (20–25)	-
*Zv*5	38	-	-	-
Para–anal	36 (33–38)	29 (28–33)	27 (25–30)	23 (20–25)
post–anal	23 (23–23)	16 (13–18)	14 (13–18)	14 (10–18)

Peritreme and peritrematic plate. Peritreme extending anteriorly to level slightly beyond *s*1. Peritrematic shield fused with dorsal shield near *z*1; with a pore (*gp*1) between

coxae I–II, with a lyrifissure (*ip*2) and a pore (*gp*2) between coxae II–III, and with two lyrifissures (*ip*s and *ip*3) and a pore (*gp*3) posteriad of stigma. Post-stigmatic area of peritrematic plate free, with a distinct suture separating the more sclerotized inner section and the adjacent thin, lightly sclerotized band, about straight and of about uniform width, ending bluntly, reaching only median level of coxa IV (Fig. 60).

Spermathecal apparatus (Fig. 61). Laelapid-type. Insemination pore and infundibulum indistinct; tubulus elongate, connected to globular sacculus by a truncate cone-shaped ramus; small sperm duct barely distinguishable.

Legs (Figs. 62–65). Lengths: I: 635 (600–690); II: 502 (475–550); III: 460 (425–513); IV: 731 (700–788). Setation (legs I–IV): coxae: $0-\frac{0\,0}{2\,0}-0$, $0-\frac{0\,0}{1\,1}-0$, $0-\frac{0\,0}{1\,1}-0$, $0-\frac{0\,0}{1\,0}-0$; trochanters: $1-\frac{1\,0}{2\,1}-1$, $1-\frac{0\,1}{1\,1}-1$, $1-\frac{1\,0}{1\,1}-1$, $2-\frac{1\,0}{1\,1}-0$; femora: $2-\frac{2\,3}{1\,3}-2$, $2-\frac{3\,2}{1\,2}-1$,$1-\frac{2\,1}{1\,0}-1$, $1-\frac{2\,1}{1\,0}-1$; genua: $2-\frac{3\,3}{2\,1}-2$,$2-\frac{3\,2}{1\,1}-2$, $2-\frac{2\,2}{1\,1}-1$, $2-\frac{2\,3}{1\,0}-1$; tibiae: $2-\frac{3\,3}{2\,1}-2$, $2-\frac{2\,2}{1\,1}-2$, $2-\frac{1\,2}{1\,1}-1$, $2-\frac{1\,3}{1\,1}-2$; tarsal setation: I not counted, 18, 18, 18. All legs with pretarsi containing a pair of strongly scletorized claws, smaller in leg I; median section of pulvilli of legs I–IV rounded. Setae of leg IV, especially tarsal setae, longer than setae of other legs.

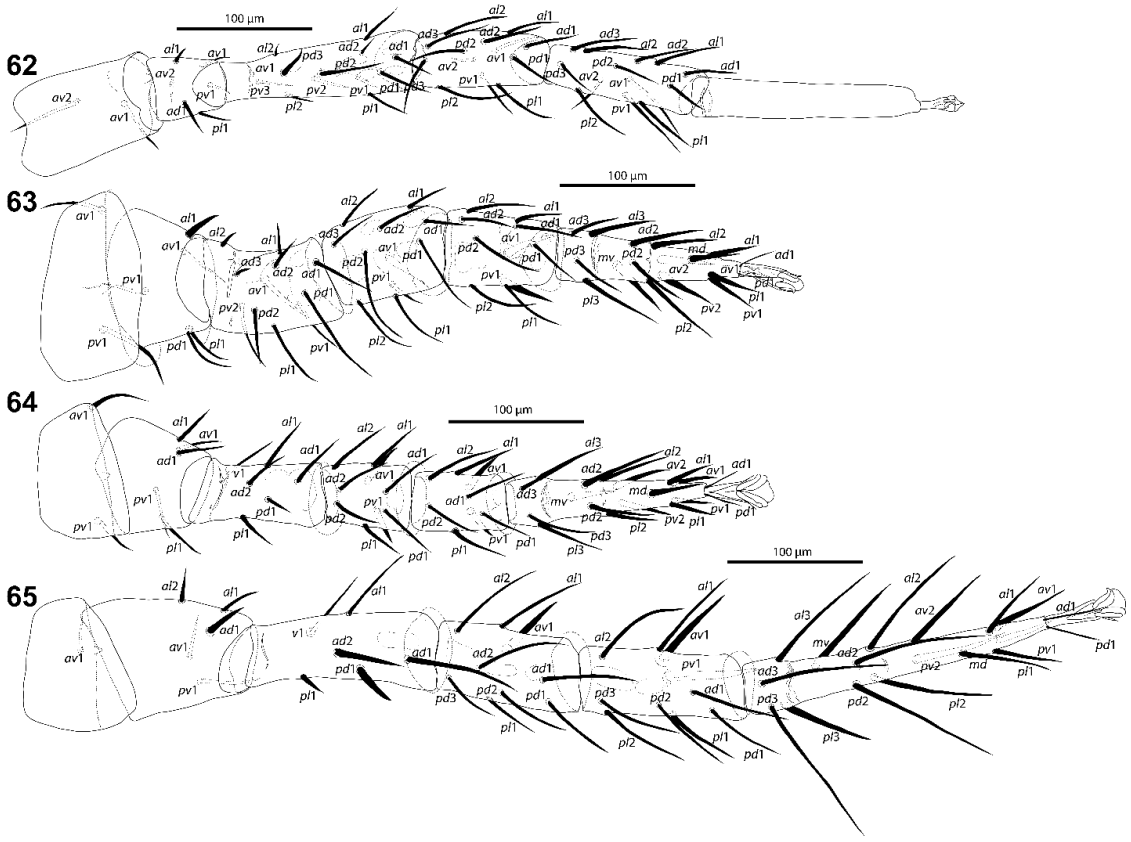


Figure 62–65. *Gaeolaelaps* sp. nov. Colombian female. 62. Leg I; 63. Leg II; 64. Leg III; 65. Leg IV.

Adult male (Figs. 66–68, five specimens measured).

Gnathosoma. Fixed cheliceral digit 50 (48–53) long, with a large offset subapical tooth and thorn-like *pilus dentilis*; movable digit 54 (53–55) long, with one large tooth; spermadactyl 58 (55–60) long, curved upward, about as long as movable digit, of about uniform diameter; dorsal seta aciculate and stout, dorsal and antiaxial lyrifissures distinct (Fig. 66). Arthrodial process of chelicera, palp chaetotaxy, apotele, epistome, deutosternum, corniculus and position of hypostomal setae as in adult female. Measurements of setae: *h*1 31 (25–38), *h*2 22 (18–28), *h*3 36 (30–40), *pc* 35 (33–40); setae aciculate and smooth.

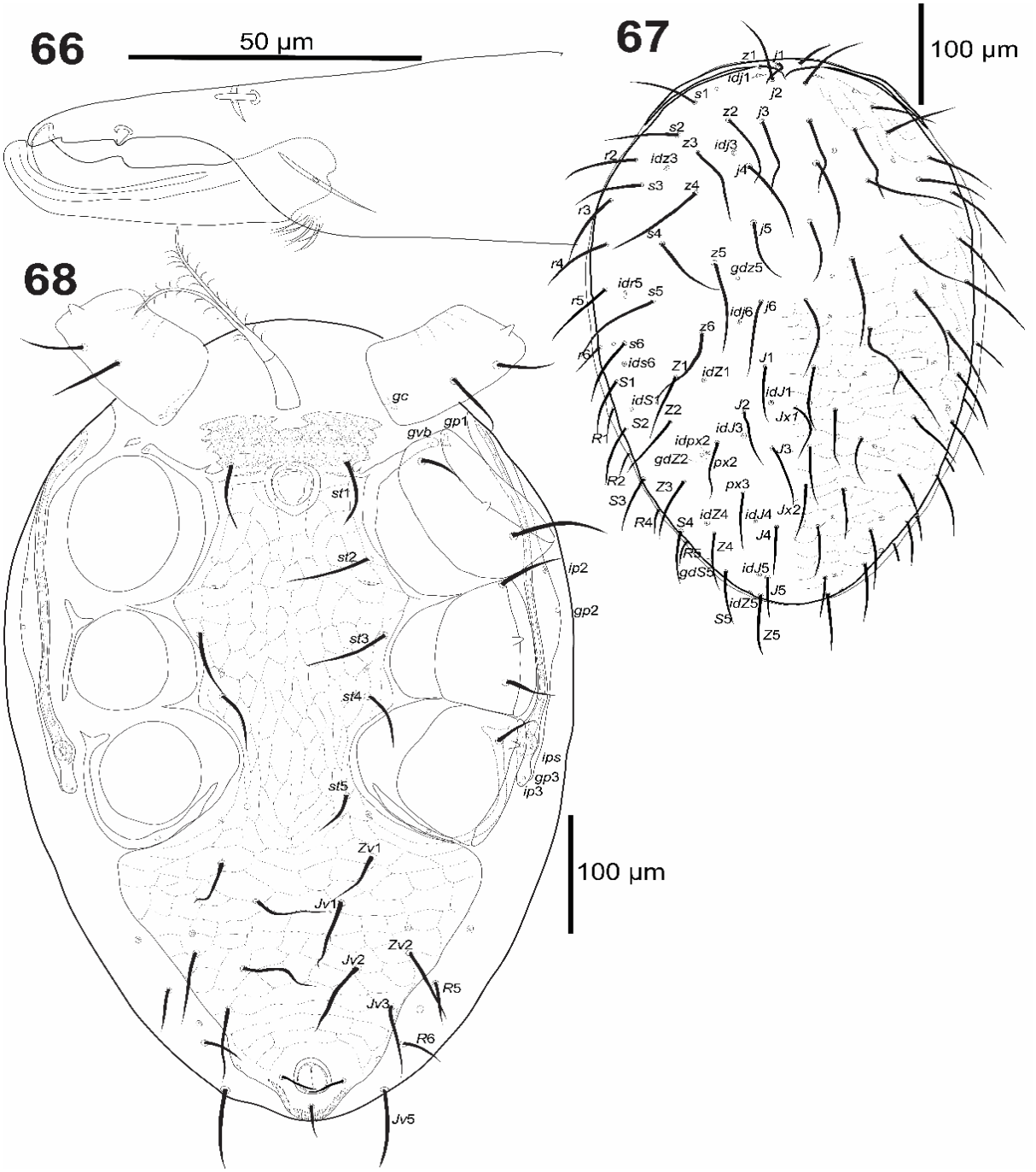
Idiosoma (Figs. 67, 68). Oval, tapering slightly posteriorly, 526 (485–575) long and 333 (295–388) wide.

Dorsal idiosoma (Fig. 67). Podonotal and opisthonotal shields fused, 514 (475–570) long and 315 (285–350) wide, almost completely covering dorsal surface of idiosoma, brownish. Podonotal region with the same setae as adult female, six pairs of distinct lyrifissures and two pairs of pores. Opisthonotal region with the same setae as adult female, nine pairs of lyrifissures and two pairs of pores. Setae *r*6 and *R*1, *R*2, *R*4–*R*6 (*R*3, *UR*1 and *UR*2 absent) on unsclerotized lateral cuticle, not visible dorsally in most specimens. Other features similar to those of adult female. Setal measurements shown in Table 9.

Ventral idiosoma (Fig. 68). Base of tritosternum 38 (37–42) long and 13 (10–15) wide proximally; laciniae 101 (98–107), separated for about 75% of their total length, pilose. Pre-sternal area similar to female, with *st*1. Sternogenital and ventrianal shields fused in a holoventral shield, reticulate, anterolateral corners extending between coxae I–II, distally bearing *gvb*; 409 (288–485) long and 153 (138–165) wide at the level of coxae IV; with nine pairs of setae (*st*2–5, *Jv*1–*Jv*3, *Zv*1 and *Zv*2) in addition to circumanal setae, five pairs of distinguishable lyrifissures and a pair of marginal pores anterolaterad of para-anal setae. Unsclerotised cuticle posterolaterad of ventrianal region with one pair of setae (*Jv*5 and; *Jv*4 and *Zv*3–5 absent) and two pairs of distinguishable lyrifissures; *gv*2 on exopodal shield posteriad of coxa IV. Shape of ventral idiosomal setae as in adult female. Setal measurements shown in Table 10.

Peritreme and peritrematic plate. As in female; *gp*1 not distinguishable.

Legs. Lengths: I: 535 (500–588); II: 439 (400–475); III: 383 (350–413); IV: 620 (575–688). Shape of setae as in adult female.



Figures 66–68. *Gaeolaelaps* sp. nov. Colombian male. 66. Chelicera; 67. Dorsal idiosoma; 68. Ventral idiosoma.

Deutonymph (Figs. 69–71, five specimens measured).

Gnathosoma. Fixed cheliceral digit 59 (55–63), with a large offset subapical tooth followed by 5–6 teeth, of which the closest to the thorn-like *pilus dentilis* larger; movable digit 53 (50–58) long, with two large teeth; dorsal seta cylindrical, with round tip, dorsal and antiaxial lyrifissures distinct (Fig. 69). Arthrodial process of chelicera, palp chaetotaxy, apotele, epistome, deutosternum, corniculus and position of hypostomal setae as in adult

female. Measurements of setae: *h*1 32 (30–38), *h*2 18 (15–20), *h*3 36 (30–43), *pc* 33 (30–38); setae aciculate and smooth.

Idiosoma (Figs. 70, 71). Oval, 441 (408–475) long and 249 (225–300) wide.

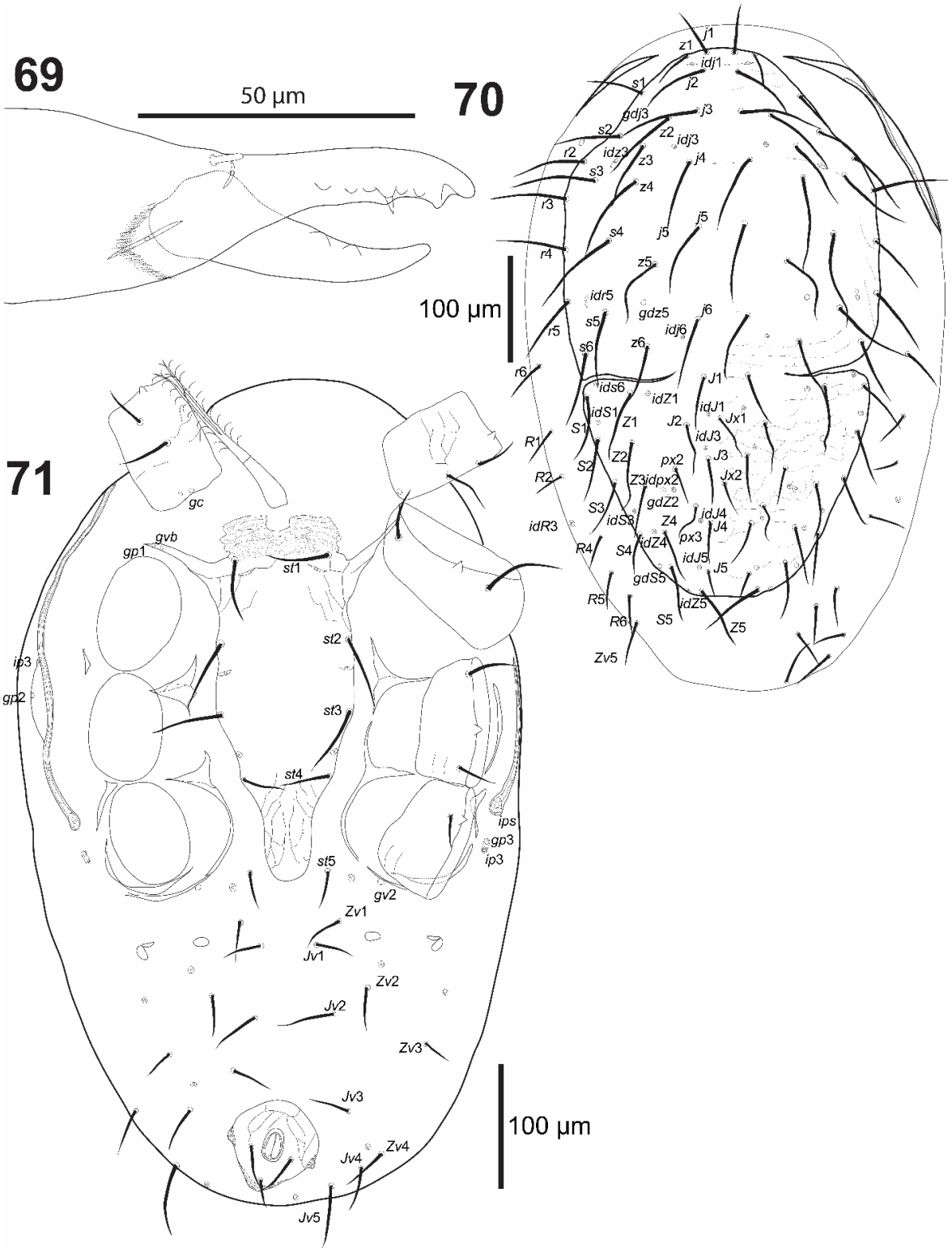
Dorsal idiosoma (Fig. 70). Dorsal shield with straight lateral incisions reaching well beyond bases of *z*6 (schizodorsal shield); 401 (348–438) long and 220 (195–250) wide, partly covering dorsal surface of idiosoma, ovoid, whitish, reticulate, except for smooth central area of podonotal region. Podonotal region with 22 pairs of setae (including *r*2–5), six pairs of lyrifissures (*ids*6 posteriad of lateral incision) and two pairs of pores. Opisthonotal region with 17 pairs of setae (including *px*2 and *px*3), ten pairs of lyrifissures and two pairs of pores; two unpaired median setae, *Jx* anteromediad of *J*3 and of *J*4. Setae *r*6, *R*1, *R*2 and *R*4–6 (*UR*1 and *UR*2 absent) on unsclerotized lateral cuticle. Other features similar to those of adult female. Setal measurements shown in Table 9.

Ventral idiosoma (Fig. 71). Base of tritosternum 42 (41–46) long and 12 (10–13) wide proximally; laciniae 102 (100–106), separated for about 72% of their total length, pilose. Pre-sternal area similar to female. Sternal shield lightly sclerotized, smooth except for light reticulation on the anterior region and posteriad of *st*4, tapering posteriad of *st*3; anterolateral corners extending between coxae I–II, bearing *gvb* and *gp*1; 193 (175–225) long and 85 (80–95) wide, with three pairs of setae (*st*2–4) and three pairs of lyrifissures (*iv*1–3); distances *st*1–3 104 (100–113), *st*2–*st*2 84 (78–93), but next to margins of extension between coxae I–II. Seta *st*5 and lyrifissure *iv*5 on unsclerotized cuticle, the latter posterolaterad of *st*5. Two pairs of small oval metapodal platelets. Opisthogaster with nine pairs of setae on unsclerotised cuticle (*Jv*1–5, *Zv*1–5) and four pairs of lyrifissures. Endopodal plate represented by a triangular section between coxae II–III and a three radiatin section between coxae III–IV, with the latter sometimes fused to an elongate posterior extension along posterior margin of caoxa IV. Exopodal plate reduced to triangular to elongate fragments between coxae II–III and III–IV, and a curved fragment partially surrounding external margin of coxa IV; *gv*2 on unsclerotized cuticle. Anal shield small, inversely curvilinear subtringular, lightly reticulate and with a pair of granulate marginal region, which contains a pair of pores anterolaterad of para-anal setae; 47 (38–53) long and 56 (50–65) wide. Shape of ventral idiosomal setae as in adult female. Setal measurements shown in Table 10.

Peritreme and peritrematic plate. Peritreme as in adult female. Peritrematic plate lightly sclerotized, not fused with dorsal shield, reduced t a small distal section between *z*1 and *r*3 and a small expansion between coxae II–III, in which a lyrifissure (*ip*2) and a pore

(*gp*2) are present. Post-stigmatic peritrematic poroid (*gp*3) and lyrifissures (*ips* and *ip*3) on soft cuticle.

Legs. Lengths: I: 433 (400–450); II: 332 (300–388); III: 326 (288–375); IV: 488 (475–513). Shape of setae as in adult female.



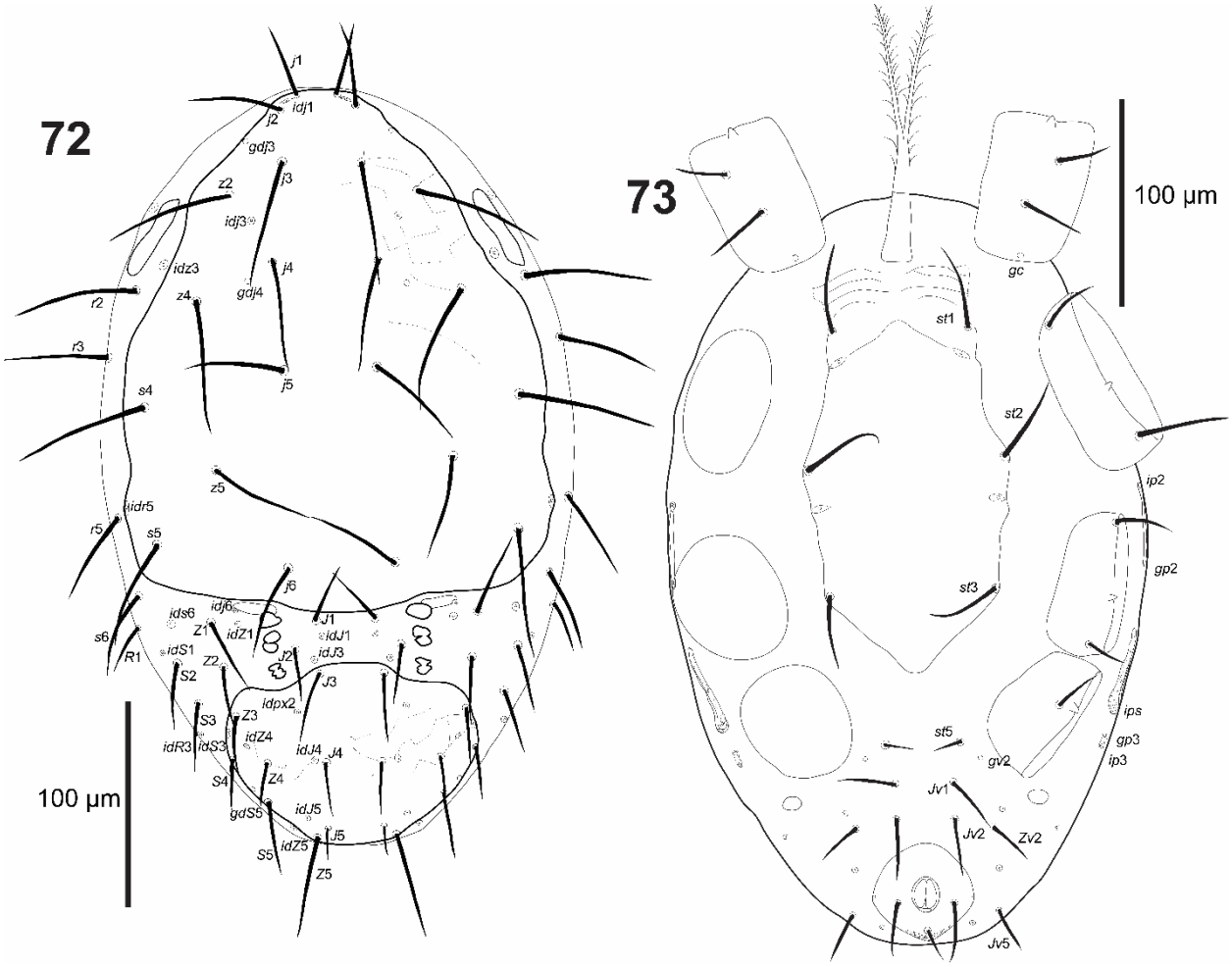
Figures 69–71. *Gaeolaelaps* sp. nov. Deutonymph. 69. Chelicera; 70. Dorsal idiosoma; 71. Ventral idiosoma.

Protonymph (Figs. 72–73, three specimen measured).

Gnathosoma. Fixed cheliceral digit 53 (50–58) long, with a large offset subapical tooth followed by four teeth, of which the closest to the thorn-like *pilus dentilis* larger; movable digit 50 (45–55) long, with two teeth; dorsal and antiaxial lyrifissures distinct, dorsal setae indistinct. Numbers of setae on palp trochanter–tarsus: 1, 4, 5, 12, 15; arthrodial process of chelicera, apotele, epistome, deutosternum, corniculus and position of hypostomal setae as in adult female. Measurements of setae: *h*1 26 (20–30), *h*2 16 (13–18), *h*3 31 (30–33), *pc* 30 (28–33); setae aciculate and smooth.

Idiosoma (Figs. 72, 73). Oval, 361 (338–405) long and 198 (173–213) wide.

Dorsal idiosoma (Fig. 72). Podonotal and opisthonotal shields separate, whitish. Podonotal shield 230 (213–250) long and 188 (188–190) wide, very lightly reticulate, with 11 pairs of setae (*j*1–6, *z*2, *z*4, *z*5, *s*4, *s*5), three pairs of lyrifissures and two pairs of pores; unsclerotized cuticule laterad of podonotal shield with four pairs of setae (*s*6, *r*2, *r*3, *r*5) and a pair of lyrifissures. Opisthonotal shield 83 (70–90) long and 188 (188–190) wide, lightly reticulate, with eight pairs of setae (*J*3–5, *Z*3–5, *S*4, *S*5), five pairs of lyrifissures and a pair of pores. Unsclerotized cuticle between podonotal and opisthonotal shields of protonymph with three pairs of lightly sclerotized and rounded-irregular platelets, the anterior adjacent to a lightly sclerotized oval element; seven pairs of setae (*J*1, *J*2, *Z*1, *Z*2, *S*2, *S*3, *R*1) and seven pairs of lyrifissures. Lyrifissure *idZ*5 on unsclerotized cuticle posteriad of opisthonotal shield. Shape and proportion of setae as in adult female. All setae aciculate. Setal measurements shown in Table 9.



Figures 72–73. *Gaeolaelaps* sp. nov. Protonymph. 72. Dorsal idiosoma; 73. Ventral idiosoma.

Ventral idiosoma (Fig. 73). Base of tritosternum 35 (33–37) long and 14 (12–15) wide proximally; laciniae 92 (88–95), separated for about 72% of their total length, pilose. Pre-sternal area only represented by transverse lines anteriad of sternal shield. Sternal shield lightly sclerotized, smooth; 131 (113–143) long and 88 (85–93) wide, with two pairs of setae (*st*2–3) and two pairs of lyrifissures (*iv*1–*iv*2); distances *st*1–3 106 (100–113), *st*2–*st*2 88 (85–93); setae *st*4 absent. Seta *st*5 on unsclerotized cuticle. Opisthogaster with four pairs of setae on unsclerotised cuticle (*Jv*1, *Jv*2, *Jv*5, *Zv*2), four pairs of lyrifissures. Endopodal and exopodal plates indistinguishable; *gv*2 on unsclerotized cuticle. Anal shield small, ovoid; 45 (38–50) long and 51 (45–60) wide. Shape of ventral idiosomal setae as in adult female. Setal measurements shown in Table 10.

Peritreme and peritrematic plate. Peritreme short, reaching slightly anterior of posterior margin of coxa III. Peritrematic plate lightly sclerotized, reduced to a small strip between coxa II–III, bearing a lyrifissure (*ip*2) and a pore (*gp*2), and a barely discernible

platelet containing the peritreme. Post-stigmatic peritrematic pore (*gp*3) and lyrifissures (*ips* and *ip*3) on soft cuticle.

Legs. Lengths: I: 365 (338–400); II: 271 (250–288); III: 264 (230–288); IV: 392 (363–425). Setation (legs I–IV): coxae: $0-\frac{0\,0}{2\,0}-0,\ 0-\frac{0\,0}{1\,1}-0,\ 0-\frac{0\,0}{1\,1}-0,\ 0-\frac{0\,0}{1\,0}-0$; trochanters: $1-\frac{0\,0}{1\,1}-1,\ 1-\frac{0\,0}{1\,1}-1,\ 1-\frac{1\,0}{1\,1}-1,\ 1-\frac{1\,0}{1\,1}-0$; femora: $2-\frac{2\,2}{1\,1}-2,\ 1-\frac{2\,2}{1\,1}-1{,}1-\frac{2\,1}{1\,0}-0,\ 1-\frac{2\,1}{0\,0}-0$; genua: $1-\frac{2\,2}{1\,1}-1{,}1-\frac{2\,2}{0\,0}-1,\ 1-\frac{2\,2}{0\,0}-1,\ \ 1-\frac{2\,2}{0\,0}-0$; tibiae: $1-\frac{2\,2}{1\,1}-1,\ 1-\frac{1\,2}{1\,1}-1,\ 1-\frac{1\,2}{1\,1}-1,\ 1-\frac{1\,2}{1\,1}-1$; tarsal setation: I not counted, 17, 17, 17. Shape of setae as in adult female.

Remarks. The main features that distinguish the females of this species from other species in the genus are: the shape of the epistome with few denticles (also observed few denticles in illustration of the original description *Gaeolaelaps magkadikitus* (Rosario, 1981) and in *Gaeolaelaps variabilis* (Faraji & Halliday, 2009)), the expansion of the epigynial shield, that it is separated from anal shield by less than half length of anal shield (also observed in *Gaeolaelaps franzi* (Aswegen & Loots, 1970)) and *st*1 in pre-sternal area (also observed in few species: *Gaeolaelaps aculeiferoides* (Teng, 1982), *Gaeolaelaps ardoris* (Karg, 1993), *Gaeolaelaps debilis* (Ma, 1996), *Gaeolaelaps franzi* (Aswegen & Loots, 1970), *Gaeolaelaps krantzi* (Arutunjan, 1993), *Gaeolaelaps minor* (Costa, 1968)).

This species is more similar to *G. franzi* by having *st*1 in pre-sternal area; deutosternal groove with six transverse lines of denticles; and epigynial shield tongue-shaped, posteriorly expanded, with similar reticulation reticulate. However, the latter species differs from the species here described by having shorter dorsal setae (post-anal seta 12 µm, vertical seta 20 µm, scapular seta 12 µm and seta J5 20 µm).

Etymology. The specific name is a homage to an indigenous group that has inhabited the cundiboyacense highlands, including the Bogota plateau, before the Spanish conquest.

***Cosmolaelaps claviger* (Berlese)**

Laelaps claviger Berlese, 1883: IV, 2

Cosmolaelaps claviger.— Hull, 1918: 68; Afifi & Van Der Geest, 1984: 587; Luxton, 1998: 18; Moreira et al., 2014: 319.

Hypoaspis (*Cosmolaelaps*) *claviger*.— Evans & Till, 1966: 182; Karg, 1971: 166

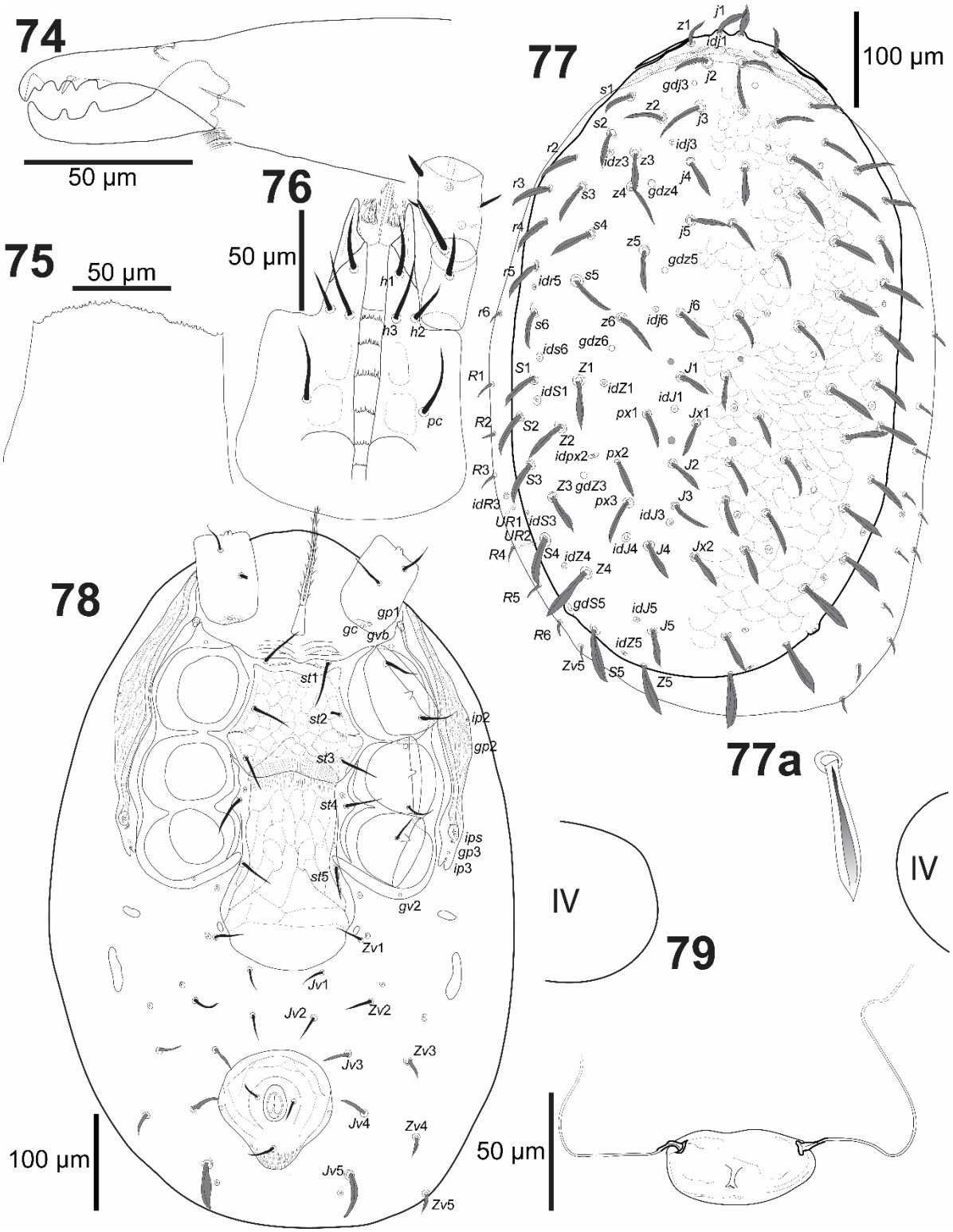
Material measured: six ♀ and five ♂ from soil (pH 5.6 ± 0.1; organic matter 23 ± 3.4%; humidity 34 ± 2.7%; temperature 15.9 ± 0.5°C) at FV, collected on August 25 and December 14, 2016.

Additional material examined: 11 ♀ and one ♂ from FV.

Diagnosis: female with anterior region of epistome slightly convex, with margin denticulate; fixed cheliceral digit with a large offset tooth followed by three teeth and setiform *pilus dentilis*; deutosternal groove delimited by subparallel lateral lines, with seven transverse lines, the most distal smooth and others with 7-12 irregular denticles; dorsal shield oval, brownish, reticulate, almost totally covering the idiosoma, with 39 pairs of setae (including *px*1–3) and two unpaired setae, all spatulate, with a tiny basal asymmetric knob; pre-sternal area very weakly sclerotized, represented only by transverse lines; opisthogaster with four pairs of aciculate setae (*Jv*1–2 and *Zv*1, *Zv*2) and six pairs of stout-spatulated setae (*Jv*3–5 and *Zv*3–5) on unsclerotised cuticle; one pair of metapodal platelets; a pair of oval platelets next to edge of epigynial shield, which bears *st*5. Male spermadactyl curved upward, extending well beyond tip of movable digit, of about uniform diameter and tapering slightly to a blut tip; holoventral shield reticulate, anterolateral corners extending between coxae I–II.

Adult female (Figs. 74–79, six specimens measured).

Gnathosoma. Chelicera with arthrodial process shaped as a coronet-like fringe; fixed cheliceral digit 63 (60–68) long, with a deep axial subapical pocket to receive apex of movable digit, with a large offset subapical tooth followed by three similarly large teeth and setiform *pilus dentilis*; movable digit 59 (58–63) long, with two large teeth; dorsal seta aciculate, stout, dorsal and antiaxial lyrifissures distinct (Fig. 74). Numbers of setae on palp trochanter–tarsus: 2, 5, 6, 14, 15; palp apotele bifurcate. Anterior region of epistome slightly convex, with margin denticulate (Fig. 75); deutosternal groove delimited by subparallel lateral lines (Fig. 76), with seven transverse lines, the most distal smooth and others with 7–12 irregular denticles; with a pair of smooth, transverse and curved lines external to deutosternum, at the level or posteriad of second most proximal line of denticles. Internal malae distinctly separated from each other and ventrally fimbriate, flanked by up to four pairs of curved, fimbriate structures. Corniculi horn-shaped, about twice as long as their largest width, well separated from each other, subparallel. Hypostomal seta *h*3 about in longitudinal line with *h*1 and mediad and slightly posteriad of *h*2. Measurements of setae: *h*1 24 (20–30), *h*2 21 (18–25), *h*3 33 (28–38), *pc* 28 (25–30); setae aciculate and smooth.



Figures 74–79. *Cosmolaelaps claviger* (Berlese, 1883). Colombian female. 74. Chelicera; 75. Epistome; 76. Hypostome and proximal palp segment; 77. Dorsal idiosoma; 77a. Detail of setae; 78. Ventral idiosoma; 79. Spermathecal apparatus.

Idiosoma (Figs. 77, 78). Ellipsoidal, 620 (605–638) long and 376 (363–400) wide.

Dorsal idiosoma (Fig. 77). Podonotal and opisthonotal shields fused, 573 (550–593) long and 363 (338–413) wide, almost totally covering dorsal surface of idiosoma, ellipsoidal, brownish, reticulate. Podonotal region with 22 pairs of setae (including *r*2–5), six pairs of lyrifissures and four pairs of pores. Opisthonotal region with 18 pairs of setae (including *px*1–3 between *J* and *Z* series), two unpaired median setae *Jx* anteromediad of *J*2 and *J*4, ten pairs of lyrifissures and two pair of pores. Setae *r*6, *R*1–6, *UR*1–4 (some specimens with only *UR*2–4) and lyrifissure *idR*3 on unsclerotized lateral cuticle. All dorsal shield setae spatulate (Fig. 77a) and sometimes with barely disitinguishable basal asymmetric knob; setae *j*1 inserted anteriorly on a small protuberance. Setae on unsclerotized cuticle aciculate, stout. Setal measurements shown in Table 11.

Table 11. Length of dorsal idiosomal setae of Colombian specimens of ***Cosmolaelaps claviger* (Berlese, 1883);** mean (minimum–maximum). - = seta absent.

Seta	Female (n = 6)	Male (n = 5)
*j*1	28 (25–30)	28 (28–30)
*j*2	35 (30–38)	26 (23–30)
*j*3	38 (35–40)	27 (23–30)
*j*4	40 (38–40)	29 (25–30)
*j*5	37 (35–38)	26 (25–28)
*j*6	37 (35–40)	26 (23–28)
*J*1	35 (33–38)	25 (25–25)
*J*2	37 (33–40)	25 (23–28)
*J*3	38 (35–40)	25
*J*4	38 (33–40)	26 (25–28)
*J*5	39 (38–40)	29 (28–30)
*J*2–*J*3	43 (33–50)	35 (33–38)
*J*3–*J*4	43 (38–50)	30 (23–38)
*j*2–*j*3	41 (38–45)	29 (25–33)
*J*x1	29 (28–30)	22 (18–25)
*J*x2	35 (33–38)	22 (20–25)
*z*1	25 (20–28)	21 (20–23)
*z*2	34 (28–40)	27 (25–28)
*z*3	38 (30–40)	29 (25–30)
*z*4	40 (38–43)	28 (25–30)
*z*5	37 (35–38)	27 (25–28)
*z*6	43 (40–45)	29 (28–30)
*Z*1	48 (45–50)	32 (30–33)

Seta	Female (n = 6)	Male (n = 5)
*Z*2	43 (43–45)	32 (28–35)
*Z*3	45 (43–50)	30 (25–33)
*Z*4	54 (53–55)	35 (33–35)
*Z*5	55 (50–60)	36 (30–40)
*s*1	30 (28–33)	24 (23–25)
*s*2	33 (25–38)	26 (25–28)
*s*3	35 (28–38)	27 (25–28)
*s*4	40 (38–45)	30 (28–30)
*s*5	43 (40–45)	30 (28–33)
*s*6	43 (38–45)	31 (28–33)
*S*1	39 (38–43)	29 (25–30)
*S*2	40 (38–43)	29 (25–30)
*S*3	40 (38–43)	29 (28–30)
*S*4	43 (40–45)	29 (25–33)
*S*5	53 (50–55)	34 (33–35)
*px*1	34 (30–38)	24 (23–25)
*px*2	37 (35–38)	24 (23–25)
*px*3	40 (38–40)	26 (25–28)
*r*2	34 (30–38)	25 (23–28)
*r*3	36 (33–38)	28
*r*4	37 (35–40)	25 (23–28)
*r*5	39 (38–40)	29 (28–30)
*r*6	19 (18–20)	11 (10–13)
*R*1	18	11 (10–13)
*R*2	17 (13–20)	11 (8–15)
*R*3	17 (13–20)	10 (8–13)
*R*4	17 (15–20)	11 (10–13)
*R*5	17 (15–18)	11 (10–13)
*R*6	19 (15–23)	12 (10–13)
*UR*1	17 (15–20)	10 (8–13)
*UR*2	16 (14–18)	8 (7–9)
*UR*3	15 (14–20)	8 (7–10)
*UR*4	17 (16–20)	9 (9–12)

Ventral idiosoma (Fig. 78). Base of tritosternum 33 (31–37) long and 15 (13–15) wide proximally; laciniae 101 (99–105), almost totally separated from each other, pilose. Presternal area very weakly sclerotized, represented only by transverse lines. Sternal shield reticulate, with posterior margin concave, anterolateral corners extending between coxae I–II, 127 (118–138) long and 160 (150–175) wide, with three pairs of setae (*st*1–3) and two pairs

of lyrifissures (*iv*1 and *iv*2); distances *st*1–3 103 (88–115), *st*2–*st*2 91 (88–93). Fourth pair of sternal setae (*st*4) and third pair of lyrifissure (*iv*3) on unsclerotized cuticle. Epigynial shield tongue-shaped, reticulate; anterior hyaline region irregularly convex and slightly overlapping posterior margin of sternal shield; 191 (180–213) long and 144 (138–150) wide; distance *st*5–*st*5 88 (83–98); seta *st*5 inserted on shield margin and lyrifissure *iv*5 on unsclerotised cuticle posterolaterad of *st*5. Distance between epigynial and anal shields at least the same as length of anal shield. A pair of ellipsoidal platelets next to edge of epigynial shield. With two pairs of metapodal platelets, the anterior ellipsoidal; the posterior much larger, bacillate. Opisthogaster with ten pairs of setae (some specimens also with 1 or 2 *Sv* setae), four pairs of lyrifissures on unsclerotised cuticle. Anterior section of endopodal plate fused with sternal shield; section behind sternal shield represented by an elongate v-shaped platelet between coxae III–IV. Exopodal plate distinctly sclerotized as a continuous narrow strip, extending anteriorly between coxae I–II and bearing pores *gvb* (which in most other species are located at the end of the extension of the sternal shield between these coxae) and posteriorly surrounding completely posterior margin of coxa IV, bearing pores *gv*2. Anal shield inversely pear-shaped, reticulate; 125 (113–143) long and 108 (100–115) wide, with a pair of marginal pores about in transverse line with or slightly posteriad of para-anal setae, the latter about as long as or slightly shorter than post-anal seta and inserted between mid-length and posterior margin of anal opening; anal opening almost 1/4 as long as shield, 28 (25–33) long, located at shield center. All ventral setae aciculate, except *Jv*3, *Jv*4, *Zv*3–5 (aciculate but stout) and *Jv*5 (spatulate). Setal measurements shown in Table 12.

Table 12. Length of ventral idiosomal and ventral gnathosomal setae of Colombian specimens of ***Cosmolaelaps claviger* (Berlese, 1883);** mean (minimum–maximum). - = seta absent.

Seta	Female (n = 6)	Male (n = 5)
*st*1	43 (38–50)	29 (25–30)
*st*2	38 (35–40)	27 (25–28)
*st*3	35 (30–38)	28 (25–30)
*st*4	30 (25–33)	25 (20–33)
*st*5	33 (25–38)	25 (23–28)
*Jv*1	25 (23–28)	21 (20–25)
*Jv*2	23 (20–25)	22 (20–23)
*Jv*3	25 (23–30)	18 (18–20)
*Jv*4	27 (25–30)	15
*Jv*5	40 (35–45)	38 (35–40)
*Zv*1	23 (20–28)	18 (18–20)

*Zv*2	21 (20–25)	17 (15–18)
*Zv*3	23 (18–25)	
*Zv*4	24 (23–25)	
*Zv*5	23 (20–25)	
Para–anal	20 (18–23)	16 (15–18)
post–anal	24 (20–30)	19 (15–23)

Peritreme and peritrematic plate. Peritreme extending to abut each other anteriorly. Peritrematic plate broad and well ornamented, fused with dorsal shield near *z*1; with a lyrifissure (*ip*2) and a pore (*gp*2) between coxae II–III, and with two lyrifissures (*ip*s and *ip*3) and a pore (*gp*3) posteriad of stigma; pore (*gp*1) in an accessory irregular platelet between coxae I–II. Post-stigmatic area of peritrematic plate free, about straight, slightly tapering posteriorly and with a distinct terminal median incision, extending behind to median level of coxa IV (Fig. 78).

Spermathecal apparatus (Fig. 79). Laelapid-type. Insemination pore apparently located at anterior margin at base of coxa IV; infundibulum indistinct; tubulus elongate, connected to globular sacculus by a truncate cone-shaped ramus; sperm duct distinct.

Legs (Figs.80–83). Lengths: I: 567 (538–588); II: 444 (425–475); III: 427 (413–463); IV: 630 (618–650). Setation (legs I–IV): coxae: $0-\frac{0\,0}{2\,0}-0$, $0-\frac{0\,0}{1\,1}-0$, $0-\frac{0\,0}{1\,1}-0$, $0-\frac{0\,0}{1\,0}-0$; trochanters: $1-\frac{1\,0}{2\,1}-1$, $1-\frac{0\,1}{1\,1}-1$, $1-\frac{1\,0}{1\,1}-1$, $2-\frac{1\,0}{1\,1}-0$; femora: $2-\frac{2\,3}{1\,3}-2$, $2-\frac{3\,2}{1\,2}-1$,$1-\frac{2\,1}{1\,0}-1$, $1-\frac{2\,1}{1\,0}-1$; genua: $2-\frac{3\,3}{2\,1}-2$,$2-\frac{3\,2}{1\,1}-2$, $2-\frac{2\,2}{1\,1}-1$, $2-\frac{2\,3}{1\,0}-1$; tibiae: $2-\frac{3\,3}{2\,1}-2$, $2-\frac{2\,2}{1\,1}-2$, $2-\frac{1\,2}{1\,1}-1$, $2-\frac{1\,3}{1\,1}-2$; tarsal setation: I not counted, 18, 18, 18. All legs with pretarsi containing a pair of strongly scletorized claws; median section of pulvilli of legs I–IV rounded. Most leg setae stout, some distintctly more than others (*pd*1 of trochanter I, *pd*2 of femur II, *av* and *pv* of genu and tibia III, *ad1* of trochanter IV, *ad*1, *ad*2 and *av* of femur IV, *av* of genu IV, *av* and *pv* of tibia IV and *pd*2 and *pd*3 of tarsus IV).

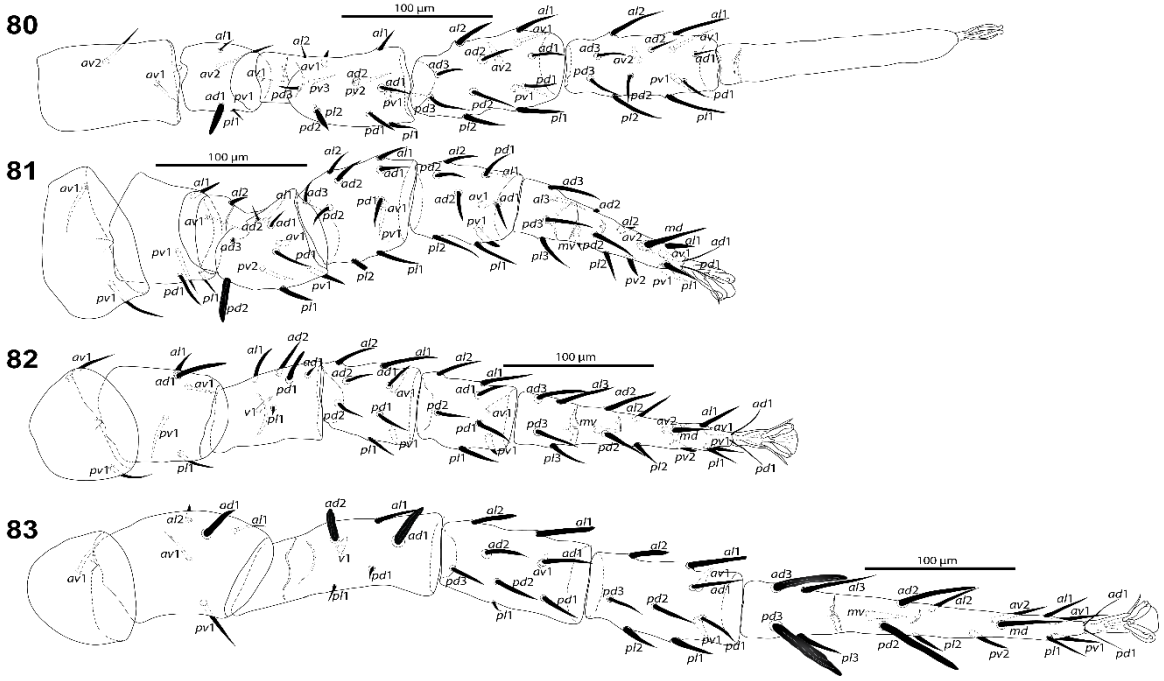
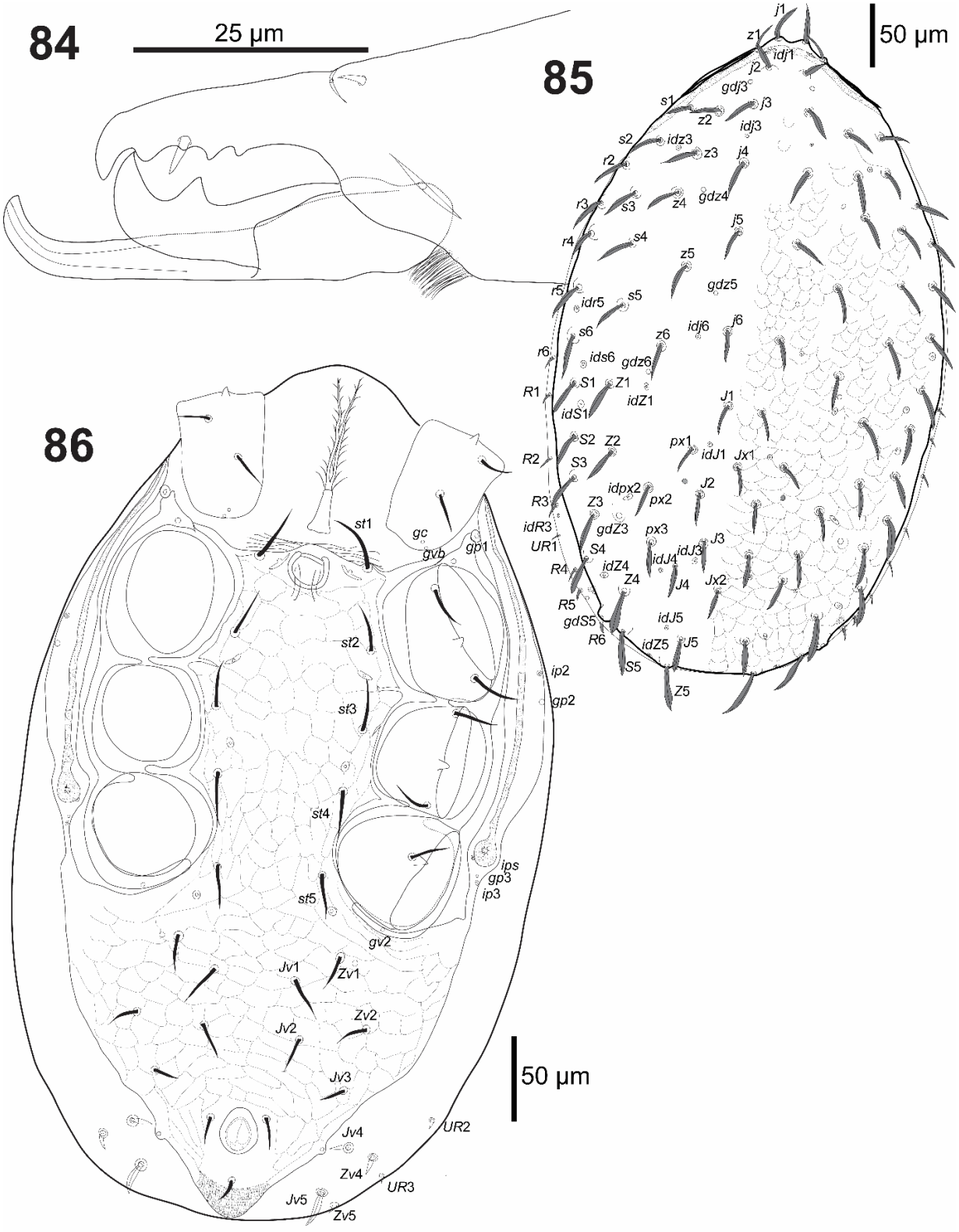


Figure 80–83. *Cosmolaelaps claviger* (Berlese 1883). Colombian female. 80. Leg I; 81. Leg II; 82. Leg III; 83. Leg IV.

Adult male (Figs. 84–86, five specimens measured).

Gnathosoma. Fixed cheliceral digit 38 (30–43) long, with a large offset subapical tooth and three similarly largeteeth and stout *pilus dentilis*; movable digit 35 (28–45) long, with one large tooth; spermadactyl 51 (43–58) long, curved upward, extending well beyond tip of movable digit and tapering slightly to a blunt tip; dorsal seta thorn-shaped, dorsal and antiaxial lyrifissures distinct (Fig. 84). Arthrodial process of chelicera, palp chaetotaxy, apotele, epistome, deutosternum, corniculus and position of hypostomal setae as in adult female. Measurements of setae: *h*1 17 (15–20), *h*2 17 (15–18), *h*3 24 (23–25), *pc* 24 (23–25); setae aciculate and smooth.

Idiosoma (Figs. 85, 86). Ellopsoidal, 475 (468–483) long and 285 (263–300) wide.



Figures 84–86. *Cosmolaelaps claviger* (Berlese 1883). Male. 84. Chelicera; 85. Dorsal idiosoma; 86. Ventral idiosoma.

Dorsal idiosoma (Fig. 85). Podonotal and opisthonotal shields fused, 453 (425–468) long and 265 (250–275) wide, ellipsoidal, brownish, reticulate. Podonotal region with the

same setae, lyrifissures and pores as adult female, almost totally covering dorsal surface of idiosoma. Opisthonotal region with the same setae and pores of adult female, and nine pair of lyrifissures. Setae *r*6, *R*1–6 and *UR*3–4 (*UR*1 and *UR*2 sometimes absent) on unsclerotized lateral cuticle, usually not visible dorsally. Other features similar to those of adult female. Setal measurements shown in Table 11.

Ventral idiosoma (Fig. 86). Base of tritosternum 26 (25–28) long and 12 (10–13) wide proximally; laciniae 68 (67–71), almost totally separated from each other, pilose. Pre-sternal area similar to adult female. Sternogenital and ventrianal shields fused in a holoventral shield, reticulate, anterolateral corners extending between coxae I–II; 368 (350–388) long and 110 (80–125) wide at the level of coxae IV; with ten pairs of setae (*st1–5*, *Jv*1–*Jv*3, *Zv*1 and *Zv*2) in addition to circumanal setae, five pairs of distinguishable lyrifissures and a pair of marginal pores about in transverse line with or slightly posteriad of para-anal setae. Unsclerotised cuticle posterolaterad of ventrianal region with four pairs of setae (*Jv*4, *Jv*5 and *Zv*4; *Zv*3 absent). Exopodal plate as in adult female, including position of *gvb* and *gv*2. Al setae aciculate, except for *Jv*4 and *Zv*4 (thorn-shaped), and *Jv*5 (spatulate). Setal measurements shown in Table 12.

Peritreme and peritrematic plate. As in adult female, except that peritrematic plate is fused to holoventral shield at level of coxae IV by a narrow strip.

Legs. Lengths: I: 450 (425–463); II: 339 (318–350); III: 366 (350–375); IV: 506 (500–525). Shape of setae as in adult female.

Remarks. This species was originally described from Italy, from moss. The specimens examined are similar in size to what was mentioned for the type specimens (idiosoma respectively 600 and male idiosoma 500) and to specimens from Britain and Europe, according to the complementary description by Evans & Till (1966) (female dorsal shield 654 long and 366 wide, male dorsal shield 486 long and 282 wide). According to Evans & Till (1966), this species has dorsal shield with 39 pairs of setae and four unpaired accessory setae; however, our interpretation of figure 24A of that publication is the presence of 40 pairs of setae and two unpaired median setae *Jx*, as observed in Colombian specimens.

The present complementary description provides additional information not given in the original description nor in the complementary description by Evans and Till (1966), including measurements of all dorsal and ventral idiosomal setae, leg chaetotaxy, and characteristics of the spermatheca.

A common feature of both adult males and females is the presence of soil particles adherent to the dorsum of the idiosoma. This characteristic was also mentioned in the original description of the species.

***Stratiolaelaps scimitus* (Womersley)**

Comolaelaps scimitus Womersley, 1956: 580

Hypoaspis (*Cosmolaelaps*) *scimitus* – Karg, 1978b: 8

Hypoaspis (*Stratiolaelaps*) *miles elsi* – Aswegen & Loots, 1970: 205 [Junior synonym by Walter & Campbell 2003: 266]

Cosmolaelaps scimitus – Farrier & Hennessey, 1993: 69

Hypoaspis (*Stratiolaelaps*) *antennata* – Karg, 1993: 262 [Junior synonym by Walter & Campbell, 2003: 266]

Stratiolaelaps scimitus – Walter & Campbell, 2003: 266; Faraji & Halliday, 2009: 260; Moreira et al., 2014: 322]

Material measured: three ♀ from soil (pH 4.9 ± 0.2; organic matter 47 ± 7.1%; humidity 39 ± 3.7%; temperature 14.5 ± 0.1°C) at CV, collected on August 14, 2015 and June 7, 2016; one ♀ from soil (pH 4.0 ± 0.1; organic matter 86 ± 5%; humidity 70 ± 2.1%; temperature 10.6 ± 0.1°C) at LV, collected on January 10, 2017.

Additional material examined: 33 ♀ from CV and LV.

Diagnosis: anterior region of female epistome with a short triangular medial projection and with margin denticulate; fixed cheliceral digit with a large offset tooth followed by two similarly large teeth and setiform *pilus dentilis*; deutosternal groove delimited by subparallel lateral lines, with eight transverse lines, the most distal and the most proximal smooth and others with 10-16 denticles; dorsal shield gradually tapering posteriorly from level of *r*3–4, exposing a great part of the idiosoma, brownish, reticulate on opisthosomal region and on anterolateral area of podonotal region, mostly smooth elsewhere, with 37 pairs of spatulate setae; unsclerotized lateral cuticle with 13 pairs of setae (*r*6, *R*1–6 and *UR*1–6); pre-sternal platelets represented by 3–4 transverse, anastomosing strips; opisthogaster with three pairs of aciculate setae (*Jv*1, *Jv*2 and *Zv*1) and seven pairs of stout to spatulate setae (*Jv*3–*Jv*5 and *Zv*2–*Zv*5) on unsclerotised cuticle; a pair of roundish metapodal platelets; epigynial shield bearing only *st*5.

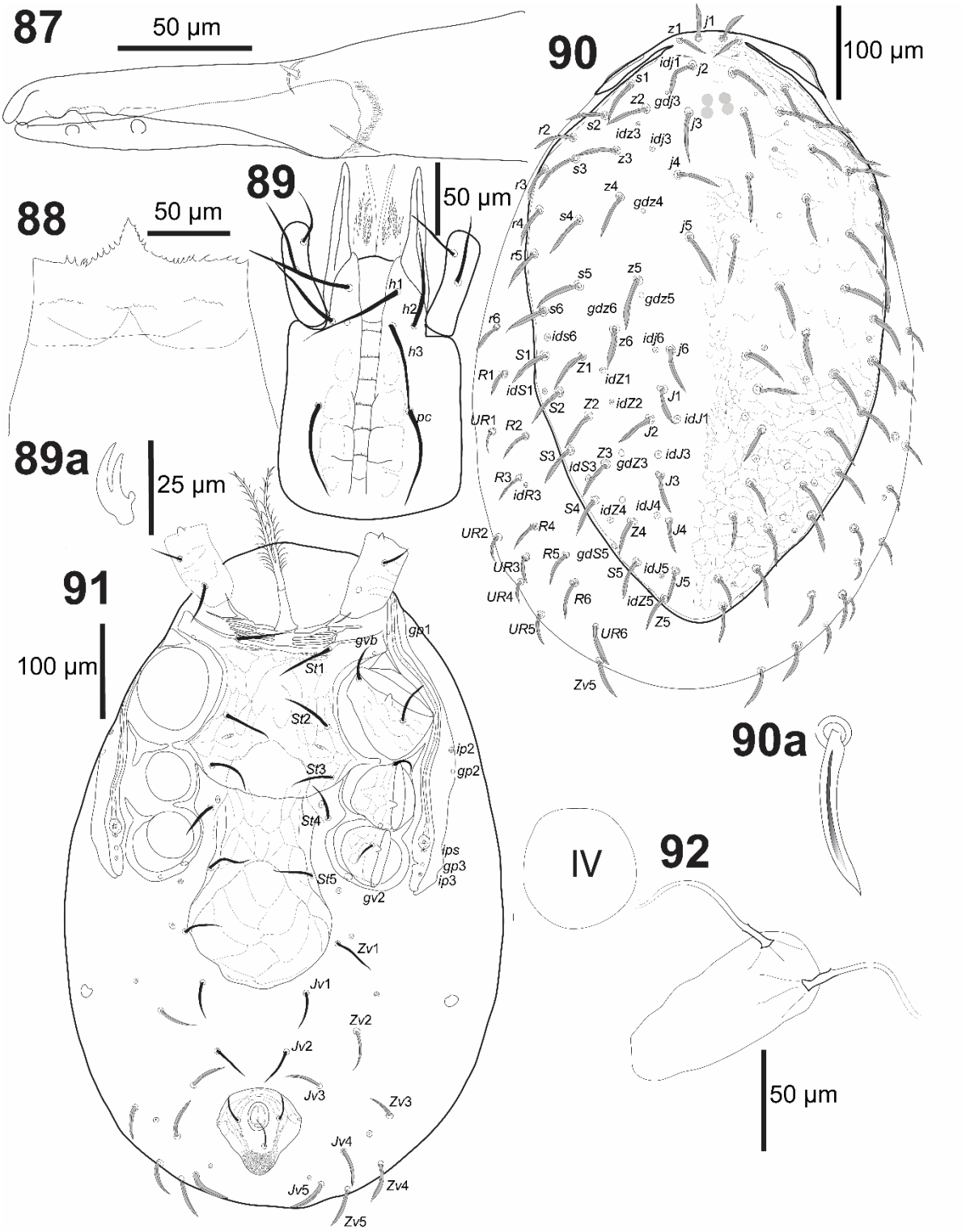
Adult female (Figs. 87–96, four specimens measured).

Gnathosoma. Chelicera with arthrodial process shaped as a coronet-like fringe; fixed cheliceral digit 131 (125–135) long, with a large offset tooth followed by three similarly large teeth and setiform *pilus dentilis*; movable digit 124 (118–128) long, with two large teeth; dorsal seta thorn-shaped, dorsal and antiaxial lyrifissures distinct (Fig. 87). Numbers of setae on palp trochanter–tarsus: 2, 5, 6, 14, 15; palp apotele with two relatively large tines and a third short, knob-like tine (Fig. 89a). anterior region of female epistome with a short triangular medial projection and with margin denticulate (Fig. 88); deutosternal groove delimited by subparallel lateral lines (Fig. 89), with eight transverse lines, most distal and most proximal smooth and others with 10-26 denticles; with two pairs of smooth, transverse lines external to deutosternum, at the level of second most proximal line of denticles or posteriad to it. Internal malae distinctly separated from each other and ventrally fimbriate, flanked by a pair of coarsely fimbriate structures. Corniculi horn-shaped, more than seven times as long as their largest width, reaching palp genu, well separated from each other, subparallel. Hypostomal seta *h*3 about in longitudinal line with *h*1 and in transverse line with *h*2. Measurements of setae: *h*1 72 (70–74)), *h*2 57 (55–61), *h*3 60 (53–64), *pc* 62 (58–67); setae aciculate and smooth.

Idiosoma (Figs. 90, 91). Ellipsoidal, 712 (683–750) long and 481 (470–500) wide.

Dorsal idiosoma (Fig. 90). Podonotal and opisthonotal shields fused, 625 (613–636) long and 376 (363–388) wide, gradually tapering from level of setae *r*3–4, exposing a great part of the idiosoma, brownish, reticulate on opisthosomal region and on anterolateral area of podonotal region, mostly smooth elsewhere. Podonotal region with 22 pairs of setae (including *r*2–5), five pairs of lyrifissures and three pairs of pores. Opisthonotal region with 15 pairs of setae, ten pairs of lyrifissures and two pair of pores. Setae *r*6, *R*1–6 and *UR*1–6 and lyrifissure *idR*3 on unsclerotized lateral cuticle. All dorsal shield setae spatulate (Figs. 90, 90a). Setal measurements shown in table 13.

Ventral idiosoma (Fig. 91). Base of tritosternum 45 (44–47) long 14 (13–18) wide proximally; laciniae 85 long, separated for about 55% of their total length, pilose. Pre-sternal platelets represented by 3–4 transverse, anastomosing strips. Sternal shield reticulate, with posterior margin convex, broad anterolateral corners extending between coxae I–II, distally bearing pores *gvb*; 158 (155–163) long and 203 (200–208) wide, with three pairs of setae (*st*1–3) and two pairs of lyrifissures (*iv*1 and *iv*2); distances *st*1–3 132 (125–139), *st*2–*st*2 105 (100–108). Fourth pair of sternal setae (*st*4) and third pair of lyrifissure (*iv*3) on unsclerotized cuticle.



Figures 87–92. *Stratiolaelaps scimitus* (Womersley, 1956). Colombian female. 87. Chelicera; 88. Epistome; 89. Hypostome and proximal palp segment; 90. Dorsal idiosoma; 90a. Detail of setae; 91. Ventral idiosoma; 92. Spermathecal apparatus.

Epigynial shield tongue-shaped, reticulate; anterior hyaline region irregularly convex and overlapping posterior margin of sternal shield; 211 (198–223) long and 147 (145–152) wide; distance st5–st5 108 (105–110); seta st5 inserted on shield margin and lyrifissure iv5 on

unsclerotised cuticle posterolaterad of st5. Distance between epigynial and anal shields exceeding slightly length of anal shield. With a pair of roundish metapodal platelets. Opisthogaster with ten pairs of setae on unsclerotised cuticle, two pair of lyrifissures and a pair of pores. Anterior section of endopodal plate fused with sternal shield; section behind sternal shield represented by an elongate v-shaped platelet between coxae III–IV. Exopodal plate represented by triangular platelet between coxae I–II and tri-radiate platelets between coxae II–III and III–IV, the latter fused to a curved platelet partially surrounding external margin of coxa IV, bearing pore *gv*2. Anal shield small, inverted pear-shaped, reticulate; 91 (88–93) long and 86 (83–89) wide, with a pair of marginal pores about in transverse line with para-anal setae, the latter about as long as post-anal seta and inserted between mid-length and posterior margin of anal opening; anal opening almost 1/3 as long as shield, 30 (28–33) long, located slightly anteriad of shield center. All ventral setae aciculate, except *Jv*3–*Jv*5 and *Zv*2–*Zv*5 (stout to spatulate). Setal measurements shown in table 13.

Table 13. Length of dorsal and ventral idiosomal setae of Colombian specimens of ***Stratiolaelaps scimitus* (Womersley, 1956)**; mean (minimum–maximum). - = seta absent.

Dorsal setae		Ventral setae	
Seta	**Female (n = 4)**	**Seta**	**Female (n = 4)**
*j*1	35 (33–38)	*st*1	58 (57–60)
*j*2	49 (43–53)	*st*2	51 (50–52)
*j*3	53 (50–55)	*st*3	44 (43–46)
*j*4	52 (50–53)	*st*4	39 (38–41)
*j*5	53 (50–57)	*st*5	44 (43–47)
*j*6	48 (45–50)	*Jv*1	40 (38–41)
*J*1	41 (40–43)	*Jv*2	27 (0–41)
*J*2	41 (40–42)	*Jv*3	38 (35–40)
*J*3	41 (40–43)	*Jv*4	41 (40–42)
*J*4	36 (33–38)	*Jv*5	46 (45–48)
*J*5	37 (36–38)	*Zv*1	42 (40–46)
*J*2–*J*3	57 (55–61)	*Zv*2	41 (40–43)
*J*3–*J*4	48 (45–50)	*Zv*3	29 (28–30)
*j*2–*j*3	48 (43–50)	*Zv*4	41 (40–44)
*z*1	33 (28–40)	*Zv*5	44 (43–45)
*z*2	49 (46–50)	Para–anal	27 (25–29)
*z*3	45 (43–50)	post–anal	27 (25–30)
*z*4	49 (48–50)		
*z*5	52 (50–56)		
*z*6	43 (40–46)		

Dorsal setae		Ventral setae	
Seta	**Female (n = 4)**	**Seta**	**Female (n = 4)**
*Z*1	44 (40–48)		
*Z*2	41 (40–43)		
*Z*3	43 (43–43)		
*Z*4	41 (40–43)		
*Z*5	40 (39–40)		
*s*1	43 (38–47)		
*s*2	38 (33–40)		
*s*3	46 (40–52)		
*s*4	45 (38–50)		
*s*5	45 (38–52)		
*s*6	41 (38–46)		
*S*1	44 (43–47)		
*S*2	42 (40–45)		
*S*3	43 (40–45)		
*S*4	42 (40–44)		
*S*5	43 (43–43)		
*px*2			
*px*3			
*r*2	49 (45–53)		
*r*3	39 (35–43)		
*r*4	47 (45–48)		
*r*5	38 (30–46)		
*r*6	25 (20–30)		
*R*1	27 (27–28)		
*R*2	31 (28–34)		
*R*3	32 (30–33)		
*R*4	35 (34–35)		
*R*5	35 (33–37)		
*R*6	40 (38–41)		
*UR*1	24 (20–28)		
*UR*2	28 (28–30)		
*UR*3	28 (25–30)		
*UR*4	28 (25–33)		
*UR*5	35 (33–38)		
*UR*6	42 (40–45)		

Peritreme and peritrematic plate. Peritreme extending anteriorly to level between *z*1 and *s*1. Peritrematic shield distinctly wide posteriad of coxa II, fused with dorsal shield near *z*1; with a pore (*gp*1) between coxae I–II, a lyrifissure (*ip*2) and a pore (*gp*2) between

coxae II–III, and with two lyrifissures (*ip*s and *ip*3) and a pore (*gp*3) posteriad of stigma. Post-stigmatic area of peritrematic plate free, with a distinct suture separating the more sclerotized inner section and the adjacent broad, lightly sclerotized band, about straight and tapering posteriorly, extending behind to level of posterior margin of coxa IV (Fig. 91).

Spermathecal apparatus (Fig. 92). Laelapid-type. Insemination pore apparently located at anterior margin at base of coxa IV; infundibulum indistinct; tubulus elongate and with posterior end differentiated in a sclerotized ramus, of about same diameter as tubulus, except for slightly flaring tip, attached to the ovoid sacculus; sperm duct indistinct.

Legs (Figs. 93–96). Lengths: I: 480 (410–550); II: 471 (418–525); III: 444 (388–500); IV: 531 (475–588). Setation (legs I–IV): coxae: $0-\frac{0\,0}{2\,0}-0$, $0-\frac{0\,0}{1\,1}-0$, $0-\frac{0\,0}{1\,1}-0$, $0-\frac{0\,0}{1\,0}-0$; trochanters: $1-\frac{1\,0}{2\,1}-1$, $1-\frac{0\,1}{1\,1}-1$, $1-\frac{1\,0}{1\,1}-1$, $2-\frac{1\,0}{1\,1}-0$; femora: $2-\frac{2\,3}{1\,3}-2$, $2-\frac{3\,2}{1\,2}-1$,$1-\frac{2\,1}{1\,0}-1$, $1-\frac{2\,1}{1\,0}-1$; genua: $2-\frac{3\,3}{2\,1}-2$,$2-\frac{3\,2}{1\,1}-2$, $2-\frac{2\,2}{1\,1}-1$, $2-\frac{2\,3}{1\,0}-1$; tibiae: $2-\frac{3\,3}{2\,1}-2$, $2-\frac{2\,2}{1\,1}-2$, $2-\frac{1\,2}{1\,1}-1$, $2-\frac{1\,3}{1\,1}-2$; tarsal setation: I not counted, 18, 18, 18. All legs with pretarsi containing a pair of strongly scletorized claws; median section of pulvilli of legs I–IV rounded. Leg setae aciculate, except *al* of trochater II (thorn-shaped) and *pd*2 of femur II (spatulate).

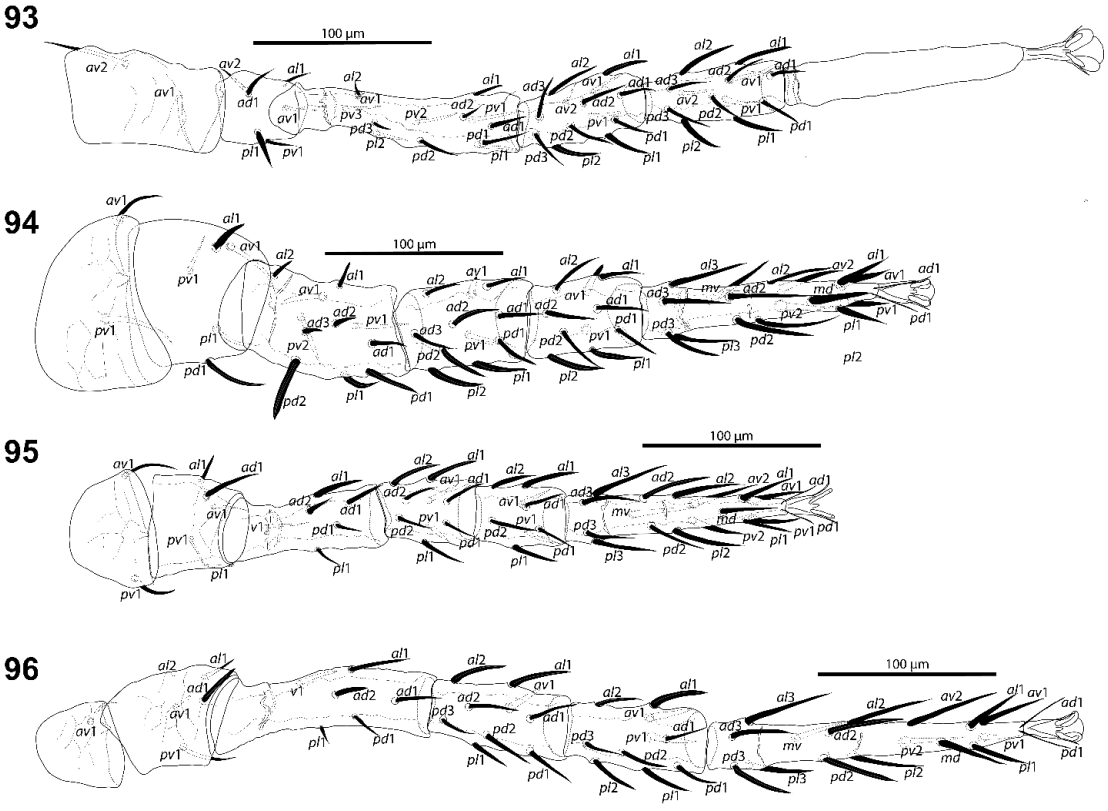


Figure 93–96. *Stratiolaelaps scimitus* (Womersley, 1956). Colombian female. 93. Leg I; 94. Leg II; 95. Leg III; 96. Leg IV.

Remarks. According to the revision of Walter & Campbell (2003), *S. scimitus* is very similar to *S. Stratiolaelaps miles* (Berlese, 1892), and they could be distinguished by the apotele (with only two tines in *S. miles*, and with an additional small tine in *S. scimitus*), the relative length of para-anal and post-anal setae (post-anal distinctly shorter in *S. miles*, and of about equal length in *S. scimitus*) and the curvature of margin of dorsal shield behind *S*2 (tapering gradually in *S. miles*, and tapering abruptaly in *S. scimitus*). The Colombian specimens fit better the characteristics mentioned for *S. scimitus*, except that the curvature of the posterolateral dorsal shield margin tapers gradually behind.

4.4. Discussion

Three laelapid species reported in this study, *G. aculeifer*, *G. queenslandicus* and *Gaeolaelaps* sp. nov., were found in a relatively large number in the soil inside the greenhouses, although they were also found in areas of natural vegetation. *Gaeolaelaps aculeifer* and *Gaeolaelaps* sp. nov. were found in large numbers and in all development stages in all greenhouses studied and in the natural vegetation close to the greenhouses, whereas *G. queenslandicus* was found primarily in the soil inside the greenhouses and in smaller number compared to the two previously named species. These facts suggest that these species are well adapted to the conditions of the rose cultivations.

Gaeolaelaps aculeifer is a well-known predator, whose distribution seemed to be restricted to temperate regions, mainly in Europe and North America (Moreira & Moraes 2015), although it has also been reported from Asia (Karg 1993a), Australia (Strong & Halliday 1994), Hawaiian islands (Tenorio 1982) and Iran (Kordeshami *et al.* 2015). Karg (1993b) reported this species in South America, but did not specify its distribution in this vast subcontinent, while Silva *et al.* (2018) reported this species in nests of *Gallinago paraguaiae* (Vieillot, 1816) in a region in southern Brazil. This is the first time that this species is reported in a region near to Equatorial line, although the climatic conditions of the Bogotá plateu are similar to the temperate zones where this mite is usually found.

In this study, *G. aculeifer* was found in soil of both rose cultivation and fragments of natural vegetation. It was previously reported from a wide variety of soils (Evans & Till 1966) that include both more conserved sites, as the costal meadows in Latvia (Salmane 1999), grassy arable fallows in Austria (Wissuwa *et al.* 2012), soil of oak forest in Iran (Kordeshami *et al.* 2015), and cultivated land, as gardens in Canada (Kevan & Sharma 1964) and citrus

orchards in Spain (Navarro-Campos *et al.* 2012). Its presence in crop areas, as well as in more conserved areas, may be due to its lower sensitivity to chemicals commonly used in agriculture, compared to other invertebrates (Jaabiri Kamoun *et al.* 2018; Owojori *et al.* 2014).

As *G. aculeifer* is a widely known species and currently included in standardized eco-toxicological tests ([OECD] Organisation for Economic Co-operation and Development 2016)(OECD 2016), it is known, in a better way, the characteristics in which this mite is found and can develop, compared with the other species found in this study. According to a review by Jänsch *et al.* (2005), *G. aculeifer* seems to prefer a neutral pH, temperature between 18 and 25 °C, relatively moist and well-aerated soils and a wide range of organic matter content. But the authors conceived the possibility that this species can tolerate low pH, such as those observed in soils with high content of organic matter, confirmed in this study.

G. angustus and *G. queenslandicus*, were described from specimens from Australia and Germany, respectively. Only the latter has been reported from other places, namely the Galapagos Islands (Karg 1993a), the Hawaiian islands (Tenorio 1982) and Brazil, in South America (Casanueva 1990; Freire 2007; Marticorena 2017).

Several *Gaeolaelaps* species have been reported and described from different places in South America, including the Andean region (Hyatt 1964; Karg 1978b, 1979, 1982, 1989, 1994, 2000, 2003, 2006; Sheals 1962); however, apparently none of them has been found in agricultural areas in he Andean region. Therefore, it is not surprising that *Gaeolaelaps* sp. nov. has not been reported before, despite its high abundance in rose cultivation.

Gaeolaelaps brevipellis, *Cosmolaelaps claviger*, and *Stratiolaelaps scimitus* seem to be species tyhpically found in areas of natural vegetation, where soil pH is usually lower, the organic matter content and humidity are usually higher (eg. soil pH in FV was lower than in FR, a rose crop area nearby). Alternatively, their absence from rose cultivation may reflect its susceptibility to the synthetic chemical used by growers. *Gaeolaelaps brevipellis* was described from specimens collected on El Bolson, Argentina, without reference of the ecosystem and characteristics of the habitat (Karg 1979). *Cosmolaelaps claviger* has been mostly reported in temperate areas; however, some specimens have been collected in Côte d'Ivoire and Brazil (Klompen & Johnson 2018).

The *Stratiolaelaps* species found in this study is placed is the *miles*-group, which has a cosmopolitan distribution. In a molecular and morphological study, Walter & Campbell (2003) concluded that the apparently cosmopolitan *S. miles* could actually be composed of a complex of cryptic species, of which the species found in this study can be part. Apparently,

five species of *Stratiolaelaps* have been described or reported from South America, namely *Stratiolaelaps brasiliensis* (Berlese, 1918) in Brazil, *Stratiolaelaps bregetovae* (Fonseca, 1959) in Bolivia, *Stratiolaelaps cardiophorus* (Berlese, 1916) in Argentina, *Stratiolaelaps longicostalis* (Karg, 1978b) in Chile and *Stratiolaelaps scimitus* (Womersley, 1956 in Brasil (reported by Freire & Moraes 2007 and Castilho et al. 2009).

Conversely, *Gymnolaelaps* sp. nov. was found exclusively in the grassland, characterised by a higher soil pH (5.1 ± 0.3) than in the forest fragment nearby (LV, 4.0 ± 0.1). *Gymnolaelaps* includes approximately 35 described species (Joharchi et al. 2011), with a worldwide distribution. Specimens of this genus has usually been found in ant nests, althought some species have been reports from rodent and bird nests, as well as in soil and litter (Joharchi and Halliday 2013). In the samples in which specimens of *Gaeolaelaps* sp. nov. were found, no ants or signs of the existence of a nearby ant nest were observed, indicating that it has no relation to that group of organisms.

This is the first morphological study of laelapid species from Colombia. Given the importance of rose cultivation in that country, it is important to determine the predators that can survive prevailing conditions of the natural vegetation as well as the condition of rose cultivation, where pesticides are commonly used and other growing practices that alter the environment profoundly are also employed. A subsequent activity after the conduction of this study is the ecological study to be conducted envisioning the discovery of species potentially useful fo the biological control of thrips and other edaphic pest species.

Acknowledgements

This research was supported by “Vicerrectoria Academica” of “Pontificia Universidad Javeriana (Project No. 000000000007367). We thank COLCIENCIAS (Departamento Administrativo de Ciencia, Tecnología e Innovación, Colombia) for the scholarship to the first author (Process No. 617-2013, Chapter 3). We also thank Council members (Peter Reutimann, Reinhard Gerecke, Peter Martin, Heinrich Schatz) of the foundation Pro Acarologia Basiliensis, Switzerland, for the donation of a microscope, which was very useful for the identification of the specimens in Colombia. We express our appreciation for help given by Bruce Halliday, David E. Walter, Alireza Nemati, Shahrooz Kazemi, Frederick Beaulieu, and Grazielle Furtado for the valuable suggestions and comments about the identification of the Colombian specimens; Augusto Ramirez-Godoy, Universidad Nacional de Colombia, for granting space for sampling processing and for the

support; and Jason Dunlop and Anja Friederichs, Museum für Naturkunde, Leibniz Institute for evolution and Biodiversity Science, for lending the types of *G. brevipellis*.

References

[OECD] Organisation for Economic Co-operation and Development (2016) Guidelines for the testing of chemicals No. 226. Predatory mite (*Hypoaspis* (*Geolaelaps*) *aculeifer*) reproduction test in soil. Available in: http://www.biotecnologiebt.it/userfiles/studies_types/2/files/OECD226-July-2016.pdf

Afifi, A.M. & Van Der Geest, L.P.S. (1984) Notes on the development and biology of the predaceous soil mite *Cosmolaealps claviger* (Berlese 1883) (Gamasida: Laelapidae). In: D. A. Griffiths and C. E. Bowman (Eds), *Acarology VI*. Ellis Horwood Limited Publishers, pp. 585–590.

Arutunjan, E.S. (1993) New species of the genus *Hypoaspis* Can., 1884 s. l. of the family Laelaptidae Berlese, 1892 (Parasitiformes). *Doklady Akademii Nauk Armenii* 94, 115–118.

Aswegen, P.I.M. & Loots, G.C. (1970) A taxonomic study of the genus *Hypoaspis* Canestrini sens. lat. (Acari: Laelapidae) in the Ethiopian region. *Publicações Culturais da Companhia de Diamantes de Angola* 82, 169–213.

Azevedo, L.H. de, Emberson, R.M., Esteca, F. de C.N. & Moraes, G.J. de (2015) Macrochelid Mites (Mesostigmata: Macrochelidae) as Biological Control Agents. In: D. Carrillo, G. J. de Moraes, and J. E. Peña (Eds), *Prospects for Biological Control of Plant Feeding Mites and Other Harmful Organisms*. Springer International Publishing, Switzerland, pp. 103–132.

Bahrami, F., Arbabi, M., Shoushtari, R.V. & Kazemi, S. (2011) Mesostigmatic Mites Associated with Coleoptera and Biodiversity Calculation of These Mites Phoretic on Dung Beetles in Golestan Province (North of Iran). *Middle-East Journal of Scientific Research* 9, 345–366.

Beaulieu, F. (2009) Review of the mite genus Gaeolaelaps Evans & Till (Acari: Laelapidae), and description of a new species from North America, G. gillespiei n. sp. *Zootaxa* 2158, 33–49.

Berlese, A. (1916). *Centuria seconda di Acari Nuovi*. Redia, 12, 125-177.

Berlese, A. (1918) *Centuria quarta di Acari Nuovi*. Redia, 13, 115-192.

Berlese, A. (1883) *Acari, Myriapoda et Scorpiones Hucusque in Italia Reperta, fasc. IV*. PATAVII Ty.

Berlese, A. (1892) *Acari, Miriapoda et Scorpiones Hucusque in Italia Reperta, fasc. LXIII.*

Canestrini, G. (1884) Acari nuovi o poco noti. I. Acari Italiani. II. Acari dell'Australia. *Atti del Reale Intituto Veneto* 2, 693–724.

Canestrini, G. (1885) Prospetto dell'acarofauna italiana. Famiglia dei Gamasini. *Atti del Reale Intituto Veneto di Scienze, Lettere ed Arti* 6, 49–127.

Carrillo, D., Moraes, G.J. de & Peña, J.E. eds. (2015) *Prospects for Biological Control of Plant Feeding Mites and Other Harmful Organisms*. Springer International Publishing, Switzerland. https://doi.org/10.1007/978-3-319-15042-0

Casanueva, M.E. (1990) Comparative and phylogenetic studies of Laelapidae (Acari: Mesostigmata). Partial Fulilllment of the Requirements for the Degree Doctor of Philosophy. The Ohio State University. 194 p. Available in: https://etd.ohiolink.edu/!etd.send_file?accession=osu1487673114113136&disposition=inline

Castilho, R.C., Moraes, G.J., Silva, E.S., Freire, R.A.P., Eira, F.C. (2009) The predatory mite Stratiolaelaps scimitus as a control agent of the fungus gnat Bradysia matogrossensis in commercial production of the mushroom Agaricus bisporus. *International Journal of Pest Management*, 55 (3), 181-185.

Costa, M. (1966) A redescription of *Hypoaspis queenslandicus* (Womersley, 1956) comb. nov (Acari, Mesostigmata) with notes on the genus *Hypoaspis* Canestrini. *Israel Journal of Zoology* 15, 141–147.

Costa, M. (1968) Little known and new litter-inhabiting laelapine mites (acari, mesostigmata) from israel. *Israel Journal of Zoology* 17, 1–30.

Evans, G.O. (1963) Observations on the chaetotaxy of the legs in the free-living Gamasina (Acari: Mesostigmata). *Bulletin of the British Museum (Natural History). Zoology* 10, 275–303.

Evans, G.O. & Till, W.M. (1966) Studies on the British Dermanyssidae (Acari: Mesostigmata). Part II Classification. *Bulletin of The British Museum (Natural History) Zoology* 14, 109–370.

Faraji, F., Abedi, L. & Ostovan, H. (2008) A new species of *Hypoaspis* Canestrini from Iran with a key to the Iranian species of *Hypoaspis* (Acari, Gamasina, Hypoaspididae). *Zoosystematics and Evolution* 84, 205–209.

Faraji, F. & Halliday, B. (2009) Five new species of mites (Acari: Laelapidae) associated with large Australian cockroaches (Blattodea: Blaberidae). *International Journal of Acarology* 35, 245–264.

Farrier, M.H. & Hennessey, M.K. (1993) *Soil-inhabiting and free-living Mesostigmata (Acari-Parasitiformis) from North America. An annotated checklist with bibliography and index*. Technical. North Carolina Agricultural Research Service, Technical Bulletin, North Carolina, Raleigh, North Carolina.

Fenalco (2017) *Boletín Nº 46 Boletín Económico Sectorial Sector Floricultor*. Investiga: Observatorio Económico de Comercio - Fenalco Antioquia. 32 p. Available in: https://www.fenalcoantioquia.com/publicaciones/boletin-sectorial46

Freire, R. a. P. (2007) Ácaros predadores do Estado de São Paulo, com ênfase em Laelapidae (Acari: Mesostigmata), com potencial de uso no controle de pragas de solo. Thesis. Presented in Partial Fulilllment of the Requirements for the Degree Doctor of Philosophy. Escola Superior de Agricultura "Luiz de Queiroz." Universidade de São Paulo. 290 p.

Fonseca, F. (1959/1960) Notas de Acarologia. XLVI. Acarofauna zooparasita na Bolivia. *Memórias do Instituto Butantan*, 29, 89-141.

Freire, R.A.P. & Moraes, G.J. (2007) Description of a new species of *Cosmolaelaps* Berlese (Acari: Laelapidae, Hypoaspidinae) from Brazil and its biological cycle. International Journal of Acarology, 33 (4), 353-358.

Halbert, J.N. (1923) Notes on Acari with descriptions of new species. *Journal of the Linnean Society, Zoology* 35, 363–392 + 3 plates.

Hull, J.E. (1918) Terrestrial Acari of the Tyne Province London. *Transactions of the Natural History Society of Northumberland* 5, 13–88.

Hunter, P.E. & Costa, M. (1971) Description of Gymnolaelaps shealsi n. sp. (Acarina: Mesostigmata) associated with the imported fire ant. *Journal of the Georgia Entomological Society* 6, 51–53.

Hyatt, K.H. (1964) A collection of Mesostigmata (Acari) associated with Coleoptera and Hemiptera in Venezuela. *Bulletin of the British Museum (Natural History)* 11, 465–509.

Jaabiri Kamoun, I., Jegede, O.O., Owojori, O.J., Bouzid, J., Gargouri, R. & Römbke, J. (2018) Effects of deltamethrin, dimethoate, and chlorpyrifos on survival and reproduction of the collembolan Folsomia candida and the predatory mite Hypoaspis aculeifer in two

African and two European soils. *Integrated Environmental Assessment and Management* 14, 92–104.

Jänsch, S., Amorim, M.J. & Römbke, J. (2005) Identification of the ecological requirements of important terrestrial ecotoxicological test species. *Environmental Reviews* 13, 51–83.

Jimeno, E. & Sierra, A. (2008) Composición y diversidad de la comunidad de ácaros (Arachnida: Acari) de hojarasca en dos coberturas vegetales en el Santuario de Flora y Fauna Otún Quimbaya (Risaralda -Colombia). Universidad El Bosque.

Joharchi, O., Halliday, B., Saboori, A. & Kamali, K. (2011) New species and new records of mites of the family Laelapidae (Acari: Mesostigmata) associated with ants in Iran. Zootaxa, 2972, 22–36.

Joharchi, O., Halliday, B. (2013) A new species and a new record of Gymnolaelaps Berlese from Iran (Acari: Laelapidae), with a review of the species occurring in the Wetern Palaearctic Region. Zootaxa, 3646 (1), 39-50. doi: 10.11646/zootaxa.3646.1.3

Karg, W. (1962) Zur systematik und postembryonalen entwicklung der Gamasiden (Acarina, Parasitiformes) landwirtschaftlich genutzter böden. *Mitteilungen aus dem Zoologischen Museum in Berlin* 38, 23–119.

Karg, W. (1965) Larvalsystematische und phylogenetische Untersuchung sowie Revision des Systems der Gamasina Leach, 1915 (Acarina, Parasitiformes). *Mitteilungen aus dem Zoologischen Museum in Berlin* 41, 193–340.

Karg, W. (1971) *Acari (Acarina), Milben. Unterordnung Anactinochaeta (Parasitiformes). Die freilebenden Gamasina (Gamasides), Raubmilben. Die Tierwelt Deutschlands*. 59th ed.

Karg, W. (1978a) Die gattung *Pseudoparasitus* Oudemans, 1902. *Mitteilungen aus dem Zoologischen Museum in Berlin* 54, 203–212.

Karg, W. (1978b) Zur Kenntnis der Milbengattungen *Hypoaspis*, *Androlaelaps* und *Reticulolaelaps* (Acarina, Parasitiformes, Dermanyssidae). *Zoologisches Jahrbuch der Systematik* 105, 1–32.

Karg, W. (1979) Die gattung *Hypoaspis* Canestrini, 1884 (Acarina, Parasitiformes). *Zoologisches Jahrbuch der Systematik* 106, 65–104.

Karg, W. (1982) Zur Kenntnis der raubmilbengattung Hypoaspis Canestrini, 1884 (Acarina, Parasitiformes). *Mitteilungen aus dem Zoologischen Museum in Berlin* 58, 233–256.

Karg, W. (1989) Zur kenntnis der untergattungen Geolaelaps, Alloparasitus und Laelaspis der raubmilbengattung Hypoaspis Canestrini, 1884 (Acarina, Parasitiformes). *Mitteilungen aus dem Zoologischen Museum in Berlin* 65, 115–126.

Karg, W. (1993a) Raubmilben der Hypoaspididae, Laelapidae und Phytoseiidae auf dem Galapagos-Archipel (Acarina, Parasitiformes). *Mitteilungen aus dem Zoologischen Museum in Berlin* 69, 261–284.

Karg, W. (1993b) *Teil 59. Acari (Acarina), Milben Parasitiformes (Anactinochaeta) Cohors Gamasina LEACH Raubmilben*. Gustav Fischer Verlag Jena, Villengang, Germany.

Karg, W. (1994) Raubmilben der cohors Gamasina Leach (Acarina, Parasitiformes) vom Galapagos-Archipel. *Mitteilungen aus dem Zoologischen Museum in Berlin* 70, 179–216.

Karg, W. (2000) Zur Systematik der Raubrnilbenfamilien Hypoaspididae v. Vitzthum, 1941 und Rhodacaridae Oudemans, 1902 (Acarina, Parasitiformes) mit neuen Arten aus Sud- und Mittelarnerika. *Mitteilungen aus dem Museum für Naturkunde in Berlin, Zoologische Reihe* 76, 243–262.

Karg, W. (2003) Die raubmilbengattungen Afrogamasellus Loots et Ryke und *Oloopticus* Karg mit zwei neuen Arten - Ein Beitrag zur Evolution der Bodenmilben (Acarina, Gamasina). , 75 (1), 23-33. *Abhandlungen und Berichte des Naturkundemuseums Görlitz* 75, 23–33.

Karg, W. (2006) The systematics of Parasitiformes, especially of Gamasina Leach (Acarina), with new species from Ecuador. *Mitteilungen aus dem Museum für Naturkunde in Berlin – Zoologische Reihe* 82, 140–169.

Kavianpour, M. & Nemati, A. (2014) *Gaeolaelaps* (Acari : Laelapidae) mites of Iran with description of a new species. *Journal of Crop Protection* 3, 315–325.

Kavianpour, M., Nemati, A., Gwiazdowicz, D.J. & Kocheili, F. (2013) A new species of the genus *Gaeolaelaps* (Acari, Mesostigmata, Laelapidae) from Iran. *ZooKeys* 277, 1–11.

Kazemi, S., Rajaei, A. & Beaulieu, F. (2014) Two new species of *Gaeolaelaps* (Acari: Mesostigmata: Laelapidae) from Iran, with a revised generic concept and notes on significant morphological characters in the genus. *Zootaxa* 3861, 501–530.

Kevan, D.K.M. & Sharma, G.D. (1964) Observations on the biology of *Hypoaspis aculeifer* (Canestrini 1884), apparently new to North America (Acarina: Mesostigmata: Laelaptidae). *Acarologia* 6, 647–658.

Khalesi, T. & Kazemi, S. (2018) A new species and new record of *Gaeolaelaps* Evans& Till (Acari: Mesostigmata: Laelapidae) from Iran. *Acarologia* 58, 628–639.

Klompen, H. & Johnson, N. (2018). Ohio State Acarology Laboratory (OSAL), Ohio State University. Museum of Biological Diversity, The Ohio State University. *Occurrence dataset* https://doi.org/10.15468/dzwr2y accessed via GBIF.org on 2018-06-27. https://www.gbif.org/occurrence/1019087850

Kordeshami, A.B., Khajehali, J. & Nemati, A. (2015) Some edaphic mesostigmatic mites from Lordegan, Chaharmahal Bakhtiari province with their world distribution. *Journal of Crop Protection* 4, 589–604.

Krantz, G.W. & Ainscough, B.D. (1990) Acarina: Mesostigmata (Gamasida). In: D. L. Dindal (Ed), *Soil Biology Guide*. A Wiley-Interscience Publication, New York, pp. 583–666.

Lindquist, E.E. & Evans, G.O. (1965) Taxonomic concepts in the Ascidae, with a modified setal nomenclature for the idiosoma of the Gamasina (Acarina: Mesostigmata). *Memoirs of the Entomological Society of Canada* 97, 5–66.

Lindquist, E.E., Krantz, G.W. & Walter, D.E. (2009) Order Mesostigmata. In: G. W. Krantz and D. E. Walter (Eds), *A Manual of Acarology*. Texas Tech University Press, Lubbock, Texas, pp. 124–232.

Lindquist, E.E. & Moraza, M.L. (2008) A new genus of flower-dwelling melicharid mites (Acari: Mesostigmata: Ascoidea) phoretic on bats and insects in Costa Rica and Brazil. *Zootaxa* 1685, 1–37.

López-Bermúdez, R. (2014) Evaluación de la capacidad de depredación de la especie *Stratiolaelaps* sp. (Acari: Laelapidae) en poblaciones de *Thrips palmi* Karny (Thysanoptera: Thripidae). Universidad Nacional de Colombia, 66 p.

Luxton, M. (1998) The oribatid and parasitiform mites of Ireland, with particular reference to the work of J.N. Halbert (1872-1948). *Bulletin Irish Biogeographical Society* 22, 2–72.

Ma, L.-M. (1996) Three new species of the genus *Hypoaspis* from Jilin Province, China (Acari: Laelapidae). *Acta Zootaxonomica Sinica* 21, 48–54.

Marín-Beitia, E.P., Sánchez, M., Sierra, A. & Peñaranda, M.R. (2015) Poblaciones de ácaros , colémbolos y otra mesofauna en un inceptisol bajo diferentes manejos. *Revista Facultad Nacional de Agronomía Medellín* 68, 7411–7422.

Marticorena, J.L.M. (2017) Alteration of the faunistic composition of edafic mites according to land use in the Central-Southern region of Brazil. Thesis. Presented in Partial Fulilllment of the Requirements for the Degree Doctor of Philosophy. Faculdade de Ciências Agrárias e Veterinárias câmpus de Jaboticabal, Universidade Estadual Paulista – UNESP. 196 p. Available in: https://repositorio.unesp.br/.../munozmarticorena_jl_dr_jabo.pdf?

Moreira, G.F., Klompen, H. & Moraes, G. (2014) Redefinition of *Cosmolaelaps* Berlese and description of five new species from Brazil. *Zootaxa* 3764, 317–346.

Moreira, G.F. & Moraes, G.J. (2015) The Potential of Free-Living Laelapid Mites (Mesostigmata: Laelapidae) as Biological Control Agents. In: D. Carrillo, G. J. de Moraes,

and J. E. Peña (Eds), *Prospects for Biological Control of Plant Feeding Mites and Other Harmful Organisms*. Springer International Publishing, Cham, pp. 77–102.

Navarro-Campos, C., Pekas, A., Moraza, M.L., Aguilar, A. & Garcia-Marí, F. (2012) Soil-dwelling predatory mites in citrus: Their potential as natural enemies of thrips with special reference to *Pezothrips kellyanus* (Thysanoptera: Thripidae). *Biological Control* 63, 201–209.

Nemati, A. & Gwiazdowicz, D.J. (2016) A new genus and species of Laelapidae from Iran with notes on *Gymnolaelaps* Berlese and *Laelaspisella* Marais & Loots (Acari, Mesostigmata). *ZooKeys* 2016, 23–49.

Nemati, A. & Kavianpour, M. (2013) A new species of Laelapidae (Acari: Mesostigmata) from Iran. *Journal of Crop Protection* 2, 63–73.

Nemati, A. & Mohseni, M. (2013) Two new species of *Gaeolaelaps* (Acari: Laelapidae) from Iran. *Zootaxa* 3750, 191–203.

Owojori, O.J., Waszak, K. & Roembke, J. (2014) Avoidance and reproduction tests with the predatory mite *Hypoaspis aculeifer*: Effects of different chemical substances. *Environmental Toxicology and Chemistry* 33, 230–237.

Reyes, F. (2016) Desempeño del sector floricultor: Informe 2016. *Superintendencia de Sociedades. Delegatura de Asuntos Económicos y Contables. Grupo de Estudios Económicos y Financieros*, 25. Available from: https://www.supersociedades.gov.co/Historial de Noticias/2016/EE-Estudio sector Flores-2016 VI 13_Final.pdf (May 20, 2018).

Reyes, F. (2017) Desempeño del sector floricultor: Informe 2017. *Superintendencia de Sociedades. Delegatura de Asuntos Económicos y Contables. Grupo de Estudios Económicos y Financieros*, 23. Available from: https://www.supersociedades.gov.co/SiteCollectionDocuments/2017/EE-Estudio sector Flores-2017 09 28.pdf (May 20, 2018).

Rosario, R.M.T. (1981) Philippine Hypoaspidinae (Acarina: Mesostigmata: Laelapidae). *Philippine Entomologist* 5, 23–82.

Rueda-Ramírez, D., Castilho, R.C. & Moraes, G.J. de (2013) Mites of the superfamily Rhodacaroidea (Acari: Mesostigmata) from Colombia, with a key for the world species of *Desectophis* Karg (Ologamasidae). *Zootaxa* 3734, 521–535.

Rueda-Ramírez, D., Varela, A. & Moraes, G.J. de (2016) Soil mites of the families Ascidae, Blattisociidae and Melicharidae (Acari: Mesostigmata) from mountainous areas of Colombia. *Zootaxa* 4127, 493–514.

Ryke, P.A.J. (1963) Some free-living Hypoaspidinae (Acari: Mesostigmata) from South Africa. *Revista de Biologia* 5, 1–15.

Salmane, I. (1999) Soil free-living predatory Gamasina mites (Acari , Mesostigmata) from the coastal meadows of Riga Gulf , Latvia. *Latvijas Entomologs* 37, 104–114.

Sheals, J.G. (1962) Mesostigmata: Gamasina (Acari). In: C. D. Debouttevillle and E. Rapoport (Eds), *Biologie de L'Amerique Australe (I). Etudes sur la faune du sol. Centre National de La Recherche Scientifique*. Paris, pp. 83–110.

Silva, D.E., Silva, G.L. Da, Nascimento, J.M. Do & Ferla, N.J. (2018) Mite fauna associated with bird nests in Southern Brazil. *Systematic & Applied Acarology* 23, 426–440.

Solano, A. (2009) Floricultura Colombiana: Un caso de colaboración exitosa en protección de cultivos. *Asocolflores*. 63 p.

Spain, A. V. & Luxton, M. (1971) Catalog and bibliography of the acari of the New Zealand sub region. *Pacific Insects Monography* 25, 179–226.

Strong, K.L. & Halliday, R.B. (1994) Three New Species of *Hypoaspis* Canestrini (Acarina: Laelapidae) Associated with Large Australian Cockroaches. *Australian Journal of Entomology* 33, 87–96.

Teng, K.-F. (1982) On some new species and new records of Laelapid mites from China. *Acta Zootaxonomica Sinica* 7, 160–165.

Tenorio, J.M. (1982) Hypoaspidinae (Acari: Gamasida: Laelapidae) of the Hawaiian Islands. *Pacific Insects* 24, 259–274.

Tipton, V.J. (1960) The genus *Laelaps* with a review of the Laelaptinae and a new subfamily Alphalaelaptinae (Acarina: Laelaptidae). *University of California Publications in Entomology* 16, 233-356–47.

United States Department of Agriculture (1999) *Guía para la evaluación de la calidad y salud del suelo*. United States Department of Agriculture.

Walter, D.E. & Campbell, N.J.H. (2003) Exotic vs endemic biocontrol agents: Would the real *Stratiolaelaps miles* (Berlese) (Acari: Mesostigmata: Laelapidae), please stand up? *Biological Control* 26, 253–269.

Walter, D.E. & Oliver, J.H. (1989) *Geolaelaps oreithyiae*, n. sp. (Acari, Laelapidae), a thelytokous predator of arthropods and nematodes, and a discussion of clonal reproduction in the Mesostigmata. *Acarologia* 30, 293–303.

Wissuwa, J., Salamon, J.A. & Frank, T. (2012) Effects of habitat age and plant species on predatory mites (Acari, Mesostigmata) in grassy arable fallows in Eastern Austria. *Soil Biology and Biochemistry* 50, 96–107.

Womersley, H. (1956) On some new Acarina-Mesostigmata from Australia, New Zeland and New Guinea. *The Journal of the Linnean Society of London, Zoology* 42, 505–599.

Zhang, Z.-Q.Q. (2003) *Mites of Greenhouses: Identification, Biology and Control*. CABI Pub. Available from: https://books.google.com.br/books?id=zVaSCyiK540C.

5. BIOLOGY AND PREDATION CAPACITY OF A COLOMBIAN POPULATION OF *Gaeolaelaps aculeifer* (ACARI: MESOSTIGMATA: LAELAPIDAE) ON THE EDAPHIC PHASES OF *Frankliniella occidentalis* (THYSANOPTERA: THRIPIDAE)

ABSTRACT

Gaeolaelaps aculeifer (Canestrini) is a well-known generalist predator currently commercialized to control several edaphic organisms, including Diptera larvae and thrips pre-pupae and pupae. The recent detection of this species in the Bogotá plateau of Colombia raised the interest to investigate details about its biology and evaluate its potential as a biological control agent for use in that country against *Frankliniella occidentalis* Pergande (Thripidae), the western flower thrips. The objective of this work was to evaluate experimentally the biological characteristics of the Colombian population of *G. aculeifer* and its predation capacity on *F. occidentalis*, as well as the possibility to use a factitious prey for its mass production or as complementary food in predator field releases. The study was conducted with three diets: *F. occidentalis* (T), *Aleuroglyphus ovatus* (A), and *A. ovatus* + *F. occidentalis* (TA), in a randomized design experiment using *G. aculeifer* females. Predation rate was about 2.6 pre-pupae/pupae of *F. occidentalis*/female/day when only thrips was available as prey, reducing to 2.0 when thrips was combined with *A. ovatus*. Oviposition was the same when fed each of those prey and their combination. Some differences between diets were observed for duration of some periods of the life cycle, but no differences were observed for life table indexes. The greatest differences observed between this and what has been reported for other populations of *G. aculeifer* (fed other prey) refer to duration of deutonymphal period and R_o (respectively longer and higher in the former). It is concluded that the Colombian population is able to feed, develop and reproduce on pre-pupae and pupae of *F. occidentalis* and that *A. ovatus* can be used for its mass production and as complementary diet in field releases of the predator.

Keywords: Laelapidae; Colombia; Biological control; Life cycle; Predation; Mite diet

5.1. Introduction

Gaeolaelaps aculeifer (Canestrini, 1883) is a soil-dwelling predatory mite used commercially for the control of dipterans, thrips and mites since 1996 (van Lenteren 2011). This species has been reported from a wide variety of soils (Evans and Till 1966) in different countries, especially in temperate areas (Kevan and Sharma 1964; Skorupski and Luxton 1998; Salmane 2001; Fenda and Schniererová 2005; Moraza and Peña 2005; Manu 2010; Manu and Honciuc 2010; Bahrami et al. 2011; Wissuwa et al. 2012; Navarro-Campos et al. 2012; Majidi and Akrami 2013; Barczyk and Madej 2014; Kordeshami et al. 2015), but also in subtropical areas of South America (Da Silva et al. 2013; Silva et al. 2018). It has been recently found in soils of rose fields and surrounding natural vegetation in the Bogota plateau

(Rueda-Ramirez *et al.* in preparation), whose climate is classified as Cfb (Köppen-Geiger classification; Peel *et al.* 2007), also typical of temperate areas where the species was previously found.

Thrips species, especially the western flower thrips, *Frankliniella occidentalis* Pergande (Thripidae), are important rose pests in Colombia. Not only for negatively affecting rose yield and quality (Valencia 2013), but also for causing rejection of shipments when found in quarantine at importing countries (Attavian 2014). Chemical control has been shown not sufficiently effective for its control, and other control measures are considered necessary. In several countries, thrips have been controlled biologically, with the use of plant inhabiting predatory mites of the family Phytoseiidae, as *Amblyseius swirskii* Athias-Henriot and *Amblydromalus limonicus* (Garman and McGregor) (van Lenteren 2011; Buitenhuis et al. 2015), and predatory insects, as *Orius insidiosus* (Say) (Hemiptera: Anthocoridae) (van Lenteren 2011; Avellaneda et al. 2016). But soil mites have also been used for thrips control, given that thrips pre-pupae and pupae are mostly found on the soil. Buitenhuis and Shipp (2008) showed that up to 93% of the pupation of *F. occidentalis* takes place on the soil. Soil inhabiting predatory mites, such as *G. aculeifer* and the macrochelid *Macrocheles robustulus* (Berlese) (Messelink and Holstein-saj 2008; van Lenteren 2011), have also been used for thrips control (Berndt et al. 2004a). The former has been reported to prey on mites of the cohort Astigmatina (Krantz 2009), commonly found in stored food and shown as suitable for mass production of this predator (Lobbes and Schotten 1980; Glockemann 1992; Navarro-Campos et al. 2016) and other biological control agents (Gerson et al. 2003; Barbosa and de Moraes 2015; Barbosa and Moraes 2016). Astigmatina species have also been used as complementary food in field releases (Grosman *et al.* 2011; Muñoz-Cárdenas *et al.* 2017a,b). Biological control strategies with predatory mites have not been explored in Colombia for thrips control.

Since the Convention on Biological Diversity in 1992 (CBD; see www.cbd.int), importation of exotic organisms has been restricted in many countries (van Lenteren et al. 2011), including Colombia (Ministerio del Medio Ambiente 1993; Gutiérrez-Bonilla 2006; López-Ruiz et al. 2012; Ministerio de Ambiente y Desarrollo Sostenible 2012). The restriction has also been applied to the importation of biological control agents. Hence, evaluations of native potential biological control agents are warranted, especially of those that have been successively used in other countries, as *G. aculeifer* for thrips control. The first step in such evaluations should be the conduction of basic biological studies of the local population comparing it with other populations.

The objective of this work was to evaluate the biological characteristics of the Colombian population of *G. aculeifer* on *F. occidentalis*, its predation capacity on the same prey and the possibility to use a factitious prey for its mass production or as complementary food in field releases. The hypotheses raised in this study were: 1) the biological characteristics and predation potential on *F. occidentalis* of the Colombian population of *G. aculeifer* is comparable to those of populations of other countries; and 2) the provision of an alternative prey (astigmatine mite) in field releases of this predator does not affect significantly its performance as a predator of *F. occidentalis*.

5.2. Material and Methods

The work was conducted at "Laboratorio de Entomologia, Universidad Nacional de Colombia", Bogota, between May and November 2017, in a growth chamber at 21 ± 1 °C, 65 ± 10% RH, in darkness. The temperature and humidity levels were selected considering the observed conditions in representative areas of rose production in the Bogotá plateau (personal observation). Voucher specimens used in the study were deposited in the mite reference collections of "Museo Javeriano de Historia Natural, Pontificia Universidad Javeriana" (MJHN-PUJ), Bogota, Cundinamarca, Colombia, and "Departamento de Entomologia e Acarologia, Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo", Piracicaba, São Paulo state, Brazil.

5.2.1. Colony of *Gaeolaelaps aculeifer*

Mites used in this study were taken from a colony established with about 30 specimens originally collected between June and December 2016 from soil of rose cultivations in greenhouses at Cogua (05°03'23.3"N 073°55'44.4"W), Fatacativá (04°46'39.4–40.7"N 074°19'23.9–24.8"W), Guasca (04°50'38.3"N 073°53'07.9"W), Nemocón (05°07'03.1-03.2"N 073°51'31.7–31.9"W) and Tocancipá (04°59'19.3"N 073°54'15.9"W), in the Bogota plateau. The colony was maintained in rearing units corresponding to an adaptation of what was described by Abbatiello (1965) and Freire and Moraes (2007). It consisted of a plastic container (10 cm diameter and 7 cm high), whose bottom was covered with a layer about 1.5 cm thick of a mixture of nine parts of gypsum and one part of activated charcoal. The mites were fed with a mixture of all stages of an unidentified free-living rhabditid nematode on

pieces of bean pods (*Phaseolus vulgaris* L.) serving as their growing substrate (Moreira et al. 2015), and a mixture of all developmental stages of the mite *Aleuroglyphus ovatus* (Troupeau) (Sarcoptiformes, Astigmatina, Acaridae) on pieces of the commercial dog food Purina® (Freire and Moraes 2007b). The units were maintained permanently humid by daily additions of distilled water to the base, and closed with a plastic film.

5.2.2. Colony of *Frankliniella occidentalis*

A stock colony of *F. occidentalis* was maintained on bean and cucumber (*Cucumis sativus* L.) plants. Pre-pupae and pupae were obtained in auxiliary chambers each consisting each of a 1 L plastic container whose top had an opening covered with fine fabric to allow ventilation and whose bottom was covered with a few sheets of paper towel. Bean and cucumber leaves and flowers containing thrips immatures were periodically transferred to a chamber, together with flowers of chrysanthemum (*Chrysanthemum* sp.) that served as oviposition and mating sites and probably also for other purposes (Kiers et al. 2000). Post-embryonic immatures coming from the leaves moved down to the paper towel sheets to molt to pre-pupae and pupae that were easily taken from the sheets for use in the study. The flowers were from time to time transferred back to the bean and cucumber plants to provide new progeny to the stock colony.

5.2.3. Predation and oviposition on different prey

Each one of the experimental units consisted of a small Petri dish (4 cm in diameter and 1.3 cm in height) whose bottom was covered as described for the units to maintain *G. aculeifer* stock colony. The different items evaluated as prey were: pre-pupae and pupae of *F. occidentalis* (T), all stages of *A. ovatus* (A), and a mixture of both prey (TA).

Each treatment had 33–35 replicates, each corresponding to a 5–6-day-old gravid female. Females were obtained by rearing mites from the egg stage (each egg in a unit), associating each with a male and making sure mating occurred. Females were then starved for 24 h and then five pre-pupae and pupae of *F. occidentalis* were transferred to each unit. The numbers of consumed prey and of eggs laid were counted daily, when consumed and unfed prey were replaced by new prey. Evaluation was done for 10 consecutive days. Distilled water was added daily to each unit to maintain humidity. Means were compared using generalized

linear mixed models with replicates (females) as random factor and day and diet as fixed factors, with Poisson distribution, with statistical software R (version 3.4.3, 2017).

5.2.4. Life Tables

Each of 60 *G. aculeifer* females taken from the stock colony was isolated in an experimental unit of the type described in the previous test. After 12 h, the female and the eggs it laid were removed, leaving a single egg per unit. The units were divided into three groups of 20 units, each group being randomly assigned to be fed with one of the food types mentioned for the predation and oviposition test. Food was provided only from the protonymphal stage, as larvae were observed not to feed in preliminary tests. Numbers of prey offered daily to each predator were: treatment (T), five pre-pupae/pupae of *F. occidentalis*; treatment (A), 7-10 nymphs or adults of *A. ovatus*; treatment (TA), five pre-pupae/pupae of *F. occidentalis* and 7-10 nymphs or adults of *A. ovatus*. Determination of the duration of immature stages was done by searching for exuviae in the units every 12 h. At each examination, mites of each stage were examined to determine basic morphological and behavioral characteristics under a stereomicroscope (up to 50 x). The units were examined only once a day after mites reached adulthood, to determine duration of reproductive phases as well as oviposition.

Raw data were analyzed using the age-stage, two-sex life table procedure with the TWOSEX-MSChart program (Chi and Liu 1985; Chi 1988, 2016). Calculated life table parameters were intrinsic rate of increase (r_m), net reproduction rate (R_o), finite rate of increase (λ), mean generation time (T), fecundity and sex ratio.

The estimates and standard errors of developmental time, longevity, fecundity, and population parameters were obtained through the bootstrap technique, with 100,000 bootstraps. The differences between treatments for each aggregation type were assessed with paired bootstrap test with the same program described above. The figures were prepared using R, version 3.4.4 (The R foundation for Statistical Computing, 2018-03-15).

5.3. Results

5.3.1. Predation and oviposition

The mean number of *F. occidentalis* pre-pupae and pupae killed by *G. aculeifer* was significantly higher when those were not combined with *A. ovatus* (Table 1). Mean daily oviposition (2.5–2.9 eggs) rates were not statistically different between treatments (Table 1).

Table 1. Daily predation and oviposition of *Gaeolaelaps aculeifer* on different prey at 21 ± 1°C, 60 ± 15% UR and in darkness.

Diet	Predation	Oviposition
F. occidentalis pre-pupae and pupae	2.6 ± 0.1a	2.9 ± 0.1a
Aleuroglyphus ovatus	-[1]	2.5 ± 0.1a
A. ovatus + *F. occidentalis* pre-pupae and pupae	2.0 ± 0.1b	2.9 ± 0.1a

[1] not evaluated; in the same column, treatments whose means are followed by a same letter are not significantly different (Generalized Linear Mixed Models, $p<0.05$).

5.3.2. Morphological and behavioral details of the predator

Eggs are whitish, ovoid and smooth, and usually laid in protected places in the rearing unit (depressions or next to particles of the mixture of gypsum and activated charcoal). These were often partially covered by the female with particles close to the eggs, with the help of their palpi and first pair of legs. Larvae and protonymphs are also whitish, the latter moving more quickly than the former. Deutonymphs are cream-yellowish, lightly sclerotized and very similar in shape to adults, allowing sex recognition soon after molting; at this stage, they moved more quickly than protonymphs. Adult females are ovoid, with a well-defined sub-triangular brownish dorsal shield that partially covers the idiosoma and that is surrounded by a whitish unsclerotized cuticle; they move very quickly. Adult males are smaller than adult females and have idiosoma posteriorly truncate and totally covered by the brownish dorsal shield; they move much more slowly than adult females. The need for insemination to allow oviposition was not evaluated in detail in this study. However, observations of a few females indicated that unfertilized females produced male offspring (arrhenotokous parthenogenesis), while fertilized females produced both female and male offspring.

5.3.3. Life table

Protonymphs, deutonymphs and adults were observed to feed on both prey types. Although not quantified in detail, observations of a few adult females indicated that each of them consumed up to four pre-pupae or pupae per day, while adult males consumed each a maximum of two pre-pupae or pupae in the same period. Survivorship of immatures (Table 2) was always very high (≥95% for each stage and for the whole immature phase); only two mites died during the study, one in the larval stage, when fed with *F. occidentalis*, and another in the protonymphal stage, when fed with *F. occidentalis* + *A. ovatus* (Table 2, Figure 1). Duration of the deutonymphal stage was significantly longer when prey was *F. occidentalis* than when it was *A. ovatus*. As a consequence, duration of the total immature phase was also significantly longer on *F. occidentalis*. No other significant differences were observed for duration of immatures. The larval stage was the shortest (1.8–1.9 days), and the deutonymphal stage, the longest (8.6–9.5 days).

Table 2. Mean duration of the different developmental stages, pre-oviposition, oviposition and post-oviposition periods (days ± SE), survivorship (%, in parentheses) and fecundity (number of eggs per female ± SE) of *Gaeolaelaps aculeifer* fed with *F. occidentalis*, *A. ovatus* and a mixture of these prey, at 21 ± 1 ° C, 60 ± 15% RH, in darkness (n= 20/diet).

	Prey		
	F. occidentalis	***A. ovatus***	***F. occidentalis + A. ovatus***
Egg	4.6 ± 0.2 (100) a	4.4 ± 0.2 (100) a	4.6 ± 0.2 (100) a
Larva	1.9 ± 0.1 (95) a	1.8 ± 0.08 (100) a	1.9 ± 0.09 (100) a
Protonymph	3.3 ± 0.3 (100) a	3.7 ± 0.3 (100) a	3.2 ± 0.2 (95) a
Deutonymph	9.5 ± 0.3 (100) a	8.6 ± 0.3 (100) b	9.1 ± 0.2 (100) ab
Egg – Adult	19.2 ± 0.3 (95) a	18.5 ± 0.2 (100) b	18.8 ± 0.2 (95) ab
Pre-oviposition	1.9 ± 0.1 a	1.5 ± 0.1 b	1.7 ± 0.1 ab
Oviposition	36.8 ± 2.7 b	49.0 ± 1.4 a	36.7 ± 1.2 b
Post-oviposition	15.4 ± 3.1 b	14.0 ± 2.1 b	25.8 ± 1.9 a
♀ longevity	61.8 ± 4.5 b	73.8 ± 0.6 a	70.0 ± 1.6 b
♂ longevity	88.0 ± 17.2 a	79.2 ± 11.0 a	85.3 ± 16.8 a
Fecundity	95.0 ± 6.8 a	99.8 ± 4.1 a	100.3 ± 2.1 a
Number of ♀*	16	15	16
Number of ♂*	3	5	3

In each row, means followed by a same letter are not significantly different (Paired bootstrap test, p> 0.05). *Number of parental eggs.

Pre-oviposition period was significantly longer when prey was *F. occidentalis* than when it was *A. ovatus*, and the opposite occurred for oviposition period and female longevity (Table 2). No significant differences were observed for fecundity on the different prey types.

Sex ratio was 84% female when diet included *F. occidentalis* and 75% female when it included only *A. ovatus* (Table 2).

On the three food types, variation in duration of each immature stage between mites was low, as indicated by the slight overlap of the curves showing the proportions of prevailing specimens in pairs of successive stages (cited as survival rates, S_{xj}, by Chi & Liu 1985) (Figure 1). Also, on the three types of food, emergence of adults started 16 days of the oviposition and was concluded in 4 days. Emergence of females started shortly before emergence of males, which in turn lived longer than females (Table 2, Figure 1).

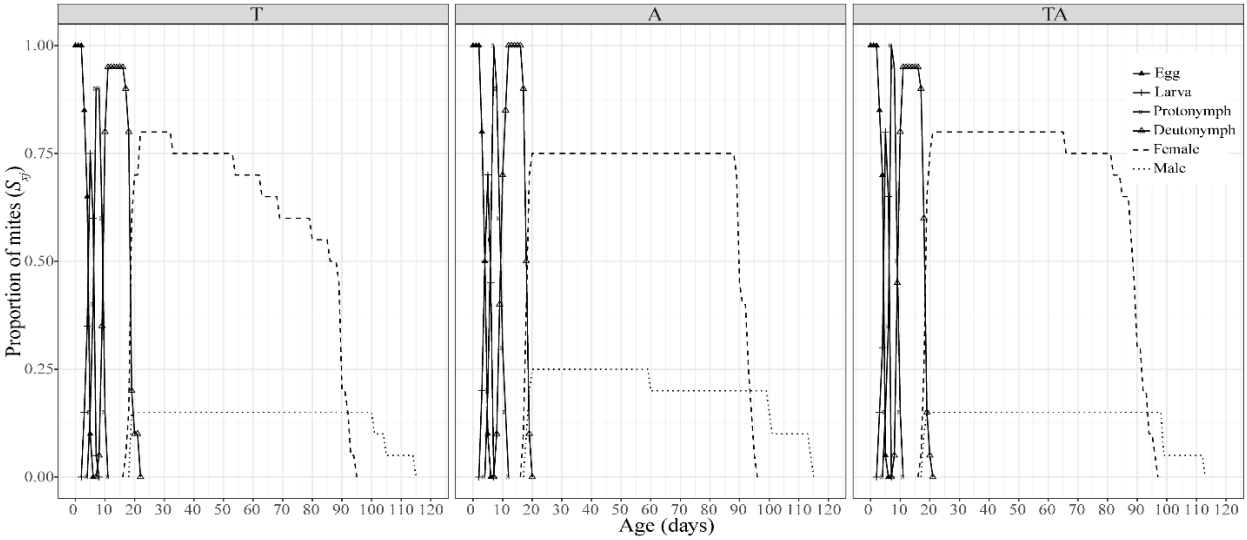


Figure 1. Proportion of *Gaeolaelaps aculeifer* in each developmental stage at each day (cited as survival rate, S_{xj}), in relation to the maximum number of each stage obtained in the study, when fed with *F. occidentalis* (T), *A. ovatus* (A), and a mixture of the two prey (TA), at 21 ± 1 ° C, 60 ± 15% RH in darkness (Day 0: oviposition).

For all diets, daily fecundity reached the highest rates at the beginning of the oviposition period, slowly reducing thereafter, reaching very low levels at the end of the third month (Figure 2). In all treatments, 80% of the fecundity was reached in the first 25 days of the oviposition period. More than 50% of the females were alive on day 72.

Maximum daily fecundity was lowest when the predator was fed only *A. ovatus* than when diet included *F. occidentalis*. However, this was compensated by the longer oviposition period on the former prey, so that total fecundity was statistically the same on all three food types (Table 1, Figure 2). The longest oviposition rate coincided with the longer survival of predators fed *A. ovatus*.

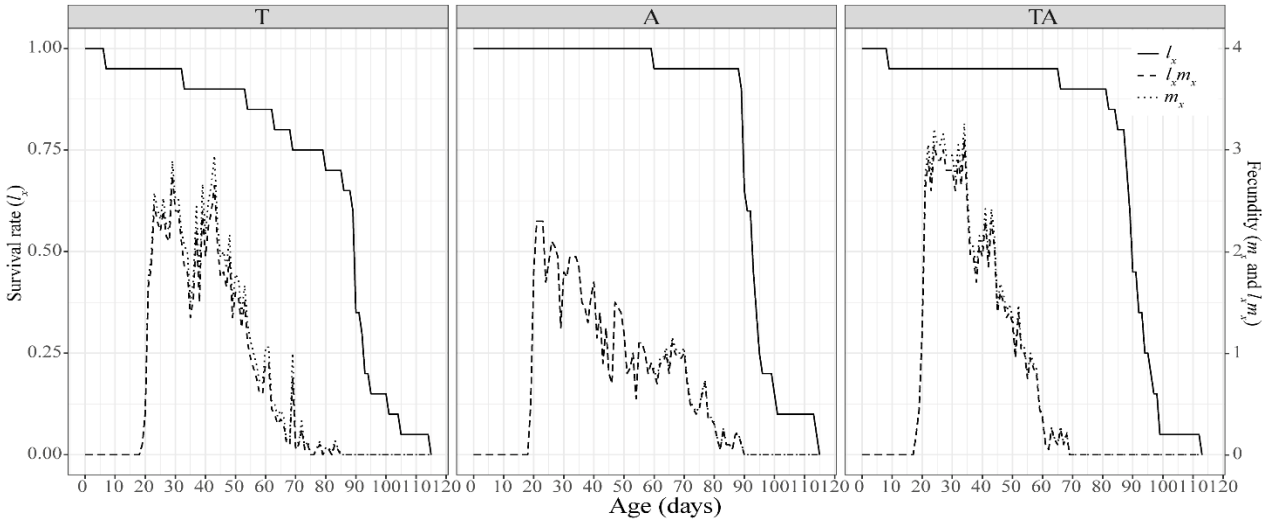


Figure 2. Age-specific survival rate (l_x), fecundity (m_x) and maternity ($l_x m_x$) of *Gaeolaelaps aculeifer* fed with *F. occidentalis* (T), *A. ovatus* (A) and a mixture of these two foods (TA), at 21 ± 1 °C, 60 ± 15% RH, in darkness.

Predator population was shown to be able to increase approximately 75–80 times in each generation (R_o), with no significant differences between food types (Table 2). The intrinsic growth rate (r_m) and the finite increase rate (λ) were not significantly different between treatments, but the generation time (T) was shorter for predators fed with the combination of both prey (Table 2).

Table 2. Life table parameters (± SE) of *Gaeolaelaps aculeifer* fed with *F. occidentalis*, *A. ovatus*, and a mixture of these two preys at 21 ± 1 ° C, 60 ± 15% RH, in darkness. For each prey, n= 20.

Prey	R_o	r_m	λ	T
A. ovatus	74.9 ± 10.1a	0.13 ± 0.005a	1.14 ± 0.006a	32.7 ± 0.6a
F. occidentalis	74.9 ± 10.1a	0.13 ± 0.004a	1.13 ± 0.005a	33.2 ± 0.4a
A. ovatus + *F. occidentalis*	80.2 ± 9.1a	0.14 ± 0.004a	1.15 ± 0.005a	30.9 ± 0.5b

R_o: net reproduction rate (♀/ ♀/ generation); r_m: the intrinsic rate of increase (♀/ ♀/ day); λ: finite rate of increase (offspring/ ♀/ day); T: mean generation time (days). In each column, means followed by the same letter are not significantly different (Paired bootstrap test, p> 0.05).

5.4. Discussion

Despite studies on the life cycle and possible use of *G. aculeifer* for the control of soil pests, including thrips (van Lenteren 2011), this is the first work to determine the life table parameters of this predator on *F. occidentalis*. The results obtained were generally similar to those reported by Amin *et al*. (2014), when the predator was fed the acarid *Rhizoglyphus echinopus* Fumouze and Robin, at 20 and 22.5 ºC. Most important differences

referred to the distinctly shorter duration of the deutonymph (about half as long) and the slightly lower (ca. 15%) fecundity in that study. The results are also similar to those of Kasuga *et al*. (2006) for predators fed the acarid *Tyrophagus similis* Volgin, except for the similar durations of protonymphs and deutonymphs in that study (respectively 6.0 and 6.5 days), at 20 ºC. A comparison of the results of this study with those of Kevan and Sharma (1964) for mites fed *Tyrophagus putrescentiae* (Schranck) is hampered by the much different temperatures (17 ºC in that case); yet, despite the lower temperature, the incubation period was much shorter in that study (ca. 34%).

Life table parameters of *G. aculeifer* where also calculated by Ajvad *et al*. (2018) on larvae of the dipteran *Lycoriella auripila* Winnertz (Sciaridae), by Chi (1981) on the collembolan *Onychiurus fimatus* Gisin (Onychiuridae), and by Barker (1969) on the mites *T. putrescentiae* and *Glycyphagus domesticus* (deGeer) (Glycyphagidae), at slightly higher temperatures (22–24°C). In all cases, R_o was much lower than found in the present study, which was related to the lower fecundity and shorter oviposition period. Differences in methodology and units of time preclude further comparisons with these studies.

The long duration of the deutonymphal period, resulting in a prolonged immature phase of almost three weeks, seems uncommon. This period seems considerably longer than observed for other mites of the cohort Gamasina (Lindquist et al. 2009), possibly because of the lower temperature employed in the present study (21 ºC) compared to other studies (close to 25 °C), on laelapids (Freire and Moraes 2007a; Moreira et al. 2015), Macrochelidae (Azevedo et al. 2018), Phytoseiidae (McMurtry et al. 1970; Li et al. 2006; Marafeli et al. 2014; Fouly and Abdel-Baky 2015) and Rhodacaridae (Castilho et al. 2009). In terms of prey consumption, this does not seem to be necessarily a problem, as our preliminary observations indicated that deutonymphs can kill almost the same number of pre-pupae and pupas as adults. However, the long immature stage most certainly had a significant bearing on the calculated rates of population increase, which were not particular high.

The results of the first part of this study (predation and oviposition experiment) showed the ability of *G. aculeifer* to use pre-pupae and pupae of *F. occidentalis* as food, and these not only allowed survivorship of the predator during the experimental period, but also its oviposition. They also indicated a comparable ability of the predator to survive and reproduce when fed with *A. ovatus*. Mean daily predation rates of *G. aculeifer* in this study were lower than reported for the same predator fed second-instar larvae, pre-pupae and pupae (Berndt et al. 2004b) or larvae (Navarro-Campos et al. 2016) of *F. occidentalis* (respectively about 3.5 and 4.0 prey/day). However, mean daily oviposition were higher in this study than

reported in the studies of Berndt *et al.* (2004) and Navarro-Campos *et al*. (2016) (respectively about 2.5 and 2.2 eggs/day). Observations (not presented) on predation of *F. occidentalis* during the second part of this study (life cycle) confirmed the results of predation rates obtained in the first part of the study, in which deutonymphs and adult females preyed up to four pre-pupae and pupae per day.

The reduction of the predation rate on *F. occidentalis* when associated with *A. ovatus* observed in this study is obviously not abnormal, for the availability of an additional food item (Holt 1977; Abrams and Hiroyuki 1996; van Baalen et al. 2001), and should not lead to the conclusion that it is negative in terms of final pest control efficacy. Most important is that the reduction was relatively small, despite the significant statistical difference. Some degree of reduction can be tolerated if the provision of another food item benefits the predator in other ways (Settle et al. 1996; Liu et al. 2006; Messelink et al. 2008; Muñoz-Cárdenas et al. 2017b, a). The great similarity of the life table parameters observed in this study for both prey species indicates that *A. ovatus* would be suitable as factitious food for mass rearing the predator and to maintain it in the field under the condition of eventual prey shortage. Complementary studies are necessary to prove that hypothesis. Navarro-Campos *et al*. (2016) reported the potential of some food sources, especially eggs of *Ephestia kuehniella* (Lepidoptera: Pyralidae) or cysts of *Artemia* sp. (Crustacea), for use as factitious prey for mass-rearing *G. aculeifer*. Similarly, the mite *Cosmolaelaps jaboticabalensis* Moreira, Klompen and Moraes (Laelapidae) showed adequate biological performance when fed with free-living nematodes, leading the authors to suggest the use of those organisms to favor persistence of the predator when released in the field (Moreira et al. 2015).

In conclusion, the first hypothesis of this study could be verified, as *G. aculeifer* was shown to be able to feed, develop and reproduce when pre-pupae and pupae of *F. occidentalis* were part of its diet. The biological characteristics of the Colombian population are comparable to those reported for other populations of the same predator (perhaps with the exception of the duration of the deutonymph), suggesting its potential for use for biological control of *F. occidentalis* in Colombia. Likewise, the second hypothesis was verified, as the presence of *A. ovatus* in the system resulted in small reduction in predation rate of *F. occidentalis* pre-pupae and pupae, suggesting that *A. ovatus* can be used as factitious food for mass rearing or as complementary food in periodic releases, when the pest in not abundant.

Acknowledgements

To COLCIENCIAS (Departamento Administrativo de Ciencia, Tecnología e Innovación, Colombia) for the scholarship to the first author (Process No. 617-2013, Chapter 3) and the agreement Pontificia Universidad Javeriana-COLCIENCIAS-SENA (Servicio Nacional de Aprendizaje, Colombia) for the support to the second author through the program JÓVENES INVESTIGADORES E INNOVADORES EN ALIANZA SENA (Process 738-2015). To Hsin Chin (Department of Plant Production and Technologies, Faculty of Agricultural Sciences and Technologies, Nigde University, Turkey) for the valuable suggestions, comments and teaching about the data preparation and analysis; Augusto Ramirez-Godoy, Universidad Nacional de Colombia, for granting space for the experiments; Luz Stella Fuentes, Centro de Bio-Sistemas Universidad Jorge Tadeo Lozano; Alexander Escobar, Bichopolis, for granting the *F. occidentalis* individuals to start the colony; Everth Ebratt Ravelo for confirming thrips identification; Eric Palevsky for the valuable comments to the manuscripts and interesting discussions about using alternative food in biological control; and Mayerly Alejandra Castro for the invaluable help in the laboratory.

References

Abbatiello MJ (1965) A Culture Chamber for Rearing Soil Mites. Turtox News 43:162–164

Abrams PA, Hiroyuki M (1996) Positive Indirect Effects Between Prey Species that Share Predators. Ecology 77:610–616. doi: 10.2307/2265634

Ajvad FT, Madadi H, Michaud JP, et al (2018) Life table of *Gaeolaelaps aculeifer* (Acari: Laelapidae) feeding on larvae of *Lycoriella auripila* (Diptera: Sciaridae) with stage-specific estimates of consumption. Biocontrol Sci Technol 28:157–171. doi: 10.1080/09583157.2018.1434613

Amin M, Khanjani M, Zahiri B (2014) Preimaginal development and fecundity of *Gaeolaelaps aculeifer* (Acari : Laelapidae) feeding on *Rhizoglyphus echinopus* (Acari : Acaridae) at constant temperatures. 3:581–587

Attavian B (2014) cut flowers and greenery import manual cut flowers and greenery, First Ed. United States Department of Agriculture - USDA

Avellaneda J, Diaz M, Acosta D, et al (2016) Colecta de antocóridos y determinación de su capacidad depredadora sobre adultos de *Frankiniella occidentalis* (Pergande) (Thysanoptera, Thripidae). Rev Fac ciencias basicas 12:8–21. doi: http://dx.doi.org/10.18359/rfcb.1850

Azevedo LH, Ferreira MP, Castilho R de C, et al (2018) Potential of *Macrocheles* species (Acari : Mesostigmata : Macrochelidae) as control agents of harmful flies (Diptera) and biology of *Macrocheles embersoni* Azevedo, Castilho and Berto on *Stomoxys calcitrans* (L.) and *Musca domestica* L. (Diptera: Muscidae). Biol Control 123:1–8. doi: 10.1016/j.biocontrol.2018.04.013

Bahrami F, Arbabi M, Shoushtari RV, Kazemi S (2011) Mesostigmatic mites associated with coleoptera and biodiversity calculation of these mites phoretic on dung beetles in Golestan Province (North of Iran). Middle-East J Sci Res 9:345–366

Barbosa MFC, de Moraes GJ (2015) Evaluation of astigmatid mites as factitious food for rearing four predaceous phytoseiid mites (Acari: Astigmatina; Phytoseiidae). Biol Control 91:22–26. doi: 10.1016/j.biocontrol.2015.06.010

Barbosa MFC, Moraes GJ de (2016) Potential of astigmatid mites (Acari: Astigmatina) as prey for rearing edaphic predatory mites of the families Laelapidae and Rhodacaridae (Acari: Mesostigmata). Exp Appl Acarol 69:289–296. doi: 10.1007/s10493-016-0043-4

Barczyk G, Madej G (2014) Comparison of the species composition of Gamasina mite communities (Acari, Mesostigmata) in selected caves of the Kraków-Częstochowa Upland (southern Poland) and their immediate surroundings. J Nat Hist 49:1673–1688. doi: 10.1080/00222933.2014.976667

Barker PS (1969) The response of a predator, *Hypoaspis aculeifer* (Canestrini) (Acarina:Laelapidae), to two species of prey. Can J Zool 47:343–345

Berndt O, Meyhöfer R, Poehling HM (2004a) The edaphic phase in the ontogenesis of *Frankliniella occidentalis* and comparison of *Hypoaspis miles* and *Hypoaspis aculeifer* as predators of soil-dwelling thrips stages. Biol Control 30:17–24. doi: 10.1016/j.biocontrol.2003.09.009

Berndt O, Poehling HM, Meyhöfer R (2004b) Predation capacity of two predatory laelapid mites on soil-dwelling thrips stages. Entomol Exp Appl 112:107–115. doi: 10.1111/j.0013-8703.2004.00185.x

Buitenhuis R, Murphy G, Shipp L, Scott-Dupree C (2015) *Amblyseius swirskii* in greenhouse production systems: a floricultural perspective. Exp Appl Acarol 65:451–464. doi: 10.1007/s10493-014-9869-9

Buitenhuis R, Shipp JL (2008) Influence of plant species and plant growth stage on *Frankliniella occidentalis* pupation behaviour in greenhouse ornamentals. J Appl Entomol 132:86–88. doi: 10.1111/j.1439-0418.2007.01250.x

Castilho RC, de Moraes GJ, Silva ES, Silva LO (2009) Predation potential and biology of *Protogamasellopsis posnaniensis* Wisniewski & Hirschmann (Acari: Rhodacaridae). Biol Control 48:164–167. doi: 10.1016/j.biocontrol.2008.10.004

Chi H (1988) Life-table analysis incorporating both sexes and variable development rates among individuals. Environ Entomol 17:26–34. doi: 10.1093/ee/17.1.26

Chi H (2016) TWOSEX-MSCHART. A computer program for age stage, two-sex life table analysis

Chi H (1981) Die Vermehrungsrate von *Hypoaspis aculeifer* Canestrini (Acarina, Laelapidae) bei Ernahrung mit *Onychiurus fimatus* Gisin (Collembola, Onychiuridae) unter verschiedenen Temperaturen. Mitteilungen der Dtsch Gesellschaft fuer Allg und Angew Entomol Kiel 3:122–125

Chi H, Liu H (1985) Two new methods for the study of insect population ecology. Bull Inst Zool, Acad Sin 24:225–240

Da Silva GL, Rocha MDS, Ferla NJ (2013) First new species of the *Phytoseius horridus* group (Acari: Phytoseiidae) described from Brazil, with a key to the Brazilian species of *Phytoseius*. Zootaxa 3681:595–599. doi: 10.11646/zootaxa.3681.5.9

Evans GO, Till WM (1966) Studies on the British Dermanyssidae (Acari: Mesostigmata). Part II Classification. Bull Br Museum (Natural Hist Zool 14:109–370. doi: 10.1111/j.1469-8137.1944.tb05001.x

Fenda P, Schniererová E (2005) Mites (Acarina, Gamasida) in littoral zone of Jakubov fishponds (Slovakia). Contrib to soil Zool Cent Eur I 9–14

Fouly AH, Abdel-Baky NF (2015) Influence of prey types on the biological characteristics of *Cosmolaelaps qassimensis* (Acari: Laelapidae). J Entomol 12:21–29. doi: 10.3923/je.2015.21.29

Freire RAP, Moraes GJ de (2007a) Description of a new species of *Cosmolaelaps* Berlese (Acari: Laelapidae, Hypoaspidinae) from Brazil and its biological cycle. Int J Acarol 33:353–358. doi: 10.1080/01647950708683697

Freire RAP, Moraes GJ de (2007b) Mass production of the predatory mite *Stratiolaelaps scimitus* (Womersley) (Acari: Laelapidae). Syst Appl Acarol 12:117–119

Gerson U, Smiley RL, Ochoa R (2003) Mites (Acari) for Pest Control. Blackwell Science Ltd, Oxford

Glockemann B (1992) Biological control of *Frankliniella occidentalis* on ornamental plants using predatory mites. EPPO Bull 22:397–404. doi: 10.1111/j.1365-2338.1992.tb00517.x

Grosman A., Messelink G., Groot EB de (2011) Combined use of a mulch layer and the soil-dwelling predatory mite *Macrocheles robustulus* (Berlese) enhance the biological control of sciarids in potted plants. Bull OEPP/EPPO Bull 68:51–54

Gutiérrez-Bonilla FDP (2006) De especies invasoras: Propuesta de lineamientos para el control de los impactos. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Bogotá, D.C.

Holt RD (1977) Predation, apparent competition, and the structure of prey communities. Theor Popul Biol 12:197–229. doi: https://doi.org/10.1016/0040-5809(77)90042-9

Kasuga S, Kanno H, Amano H (2006) Development, Oviposition, and Predation of *Hypoaspis aculeifer* (Acari: Laelapidae) Feeding on *Tyrophagus similis* (Acari: Acaridae). J Acarol Soc Japan 15:139–143. doi: 10.2300/acari.15.139

Kevan DKM, Sharma GD (1964) Observations on the biology of *Hypoaspis aculeifer* (Canestrini 1884), apparently new to North America (Acarina: Mesostigmata: Laelaptidae). Acarologia 6:647–658

Kiers E, De Kogel WJ, Balkema-Boomstra A, Mollema C (2000) Flower visitation and oviposition behavior of *Frankliniella occidentalis* (Thysan., Thripidae) on cucumber plants. J Appl Entomol 124:27–32. doi: 10.1046/j.1439-0418.2000.00433.x

Kordeshami AB, Khajehali J, Nemati A (2015) Some edaphic mesostigmatic mites from Lordegan, Chaharmahal Bakhtiari province with their world distribution. J Crop Prot 4:589–604

Krantz GW (2009) Habits and Habitats. In: Krantz GW, Walter DE (eds) A Manual of Acarology, 3rd editio. Texas Tech University Press, Lubbock, Texas, pp 64–82

Li D-Y, He Y-F, Li H-D (2006) Biology and life table of the predatory mite *Euseius aizawai* (Acari: Phytoseiidae). Syst Appl Acarol 11:159–165. doi: 10.11158/saa.11.2.3

Lindquist EE, Krantz GW, Walter DE (2009) Classification. In: Krantz GW, Walter DE (eds) A Manual of Acarology, 3rd editio. Texas Tech University Press, Lubbock, Texas, pp 97–103

Liu C, Yan L, Li H, Wang G (2006) Effects of predator-mediated apparent competition on the population dynamics of *Tetranychus urticae* on apples. BioControl 51:453–463. doi: 10.1007/s10526-005-4363-z

Lobbes P, Schotten C (1980) Capacities of increase of the soil mite *Hypoaspis aculeifer* Canestrini (Mesostigmata: Laelapidae). Zeitschrift für Angew Entomol 90:9–22. doi: 10.1111/j.1439-0418.1980.tb03497.x

López-Ruiz N, Rodríguez-Peña C, Gonzales-Ibarguen D (2012) Revisión de la normativa actual del Comercio de fauna silvestre en Colombia: un análisis comparativo con España. Corporación Universitaria Lasallista

Majidi M, Akrami MA (2013) Corresspondence Mites associated with the date palm (*Phoenix dactylifera* L.) in Larestan (Fars province), southern Iran. Persian J Acarol 2:335–339

Manu M (2010) Predatory mites (Acari: Mesostigmata-Gamasina) from soil of some spoilt areas from Retezat and Tarcu-Petreanu mountains. Stud Univ Vasile Goldis Arad, Ser Stiint Vietii 20:89–94

Manu M, Honciuc V (2010) Rank correlations at the level of soil mites (Acari: Gamasida; Oribatida) from central parks of Bucharest city, Romania. Acta Entomol serbica 15:129–140

Marafeli P, Reis P, Silveira E da, et al (2014) Life history of *Neoseiulus californicus* (McGregor, 1954) (Acari: Phytoseiidae) fed with castor bean (*Ricinus communis* L.) pollen in laboratory conditions. Brazilian J Biol 74:691–697. doi: 10.1590/bjb.2014.0079

McMurtry JA, Huffaker CB, de Vrie M (1970) Ecology of tetranychid mites and their natural enemies: a review. I. Tetranychid enemies: their biological characters and the impact of spray practices. Hilgardia 40:331–390. doi: 10.3733/hilg.v40n11p331

Messelink G, Holstein-saj R Van (2008) Improving thrips control by the soil-dwelling predatory mite *Macrocheles robustulus* (Berlese). Integr Control Prot Crop 32:135–138

Messelink GJ, Maanen R van, van Steenpaal SEF, Janssen A (2008) Biological control of thrips and whiteflies by a shared predator: Two pests are better than one. Biol Control 44:372–379. doi: 10.1016/j.biocontrol.2007.10.017

Ministerio de Ambiente y Desarrollo Sostenible (2012) Política nacional para la gestión integral de la biodiversidad y sus servicios ecosistémicos (PNGIBSE). Minist. Ambient. y Desarro. sostenible, República Colomb. 134

Ministerio del Medio Ambiente (1993) Ley 99 De 1993. Colombia

Moraza ML, Peña M a. (2005) Ácaros Mesostigmata (Acari, Mesostigmata) de hábitats seleccionados de La Gomera (islas Canarias, España). Graellsia 61:109–114. doi: 10.3989/graellsia.2005.v61.i1.9

Moreira GF, de Morais MR, Busoli AC, de Moraes GJ (2015) Life cycle of *Cosmolaelaps jaboticabalensis* (Acari: Mesostigmata: Laelapidae) on *Frankliniella occidentalis* (Thysanoptera: Thripidae) and two factitious food sources. Exp Appl Acarol 65:219–226. doi: 10.1007/s10493-014-9870-3

Muñoz-Cárdenas K, Ersin F, Pijnakker J, et al (2017a) Supplying high-quality alternative prey in the litter increases control of an above-ground plant pest by a generalist predator. Biol Control 105:19–26. doi: https://doi.org/10.1016/j.biocontrol.2016.11.004

Muñoz-Cárdenas K, Rueda-Ramirez D, Ersin F, et al (2017b) Alternative food for little-inhabiting predators decreases pest densities and above-ground plant damage. In: Muñoz-Cárdenas K (ed) What lies beneath? Linking litter and canopy food webs to protect arnamental crops. Ph.D. Thesis. University of Amsterdam, The Netherlands, pp 9–26

Navarro-Campos C, Pekas A, Moraza ML, et al (2012) Soil-dwelling predatory mites in citrus: Their potential as natural enemies of thrips with special reference to *Pezothrips kellyanus* (Thysanoptera: Thripidae). Biol Control 63:201–209. doi: 10.1016/j.biocontrol.2012.07.007

Navarro-Campos C, Wäckers FL, Pekas A (2016) Impact of factitious foods and prey on the oviposition of the predatory mites *Gaeolaelaps aculeifer* and *Stratiolaelaps scimitus* (Acari: Laelapidae). Exp Appl Acarol 70:69–78. doi: 10.1007/s10493-016-0061-2

Peel MC, Finlayson BL, McMahon TA (2007) Updated world map of the Köppen-Geiger climate classification. Hydrol Earth Syst Sci 11:1633–1644. doi: 10.5194/hess-11-1633-2007

Salmane I (2001) A check-list of Latvian Gamasina mites (Acari , Mesostigmata) with short notes to their ecology. Latv Entomol 38:27–38

Settle WH, Ariawan H, Astuti ET, et al (1996) Managing tropical rice pests through conservation of generalist natural enemies and alternative prey. Ecology 77:1975–1988. doi: 10.2307/2265694

Silva DE, Silva GL Da, Nascimento JM Do, Ferla NJ (2018) Mite fauna associated with bird nests in Southern Brazil. Syst Appl Acarol 23:426–440. doi: http://doi.org/10.11158/saa.23.3.2

Skorupski M, Luxton M (1998) Mesostigmatid mites (Acari: Parasitiformes) associated with yew (*Taxus baccata*) in England and Wales. J Nat Hist 32:419–439. doi: 10.1080/00222939800770221

Valencia E (2013) Control y manejo de los Thrips en los sistenas de floricultura colombiana. Florycultura Colomb Rev la Asoc Colomb Floric 45–49

van Baalen M, Křivan V, van Rijn PCJ, Sabelis MW (2001) Alternative food, switching predators, and the persistence of predator-prey systems. Am Nat 157:512–524. doi: 10.1086/319933

van Lenteren JC (2011) The state of commercial augmentative biological control: Plenty of natural enemies, but a frustrating lack of uptake. BioControl 57:1–20. doi: 10.1007/s10526-011-9395-1

van Lenteren JC, Cock MJW, Brodeur J, et al (2011) Will the Convention on Biological Diversity put an end to biological control? Rev Bras Entomol 55:1–5. doi: 10.1590/S0085-56262011000100001

Wissuwa J, Salamon JA, Frank T (2012) Effects of habitat age and plant species on predatory mites (Acari, Mesostigmata) in grassy arable fallows in Eastern Austria. Soil Biol Biochem 50:96–107. doi: 10.1016/j.soilbio.2012.02.025

6. BIOLOGY AND PREDATION CAPACITY OF *Parasitus bituberosus* (ACARI: MESOSTIGMATA: PARASITIDAE) ON *Frankliniella occidentalis* (THYSANOPTERA: THRIPIDAE)

ABSTRACT

Parasitus bituberosus Karg is frequently found in rose fields and nearby natural vegetation in the Bogotá plateau (Cundinamarca, Colombia). In laboratory rearing units, it is usually found aggregated, feeding voraciously on pre-pupae and pupae of *Frankliniella occidentalis* (Pergande), a common rose pest. Preliminary observations suggested that immatures of that predator could not reach the adult stage when kept in isolation. The objective of this study was to evaluate the suitability of *F. occidentalis* as prey for *P. bituberosus*, to evaluate free-living nematodes as complementary food, and to confirm the effect of aggregation on the biology of the predator. The effect of types of aggregation (mites always kept in isolation or paired only in the deutonymphal stage and early adult phase or throughout the whole life cycle) and of diets (pre-pupae and pupae of *F. occidentalis*, Rhabditidae nematodes or *F. occidentalis* + Rhabditidae nematodes) on the biology of the predator and its predation capacity on *F. occidentalis* were evaluated. Juveniles of *P. bituberosus* were observed not to feed on *F. occidentalis*, but to develop and oviposit when fed nematodes. About 77% of the mites maintained permanently in isolation died as immatures, mostly as deutonymphs. Low immature mortality occurred (21–23 %) when predators were paired at least in the deutonymphal stage and the early adult phase. Female predation rates were comparable to values reported for other predators on the same prey (female daily predation≥ 2.5). Mites permanently paired had high biotic potential, especially when diet included nematodes (r_m≥ 0.33; R_o≥ 33.90; λ≥ 1.39; daily oviposition rate≥ 10.9). The encouraging results of this study warrants further investigation of this predator, to evaluate methods for its mass production, inclusion in conservation biological control programs and performance against the pest at larger scale.

Keywords: Aggregation; Complementary food; Mite behavior; Free-living nematodes; Soil predator

6.1. Introduction

Parasitidae are free-living mites of broad distribution, found mostly in the soils with high content of organic matter (Zhang 2003; Castilho et al. 2015). Numerous studies have been published on their taxonomy (Bhattacharyya 1963; Micherdziński 1969; Evans and Till 1979; Hyatt 1980; Hennessey and Farrier 1989; Kazemi et al. 2013; Keum et al. 2016) and biology (Schousboe 1987; Al-Amidi and Downes 1990; Al-Amidi et al. 1991; Hofstetter et al. 2009; Szafranek et al. 2013).

They have been commonly reported from temperate areas, but they also seem common in the Bogota plateau (Rueda-Ramirez et al. in preparation), where climate is classified as Cfb (Köppen-Geiger classification system; Peel et al. 2007), as most of northern

Europe. *Parasitus bituberosus* Karg, originally described from Cape Town, South Africa, is one of the species reported from the Bogota plateau, where it was commonly found in soils of rose fields, an important Colombian agroecosystem, and of the natural vegetation (Rueda et al. in preparation).

Frankliniella occidentalis (Pergande) (Thripidae) is a common rose pest in the Bogota plateau (Calixto 2005), where it causes considerable economic damage, by reducing the yield of high quality flowers, as well as by increasing the number of rejected exported rose lots, due to thrips interceptions (Attavian 2014). Current control strategies of this pest, based on pesticide applications, have been inefficient, increasing the interest for the exploration of other control measures, including biological control. Hence, the evaluation of *P. bituberosus*, as a biocontrol agent of this pest seems warranted, given that part of *F. occidentalis* life cycle occurs in the soil (Berndt et al. 2004a; Buitenhuis and Shipp 2008). Buitenhuis and Shipp (2008) reported that up to 92% of the pupae of *F. occidentalis* were found in the soil.

In preliminary observations in the laboratory, we have noticed that specimens of *P. bituberosus* were commonly found in aggregations, feeding voraciously on *F. occidentalis*, and that when kept in isolation immatures of the mite could not reach adulthood. Parasitid mites have been reported to prey on beetle larvae (Kinn 1971), fly larvae (Karg 1972; Ito 1977a; Axtell and Rutz 1986; Axtell 1986; Wise et al. 1988; Al-Amidi and Downes 1990; Al-Amidi et al. 1991; Castilho et al. 2015), Collembola (Berry 1973; Al-Amidi and Downes 1990), Symphyla (Berry 1973), astigmatid mites (Lesna et al. 1995) and nematodes (Kinn 1971; Karg 1972; Ito 1977a; Al-Amidi and Downes 1990; Yasui 1997). However, no study has evaluated these mites as thrips predators. Free living nematodes are ubiquitous organisms, commonly found in the soil (Neher 2010) in association with mesostigmatid mites, conceivably serving as their prey (Ito 1971; Muraoka and Ishibashi 1976; Laakso and Seta 1999). Therefore, it is possible that nematodes can be used as prey for mass production or as complementary food in field releases of *P. bituberosus*. To evaluate the potential of this predator as a biological control agent of *F. occidentalis*, it is necessary to better understand its biology, including aspects about its aggregation behavior, as mentioned in the literature for *Parasitus fimetorum* (Berlese) (Yasui 1997) and tested for *Parasitus gregarius* Ito (Ito 1973, 1976, 1977a, b). In fact, the epithet *gregarious* was selected by the author of the species in a reference to its aggregating behavior. Hence, the objective of this study was to evaluate the suitability of *F. occidentalis* as prey for *P. bituberosus*, to evaluate free-living nematodes as complementary food, and to confirm the effect of aggregation on the biology of the predator.

6.2. Material and Methods

The work was conducted at “Laboratorio de Entomologia, Universidad Nacional de Colombia”, Bogota, between May and November 2017, in a growth chamber at 21 ± 1 ° C, 65 ± 10% RH and in darkness. Temperature and humidity levels were selected considering the observed conditions in representative rose production areas in the Bogotá plateau (unpublished data collected during samplings). Voucher specimens of the predator were deposited at the mite reference collections of “Museo Javeriano de Historia Natural, Pontificia Universidad Javeriana” (MJHN-PUJ), Bogota, and “Departamento de Entomologia e Acarologia, Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo”, Piracicaba, São Paulo State, Brazil.

6.2.1. Stock colony of the predatory mite

The colony was initiated with about 30 specimens of *P. bituberosus* collected between June and December 2016 from the soil of rose fields at Cogua (05°03'23.3"N 073°55'44.4"W), Fatacativa (04°46'39.4–40.7"N 074°19'23.9–24.8"W), Guasca (04°50'38.3"N 073°53'07.9"W), Nemocón (05°07'03.1-03.2"N 073°51'31.7-31.9"W) and Tocancipa (04°59'19.3"N 073°54'15.9"W), in the Bogota plateau (Cundinamarca, Colombia). Each colony was placed in a rearing unit prepared by an adaptation of what was described by Abbatiello (1965). It consisted of a plastic container (10 cm diameter and 7 cm high), whose bottom was covered with a layer of about 1.5 cm of a mixture of nine parts of gypsum and one part of activated charcoal (Freire & de Moraes 2007). The mites were fed with a mixture of all stages of an unidentified free-living nematode of the family Rhabditidae on pieces of bean pods (*Phaseolus vulgaris* L.), which served as their growing substrate, and a mixture of all developmental stages of *Aleuroglyphus ovatus* (Troupeau) (Acari: Sarcoptiformes: Astigmatina) on pieces of the commercial dog food Purina® (Freire and Moraes 2007). The units were closed with a piece of plastic film and maintained permanently moist by daily addition of distilled water.

6.2.2. Stock colony of *Frankliniella occidentalis*

The colony was maintained on bean and cucumber (*Cucumis sativus* L.) plants in the laboratory. To obtain pre-pupae and pupae (edaphic phases of the thrips), auxiliary chambers were used (1 L plastic container, the top opening covered with fine fabric for ventilation). Leaves and flowers of those plants were periodically transferred to the chamber, whose base was covered with several sheets of paper towel. A few *Chrysanthemum* sp. flowers were also periodically introduced to the chamber to serve as mating and oviposition substrate (Kiers et al. 2000); post-embryonic immatures subsequently developed to first and second larval instars, which then moved down to the shallow depressions of the paper towel to molt to pre-pupae and pupae.

6.2.3. Life cycle

To start the experiment, females of *P. bituberosus* were taken from the stock colony and each was transferred to an experimental unit consisting of a small Petri dish (4 cm in diameter and 1.3 cm in height) whose bottom was covered as described for the rearing units used for the predatory mites, humidified by addition of distilled water. Twelve hours later, the units were examined and individual eggs were transferred to new units for the life cycle studies described below.

Immatures were initially fed with one of the following food items: 1) *F. occidentalis* (T) offered by placing pre-larvae and larvae at the bottom of the experimental unit; 2) rhabditid nematodes of the same species used for maintenance of the predator stock colony (N), offered on small sections of bean pods; and *F. occidentalis* + rhabditid nematodes (NT). Because of the results obtained in this part of the study, all subsequent investigation was done by feeding all post-embryonic immatures of the predator with rhabditid nematodes. Hence, different types of food items were only given to adult predators, and the effect of food type could only be compared for mites at this stage. The amounts of food daily provided to each predator were based on preliminary observations, to ensure availability of surplus food, as subsequently detailed: rhabditid nematodes - approximately 50; *F. occidentalis* - seven pre-pupae and pupae for the females, five pre-pupae and pupae for males and ten pre-pupae and pupae for each pair of opposite sexes. Determination of the duration of immature stages was done by examining the units every 6 h, searching for exuviae. At each examination, mites of each stage were examined under a stereomicroscope (up to 50 x) to determine basic

morphological and behavioral characteristics. After reaching adulthood, mites were examined once a day to determine longevity and oviposition.

Biological parameters on each food type were evaluated for three types of aggregation:

Type 1: Mites continuously in isolation, except that immediately after reaching adulthood each female was maintained with a male for the first 24 h after emergence. The study was initiated with 32 predator eggs per food item.

Type 2: Eggs, larvae and protonymphs maintained in isolation; each female deutonymph maintained together with another deutonymph and the corresponding adults maintained together for the first 24 h after emergence. If necessary, deutonymphs were exchanged between units as soon as sex differences became apparent, so that each unit had a male and a female of similar ages. To allow the calculation of the life table parameters, once males were separated from the females, they were transferred to new units similar to that in which the females remained and continued receiving the same type of diet until their death. The study was initiated with 62, 55 and 60 eggs for adult mites to be fed respectively with T, N and NT.

Type 3: Mites continuously paired from the egg stage. If necessary, deutonymphs were exchanged between units as soon as sex differences became apparent, in order to have a male and a female of similar ages in each unit. The study was initiated with 52, 48 and 54 eggs for adult mites to be fed respectively with T, N and NT.

6.2.4. Life table analysis

Data were analyzed using the age-stage, two-sex life table theory with the TWOSEX-MSChart program (Chi 1988, 2016a). Calculated life table parameters were the intrinsic rate of increase (r_m), net reproduction rate (R_o), finite rate of increase (λ), mean generation time (T) and fecundity.

The estimates and standard errors of developmental time, longevity, fecundity, and population parameters were obtained through the bootstrap technique, with 100,000 bootstraps. Differences between treatments (combinations of aggregation types and food items) were assessed with paired bootstrap test with the same program described above. Figures were prepared using R, version 3.4.4 (The R foundation for Statistical Computing, 2018-03-15).

6.2.5. Predation rate on *Frankliniella occidentalis*

Predation data for treatments in which *F. occidentalis* was available as a food item in aggregation types 2 and 3 were analyzed using age-stage, two-sex consumption rate method with CONSUME-MsChart program (version 2018.02.26) (Chi 2016b). This method, as the life table analysis, consider both sexes during all stages to calculate prey suppression capacity (Chi et al. 2011). Given that predation of *F. occidentalis* in aggregation type 3 could not be directly determined for each of the partners, the number of preyed thrips was estimated for each sex according to the predation rates determined after the separation of the sexes in aggregation type 2. The parameters used in this analysis were the following, as presented by Chi and Yang (2003), Chi et al. (2011), Tuan et al. (2016) and Ajvad et al. (2018).

Age-specific predation rate (k_x):

$$k_x = \left(\frac{\sum_{j=1}^{\beta} s_{xj} c_{xj}}{\sum_{j=1}^{\beta} s_{xj}} \right)$$

Where S_{xj} is the proportion of the organism in each developmental stage at each day (cited as age-stage-specific survival rate by Chi & Lin, 1985) and C_{xj} is the age-stage-specific predation rate of individuals at age x and stage j (number of prey killed per predator at each stage on each day) (Chi and Yang 2003; Tuan et al. 2016; Ajvad et al. 2018). Taking the survival rate of the life table analysis (l_x=$\sum_{j=1}^{\beta} s_{xj}$; β is the number of life stages, in the case of this study, from 1 (egg) to 5 (adult)) into consideration, the age-specific net predation rate (q_x) gives the weighted number of pre-pupae and pupae of *F. occidentalis* killed by predator of age x:

$$q_x = l_x k_x = \sum_{j=1}^{\beta} s_{xj} c_{xj}$$

Then, the net predation rate (C_o) is defined as the summation of the q_x over all age groups giving:

$$C_o = \sum_{x=0}^{\infty} \sum_{j=1}^{\beta} s_{xj} c_{xj} = \sum_{x=0}^{\infty} k_x l_x$$

C_o represents the total number of prey killed by an average predator during its lifetime, including individuals that died in preadult stages and adults of both sexes (Chi and Yang 2003; Tuan et al. 2016).

The ratio between net predation rate (C_o) and net reproductive rate (R_o) gives the transformation rate from prey population to predator offspring (mean number of prey that a predator needs in order to produce one viable egg) which is defined as Q_p:

$$Q_p = \frac{C_0}{R_o}$$

Differences between treatments were compared as reported in the life table analysis.

6.3. Results

6.3.1. Morphological and behavioral characteristics of each developmental stage

Eggs were usually laid in protected places in the rearing unit, especially near irregularities on the surface of the base of the unit. For all treatments, eggs were always white, ellipsoidal and smooth. These were often covered by females with small particles eventually close to the eggs. Initially, larvae were also white, moving quickly, but after approximately 18 h they were distinctly more robust, yellowish, moving more slowly. Protonymphs were initially whitish and moved quickly; after 20 h, they were at their maximum sizes and yellowish. Deutonymphs were also yellowish initially, moving quickly; about a day after molting they were reddish, with evident idiosomal shields; in the following day, they were similar to adults in size and shape, allowing sex determination. Adult females and males were ovoid, reddish and fast moving. Females were mainly differentiated from males by being larger and more rounded posteriorly.

None of the post-embryonic immature stages was observed to prey on thrips pre-pupae or pupae, but they all preyed on nematodes. Conversely, adults fed on thrips pre-pupae and pupae, which twitched slightly when touched by predators, apparently preventing predation by immatures.

Cannibalism of young stages, especially eggs and larvae, by subsequent stages was observed frequently in the process of maintaining the predator colony. Observation conducted before starting the experiments showed that mating was required for oviposition to take place. During the experiment, repeated mating was frequently seen in the first (all aggregation types) and in subsequent days (aggregation type 3).

6.3.2. Duration of developmental stages

Average egg incubation period lasted a little less than a day, with no significant differences between aggregation types (Table 1). Duration of the larval stage was slightly longer than incubation period, with no significant differences between aggregation types. Duration of protonymphal stage was very close to that of larvae; despite the significant differences, averages were again very close (1.3–1.5). The deutonymphal stage was considerably longer than other stages, especially in aggregation types 1 and 2. Duration of that stage in aggregation type 3 was significantly shorter (3.5 days) than in other aggregation types (5.0 –6.9) (Table 1).

Table 1. Mean duration (days ± SE) and survivorship (%, in parentheses) of immature *Parasitus bituberosus* fed with rhabditid nematodes at 21 ± 1 ° C, 60 ± 15% RH and in darkness. Aggregation types: 1 – Mites always maintained in isolation; 2 – Eggs, larvae and protonymphs in isolation and deutonymphs paired with opposite sexes; 3 – Mites always paired (deutonymphs paired with opposite sexes).

Stages	Aggregation types		
	1	2	3
Egg	0.9 ± 0.0 (88) a	0.9 ± 0.0 (94) a	0.9 ± 0.0 (97) a
Larva	1.3 ± 0.0 (84) a	1.4 ± 0.0 (96) a	1.5 ± 0.0 (92) a
Protonymph	1.3 ± 0.0 (86) a	1.3 ± 0.0 (98) a	1.5 ± 0.0 (95) b
Deutonymph	6.9 ± 1.3 (38) a	5.0 ± 0.2 (87) a	3.5 ± 0.1 (92) b
Egg–Adult	10.4 ± 1.2 (23) a	9.8 ± 0.5 (77) a	7.5 ± 0.1 (79) b

Initial number in aggregation types 1–3 respectively 96, 177 and 154. In a same line, means followed by the same letter are not significantly different (Paired bootstrap test, $p > 0.05$).

Survivorship of eggs, larvae and protonymphs was high (≥ 84%) for the three aggregation types. Survivorship of deutonymphs was also high for mites of aggregation types 2 and 3 (≥ 87%), but low (38%) for mites of aggregation type 1. Consequently, survivorship for the whole immature phase was high (77–79%) for aggregation types 2 and 3 and low for aggregation type 1 (23%). Thus, the statistical analyses referring to parameters of the adult stage did not include mites of aggregation type 1, although the data for those mites are presented in Tables 2 and 3.

The variation in duration of eggs, larvae and protonymphs between mites was low, as indicated by the slight overlap of the curves showing the proportions of prevailing specimens in pairs of successive stages (cited as survival rate S_{xj} by Chi and Liu 1985) (Figure 1). However, variation was high for deutonymphs, especially those of aggregation type 2. Peak emergence of adults was attained slightly earlier when predators were always paired than

when they were paired only as deutonymphs, with a continuous reduction in the proportion of surviving adults in both aggregation types.

For mites always maintained in isolation (aggregation type 1), the number of males reaching adulthood was 4–5 times that of females (17 and 4 respectively), differing from what was observed for other aggregation types, when number of males and females were about the same (Table 2). These belonged to groups that were established *a priori* for the corresponding adults to be fed as follows: one female and five males with *F. occidentalis* (T), one female and four males with nematodes (N), and two females and eight males with nematodes and *F. occidentalis* (NT).

Pre-oviposition period was very short (≤ 0.1 day) for mites permanently paired, and significantly longer (1.2–2.1 days) for mites paired only in the deutonymphal stage (Table 2). No significant differences were observed between predators fed different diets within each aggregation type. For the few mites that survived to adults when maintained always in isolation, the pre-oviposition period was about one day when the diet included nematodes (N and NT) and four days when it included only thrips (T). Oviposition period was always relatively short (≤ 7.2 days) but significantly longer for mites always maintained paired when food included nematodes; no other significant differences were observed for this type of aggregation and for mites paired only in the deutonymphal stage. For mites maintained always in isolation, the oviposition period was about four days when the diet included nematodes (N and NT) and two days for the only female fed only thrips (T).

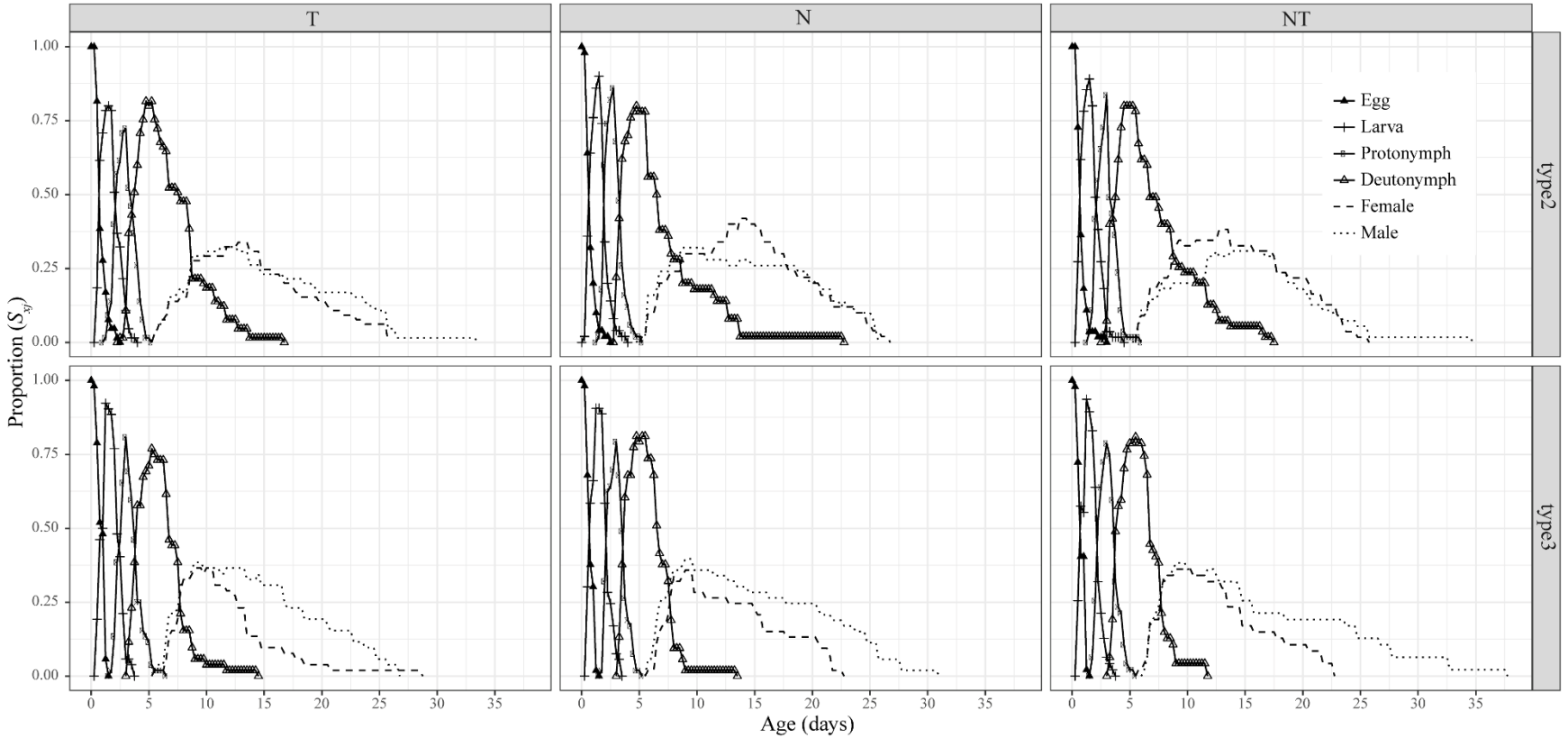


Figure 1. Proportion of *Parasitus bituberosus* in each developmental stage at each day (cited as survival rate, S_{xj}), in relation to the maximum number of each stage obtained in the study, on different diets and aggregation types. Diets: *F. occidentalis* (T), rhabditid nematodes (N) and rhabditid nematodes + *F. occidentalis* (NT); Type of aggregation: eggs, larvae and protonymphs in isolation, and deutonymphs and adults in the first 24 h after emergence paired with opposite sexes (Type 2); mites always paired (Type 3); at 21 ± 1 °C, 60 ± 15% RH and in darkness (Day 0: beginning of the predator life cycle).

Table 2. Mean duration of the pre-oviposition, oviposition and post-ovipostion period (days ± SE), longevity of female and male (days ± SE) and number of adult females and male emerged of *Parasitus bituberosus* fed with *F. occidentalis*, Rhabditid nematodes, and a mixture of these two foods at 21 ± 1 ° C, 60 ± 15% RH and dark. Aggregation types: 1 – Mites always maintained in isolation; 2 – Eggs, larvae and protonymphs in isolation, and deutonymphs and adults in the first 24 h after emergence paired with opposite sexes; 3 – Mites always paired (deutonymphs paired with opposite sexes).

	1			**2**			**3**		
	F. occidentalis	**Rhabditid nematode**	***F. occidentalis* + Rhabditid nematode**	***F. occidentalis***	**Rhabditid nematode**	***F. occidentalis* + Rhabditid nematode**	***F. occidentalis***	**Rhabditid nematode**	***F. occidentalis* + Rhabditid nematode**
Pre-oviposition	4	1	0.9 ± 0.1	2.1 ± 0.4 a	1.2 ± 0.3 a	1.8 ± 0.4 a	0.1 ± 0.0 b	0.1 ± 0.1 b	0.03 ± 0.0 b
Oviposition	2	4	4.2 ± 6.4	4.0 ± 0.4 b	4.8 ± 0.5 b	3.8 ± 0.3 b	5.0 ± 0.6 b	7.2 ± 0.9 a	7.0 ± 0.6 a
Post-oviposition	1	3	1	2.9 ± 0.6 ab	4.9 ± 0.9 a	4.2 ± 0.7 a	1.0 ± 0.2 c	1.5 ± 0.4 bc	1.7 ± 0.4 bc
Female longevity	6.5	6.5	6.4 ± 3.4	9.0 ± 0.8 ab	10.6 ± 1.0 a	10.1 ± 0.8 a	7.1 ± 0.9 b	8.5 ± 1.1 ab	8.4 ± 1.0 ab
Male longevity	9.3 ± 3.4	7.8 ± 2.2	10.7 ± 2.1	10.8 ± 1.3 a	12.6 ± 1.3 a	11.2 ± 1.3 a	11.4 ± 1.2 a	12.3 ± 1.4 a	13.4 ± 1.8 a
Number of females*	1	1	2	27	23	25	20	20	19
Number of males*	5	4	8	26	18	20	22	23	19

Means of each line followed by the same letters are not significantly different (Paired bootstrap test, p> 0.05). *Mites that reached adulthood

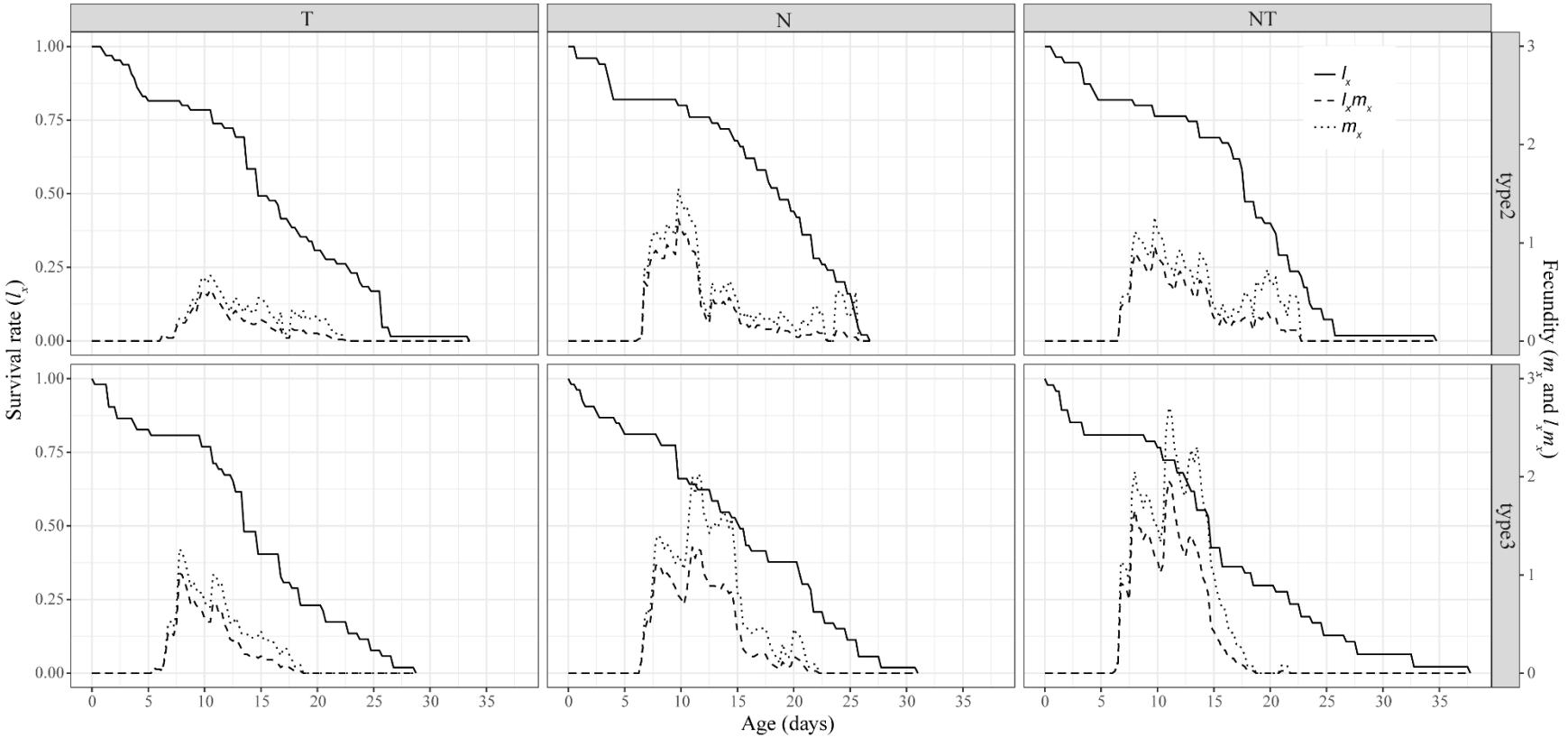


Figure 2. Age-specific survivorship rate (l_x) and fecundity (m_x) of *Parasitus bituberosus* on different diets and aggregation types. Diets: *F. occidentalis* (T), rhabditid nematodes (N) and rhabditid nematodes + *F. occidentalis* (NT); Type of aggregation: eggs, larvae and protonymphs in isolation, and deutonymphs and adults in the first 24 h after emergence paired with opposite sexes (Type 2); mites always paired (Type 3); at 21 ± 1 °C, 60 ± 15% RH and in darkness (Day 0: beginning of the predator life cycle)

Post-oviposition and female longevity were also shorter (≤ 1.7 and 8.5 days) when predators were always paired, for the three types of food. No significant differences were observed between food types within each aggregation type. Male longevity was consistently longer than female longevity, although only statistically significant for always paired mites (Paired Bootstrap test; F= 93.3, 111.4 and 181.4 for N, NT and T, respectively; d.f.=1; P<0.05). No significant differences were observed for male longevity (10.8 –13.4). Sex ratio was about 1:1.

Oviposition began about 6 days from the beginning of the predator life cycle for all types of aggregation and food types (Figure 2). Peak oviposition was attained 9–12 days of the beginning of the oviposition period.

6.3.3. Life table parameters

Total fecundity was highest for mites maintained always paired and included nematodes in their diets (89.9–109.9) and shortest for mites paired only as deutonymphs and adults in the first 24 h after emergence and fed only thrips (27.9) (Table 3). Fecundity of other combinations of aggregation type and diet had intermediate values and were statistically the same as each other. When the mites were always maintained in isolation, the fecundity of the only females that emerged was 18, 93 and 56 ± 30.5 fed only *F. occidentalis*, only nematodes and *F. occidentalis* and nematodes, respectively. Daily oviposition rate was similar when mites were fed thrips + nematodes for the two aggregation types (2 and 3) and the highest, although not significantly different from mites fed only nematodes. The pattern of response of r_m, R_o and λ to different combinations of aggregation types and diets was similar to that of fecundity. The three indexes were usually highest for mites whose diets included nematodes (by themselves or in association with thrips), and lowest when mites were paired only as deuntonymphs and adults in the first 24 h after emergence and fed only thrips. Mean generation time (*T*) was distinctly longer when mites were paired only as deutonymphs and adults in the first 24 h after emergence and fed only thrips.

Table 3. Life table parameters (± SE) of *Parasitus bituberosus* fed with *F. occidentalis*, rhabditid nematodes, and a mixture of these two foods at 21 ± 1 ° C, 60 ± 15% RH and dark. Types of aggregation: 2 – Eggs, larvae and protonymphs in isolation, and deutonymphs and adults in the first 24 h after emergence paired with opposite sexes and 3 – mites always paired.

	2			**3**		
	F. occidentalis	**Rhabditid nematode**	***F. occidentalis* + rhabditid nematode**	***F. occidentalis***	**Rhabditid nematode**	***F. occidentalis* + rhabditid nematode**
N*	65	50	55	52	53	47
Fecundity	27.9 ± 5.1 d	58.2 ± 10.1 bc	57.8 ± 6.6 bc	47.8 ± 8.0 c	89.9 ± 16.7 ab	109.9 ± 17.2 a
Daily ovipos. rate	6.6 ± 0.8 c	12.2 ± 1.6 ab	14.7 ± 1.3 a	8.9 ± 0.8 bc	10.9 ± 1.5 abc	15.0 ± 1.8 a
r_m	0.21 ± 0.02 c	0.32 ± 0.03 ab	0.30 ± 0.03 ab	0.29 ± 0.03 b	0.33 ± 0.03 ab	0.36 ± 0.02 a
R_o	11.58 ± 2.70 c	26.74 ± 6.18 ab	26.25 ± 4.87 ab	18.37 ± 4.42 bc	33.90 ± 8.61 ab	44.45 ± 10.42 a
λ	1.23 ± 3.03 c	1.38 ± 0.04 ab	1.34 ± 0.03 b	1.34 ± 0.03 b	1.39 ± 0.04 ab	1.45 ± 0.03 a
T	11.64 ± 0.64 a	10.22 ± 0.47 ab	10.97 ± 0.63 ab	9.76 ± 0.28 b	10.59 ± 0.34 ab	10.21 ± 0.23 b

r_m: the intrinsic rate of increase (♀/ ♀/ day); R_o: net reproduction rate (♀/ ♀/ generation); λ: finite rate of increase (offspring/♀/day); T: mean generation time (days). Mean of the same row followed by the same letter are not significantly different (Paired bootstrap test, p> 0.05). *Initial number of eggs.

6.3.4. Predation of *F. occidentalis* by adult predators

Mean daily and total number *F. occidentalis* preyed by each adult female and mean net predation rate (C_o) were significantly higher when both sexes were always paired and fed only thrips than when females were paired with males for only 24 h after emergence and fed thrips + nematodes (Table 4). Mean daily predation was similar when mites were always paired and fed thrips + nematodes and when mites were paired only as deutonymph and 24 h after emergence and fed only thrips. Other comparisons were not significantly different. For each treatment, female total predation was 4.6–10.2 times higher than male total predation. The mean total number of *F. occidentalis* preyed by each adult male was significantly highest when male was always paired with female and fed only thrips; other comparisons were not significantly different.

Transformation rates from prey to predator offspring (Q_p) when only thrips was offered as prey was statistically the same at both aggregation types (0.8–1.1) (Table 4).

Table 4. Predation parameters (± SE) of *Parasitus bituberosus* fed with *F. occidentalis* pre-pupae and pupae and these combined with rhabditid nematodes at 21 ± 1 ° C, 60 ± 15% RH and dark. Types of aggregation: 2 – Eggs, larvae and protonymphs in isolation, and deutonymphs and adults in the first 24 h after emergence paired with opposite sexes and 3 – mites always paired.

	2		**3**	
	F. occidentalis	***F. occidentalis* + rhabditid nematode**	***F. occidentalis***	***F. occidentalis* + rhabditid nematode**
Female daily predation (n)	2.5 ± 0.2 b (27)	1.6 ± 0.2 c (25)	4.4 ± 0.2 a (20)	2.5 ± 0.2 b (19)
Female total predation (n)	25.1 ± 3.3 ab (27)	17.4 ± 2.2 b (25)	31.4 ± 4.1 a (20)	22.8 ± 3.5 ab (19)
Male total predation (n)	3.7 ± 0.7 b (26)	1.7 ± 0.4 b (20)	6.9 ± 0.9 a (22)	3.9 ± 1.1 b (19)
C_o	11.9 ± 2.0 ab	8.5 ± 1.5 b	15.0 ± 2.4 a	10.8 ± 2.1 ab
Q_p	1.1 ± 0.2 a	-	0.8 ± 0.1 a	-

C_o: *F. occidentalis* preyed/ adult ♀ and ♂ in their life cycle (net predation rate); Q_p: transformation rate from prey population to predator offspring (*F. occidentalis* preyed to produce an offspring). In a same line, means followed by the same letter are not significantly different (Paired bootstrap test, p> 0.05).

Figure 3 shows the predation rates of the predator at each day throughout its life. The gap at the beginning of each graph reflects no predation by eggs, larvae, protonymphs and deutonymphs.

For females of aggregation type 2, daily predation rate on thrips increased quickly within the first 3–4 days of adult emergence, reaching a plateau that practically lasted until the end of the adult life (Figure 3). Daily predation ranged between about 0.3 and 0.7 thrips pre-pupae and pupae when nematodes were also present in the experimental unit, and between 0.4 and 1.0 when thrips was the only prey. For aggregation type 3, daily predation was more irregular, but usually distinctly higher than observed for aggregation type 2. When both prey were available, daily rate increased up to the fifteenth day of beginning of the mite life cycle, reducing afterward almost to zero, increasing quickly to reach a maximum of about 2.0 thrips just one day before the remaining females died. When only thrips were available, predation rate increased quickly to reach a plateau that lasted about 12 days, reducing afterward to a new plateau that lasted about 5 days. Daily predation ranged most often between 1.0 and 1.5 in the first plateau, and between 0.0 and 1.0 in the second. Male mean daily predation rate ranged between 0.0 and 0.3 for most combinations of aggregation types and diets, but between 0.0 and 0.5 for aggregation type 3, when only thrips was offered as prey.

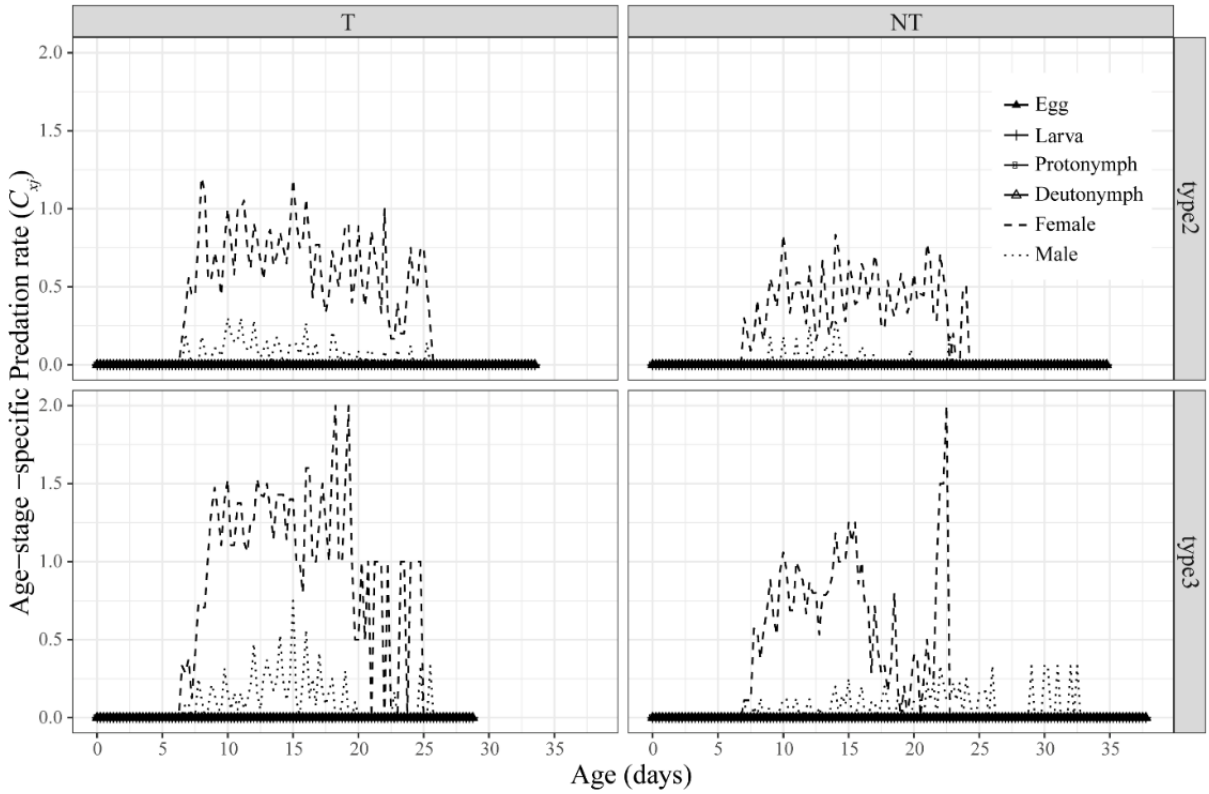


Figure 3. Stage-specific (cited as age-stage-specific) predation rates (C_{xj}) of *Parasitus bituberosus* preying on *F. occidentalis* only (T) and these combined with rhabditid nematodes (NT). Type of aggregation: deutonymphs and adults in the first 24 h after emergence paired with opposite sexes (Type 2) and mites always paired (Type 3). (Day 0: beginning of the predator life cycle)

Feeding by *Parasitus bituberosus* (expressed by k_x and q_x) began at day 6 from the beginning of the predator life cycle for both diets (NT and T) and both aggregation types (2 and 3) and fluctuated throughout the adult period (Figure 4). Both k_x and q_x decreased after reaching a maximum level, except in aggregation type 2 when both prey were available (probably because of the lower demand for nutrition in those females, that had lower oviposition rate than females of aggregation type 3. In the initial phase of predation, k_x and q_x were similar, q_x turning considerably lower than k_x with decreasing survivorship, as expected by the known relation between those two parameters, as shown in Material and Methods.

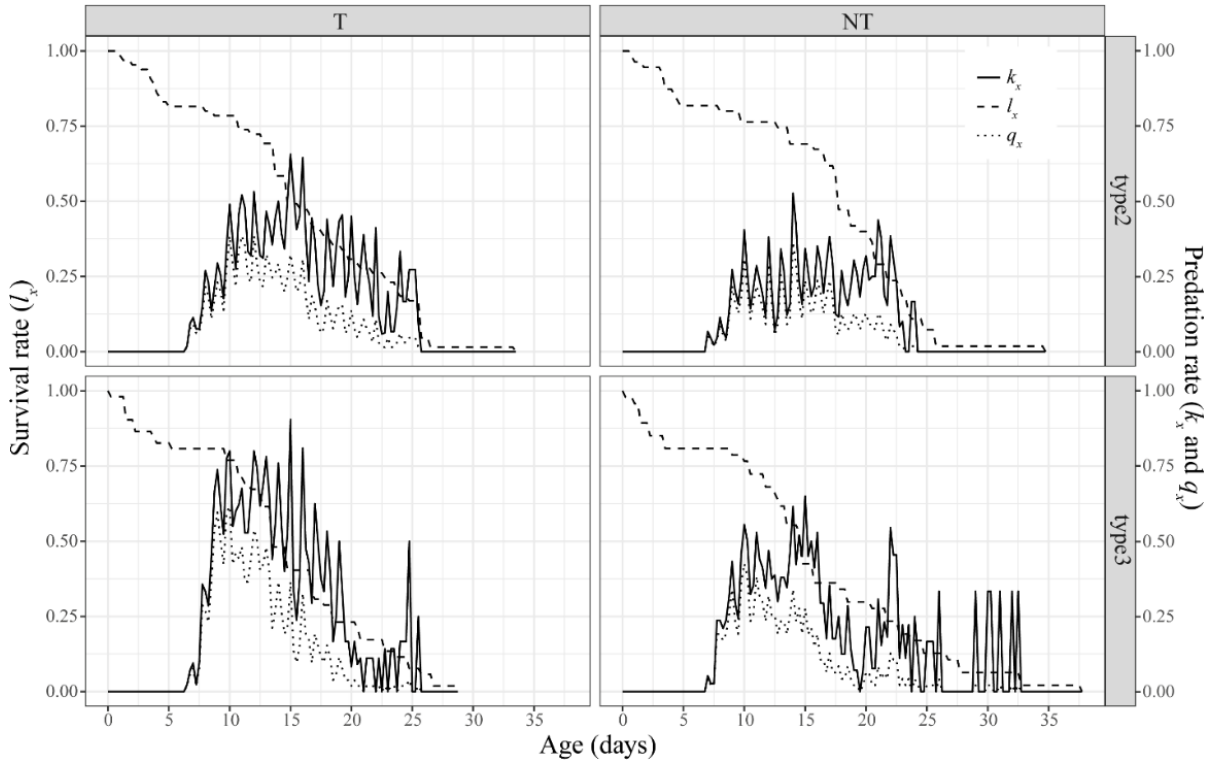


Figure 4. Age-specific predation rate (k_x), age-specific net predation rate (q_x) and survival rate (lx) of *Parasitus bituberosus* preying on *F. occidentalis* only (T) and these combined with rhabditid nematodes (NT). Type of aggregation: 2 – Eggs, larvae and protonymphs in isolation, and deutonymphs and adults in the first 24 h after emergence paired with opposite sexes; 3 – Mites always paired (deutonymphs paired with opposite sexes). (Day 0: beginning of the predator life cycle).

6.4. Discussion

The efficiency of *P. bituberosus* as a predator of *F. occidentalis* cannot be compared with that of other parasitid mites, as this is the first study about the interaction of a parasitid species and that prey. Thus, comparisons of our data can only be done with those referring to the interaction of *P. bituberosus* or other parasitids on other food sources. For *Parasitellus fucorum* (De Geer) fed with a mixture of pieces of dead mealworm, sugar-water and pollen freshly removed from the corbicula of field collected bumblebees, also at 21 ºC, Koulianos and Schwarz (1999) reported 2–3 times longer duration of egg, larval and protonymphal stages and female longevity. However, in the same study, the authors found similar values of oviposition period and fecundity as found in this study for mites paired continuously, when nematodes were included in the diet.

For *Parasitus consanguineus* Oudemans & Voigts fed with first and second instars of *Megaselia halterata* (Diptera: Phoridae) or *Lycoriella ingenua* (Diptera: Sciaridae), again at 21 ºC, Szlendak and Lewandowski (2009) reported slightly longer or shorter durations of

different developmental stages and longevity, but much lower fecundity (12.3 and 17.8 eggs/female on those respective prey) than found in this study for mites paired continuously, and on all diets.

For *P. bituberosus* fed rhabditid nematodes and at 25 ºC, Szafranek et al. (2013) reported similar duration for the egg stage, but shorter duration for other immature stages as well as female longevity in comparison with the results of this study when the mites were paired continuously. They also reported lower fecundity (59.5) but similar daily oviposition rate when compared with results of this study for mites fed only rhabditid nematodes and always paired.

Because the oviposition period was short in the mites paired only as deutonymphs and for 24 h after adult emergence, daily oviposition rates were similar to each other and high when mites were fed thrips + nematodes for the two aggregation types (2 and 3). However, considering the entire life cycle, maintaining the mites always paired and fed with thrips + nematodes had an important effect in total fecundity. The high fecundity recorded has also been observed in other parasitid species (Wise et al. 1988; Schwarz and Walzl 1996; Yasui 1997; Koulianos and Schwarz 1999), which were reported to lay about 80–220 eggs per female within oviposition periods of approximately 5–14 days, corresponding roughly to oviposition rates of ??–?? eggs per female per day. For the parasitids, short oviposition periods and high fecundity could be related to the transient habitats preferred by these mites, associated with the fact that migration to new habitats occurs at the deutonymphal stage, that is, before oviposition started. The longer oviposition periods of the Macrochelidae (also Mesostigmata), which favor the same type of habitats as parasitids (Azevedo et al. 2015), could be explained by the fact they migrate as adults, wwith mites being able to stop oviposition in one site, migrate, and start oviposition in newly reached sites. For mesostigmatid mites of the family Phytoseiidae, Sabelis (1985) reported a general trend for species with shorter oviposition periods to have higher reproduction rate.

Life table parameters allow comparisons of the increase potential of different populations. The only data in this regard for parasitid mites were given by Szafranek et al. (2013) for *P. bituberosus* fed with rhabditid nematodes, showing lower values of R_o and T than observed in this study for predators on all evaluated diets and aggregations types, except for mites paired only in deutonymph stage and adults in the first 24 h after emergence and fed only *F. occidentalis*. The values of r_m and λ reported by those authors were similar to those determined in this study for mites maintained in aggregation types 2 and 3, for which nematodes constituted part of their diets.

Even for other predators, life table parameters on pre-pupae and pupae of *F. occidentalis* are scarce. The values of R_o reported by Moreira et al. (2015) for *Cosmolaelaps jaboticabalensis* Moreira, Klompen & Moraes (Laelapidae) were comparable to those obtained in this study for the mites paired continuously and for which nematodes constituted part of their diet. However, r_m and λ were slightly lower for *C. jaboticabalensis* than obtained in this study for mites of aggregation types 2 and 3, with all diets, except for mites paired only in deutonymphal stage and fed only with *F. occidentalis*, for which those values were slightly lower.

6.4.1. Effect of aggregation on the biology of *Parasitus bituberosus*

The relatively long deutonymphal stage of mites always maintained in isolation contrasted with the quickness at which laboratory colonies of these mites usually increase. However, the reason for the higher survivorship of immatures and usually shorter duration of deutonymphal stage of paired immatures could not be determined in this study. Yasui (1997) reported that at 27 ºC the development of *P. fimetorum* from egg to deutonymph was accomplished in 60 h. However, duration of the deutonymphal stage was found to be highly variable, depending on whether it was kept in isolation (about 28 days) or under crowded conditions, with both sexes present (64 h). However, in studying a Polish population also identified *P. bituberosus*, Szafranek et al. (2013) did not report the requirement of aggregation for the development of immatures. In a personal communication, M. Lewandowski (co-author of Szafranek et al. 2013) reported having initially in their study very low molting rates from deutonymphs to adults, which increased considerably after transferring the deutonymphs to larger experimental units (a cone of 7–15 mm in diameter drilled in a glass plate of 4.0 x 3.5 x 0.5 cm). Those units were still smaller than the units used in the present work, and thus unit size might not have been an important factor determining the low survivorship of isolated predators in the present study. Rather, the actual process of transferring the mites could have been the actual important factor. This suggests that more than one factor can be involved in the ability of *P. bituberosus* to complete the deutonymphal stage, including diet (Ito 1973).

As in other Parasitinae species (ex. *P. fucorum*; Koulianos and Schwarz 1999), deutonymphs might be more resistant to environmental stresses, and this could be related to being the migrant stage. This contrasts with the high mortality of this stage in our study, most certainly because it was conducted under conditions of minimum environmental stresses.

Given the higher mortality of female deutonymphs than of other immature stages and of male deutonymphs, it is hypothesized that the former are more sensitive than the others to the presence of a stimulus of the opposite sex to molt to the next stage. The much higher mortality of deutonymphs seems related to the short female longevity and the need for mating for oviposition to take place. It is reasoned that it would be beneficial for the species that the female deutonymph waited until a companion of the opposite sex is around before molting to the adult stage. This could also explain the much higher proportion of males reaching adulthood for mites kept in continuous isolation. The effect of aggregation on molting was also reported for *P. gregarius* (Ito 1973, 1976, 1977b), for which highest immature survivorship occurred when male and female deutonymphs, or male adults and female deutonymphs were maintained together. The results of the present study suggest *P. bituberosus* to be similar to *P. gregarious* in this regard; although the results of our experiments were obtained only by pairing male and female deutonymphs, preliminary observations suggested that pairings of male adult and female deutonymph also resulted in high percentage of female adult emergence. An alternative explanation for the higher mortality of deutonymphs.

Positive effect of aggregation in the adult stage, suggested by the higher oviposition rate of females always associated with males, might at least in part be related to the possibility of multiple inseminations. This would seem expected for this species, given the determined requirement of insemination for *P. bituberosus* to oviposit. This requirement has been reported for other parasitid mites (Ito 1973; Yasui 1997). Yasui (1997) also evaluated the effect of multiple inseminations, finding that fecundity increased from about 21.1 eggs with single inseminations to about 92.5 eggs, when at least two inseminations occurred within one day. In the present study, multiple inseminations with the same male (or two males, when the first died) over the whole female lifetime (aggregation type 3) also led to higher fecundity than when male was maintained with the female only as deutonymph and during the first 24 h after female emergence.

The need for insemination to allow oviposition suggests a diplodiploid reproduction, as suggested by Sokolow (1934) and Norton et al. (1993) for Parasitidae. This type of reproduction is also commonly associated with 1:1 sex ratio (Walter 2009; Walter and Proctor 2013), which suggests the need for the continuous presence of males in the population.

6.4.2. Ability of *Parasitus bituberosus* to control *Frankliniella occidentalis*

The results of this study indicated that *P. bituberosus* cannot control *F. occidentalis* if an alternative food source is not available for immature predators, as only adults of the predator preyed on *F. occidentalis*. In the present study, the rhabditid nematode supported immature development, and it is possible that in nature this or other nematodes are of major importance in this regard, although other organisms could conceivably be consumed. Szafranek et al. (2013) reported that *P. bituberosus* completed immature development when fed with rhabditid nematodes, pygmephorid mites and sciarid larvae, but not on phorid larvae. Al-Amidi and Downes (1990) reported consumption of the dipteran *Heteropeza pygmaea* Winnertz (Cecidomyiidae) by *P. bituberosus* protonymphs and deutonymphs.

The reason for the inability of immature of *P. bituberosus* to feed on thrips has not been determined in the present study. Szafranek et al. (2013) suggested that defensive behavior of phorid larvae may deter predation by *P. bituberosus* immatures. Pre-pupae and pupae of *F. occidentalis* are larger than the immature stages of *P. bituberosus*, and it was observed that slight contortions could prevent predation by the latter. Nematodes are much smaller and usually more numerous, so they are easier to capture and kill (Szafranek et al. 2013).

Importance of free-living nematodes in the diet has been reported for several parasitid species. Szafranek et al. (2013) reported faster development and higher fecundity of *P. bituberosus* on rhabtidids than on pygmephorid mites and sciarid larvae. Ito (1977) observed that deutonymphs of *P. gregarius* preferred nematodes (*Rhabditis elongate* Scheneider) over housefly eggs and larvae. Nematode feeding has also been reported for immatures of several other groups of predatory mites (Castilho et al. 2015; Moreira et al. 2015), and it has been well documented in mites of the family Macrochelidae (Azevedo et al. 2015).

The inability of *P. bituberosus* to complete development on *F. occidentalis* is certainly a negative characteristic of the predator concerning its potential as biological control agent of this pest. For practical use, releases of the predator could only be efficacious if the alternative prey for immature development is already available, or if it is released with the predator. Provision of alternative or complementary food has been done by growers in the release of other groups of predatory mites, especially plant inhabiting phytoseiid predators (Janssen and Sabelis 2015; Muñoz-Cárdenas et al. 2017). Mites of this family have been

extensively used for the control of plant inhabiting pests around the world, some species being released preventively, together with the provision of pollen (McMurtry et al. 2013; Janssen and Sabelis 2015) or astigmatid mites (Muñoz-Cárdenas et al. 2017).

As it could be expected, the provision of alternative prey could eventually reduce the rate of predation of each individual predator on a given pest species (Holt 1977; Abrams and Hiroyuki 1996; van Baalen et al. 2001). Ito (1977a) reported that the presence of nematode *Rhabditis elongata* Schneider (Rhabditida: Rhabditidae) reduced by almost 20% the predation of housefly eggs by *P. gregarius*. However, some degree of reduction can be tolerated if the reduced rate is still sufficient to control the pest, especially if there is a gain in relation to other biological attributes of the predator, as for example increased reproduction. In this study, in addition to allowing the predator to complete its life cycle, availability of nematodes also improved the performance of the predator, as indicated by the higher rates of oviposition, intrinsic and net reproductive rates.

Female predation rates of *P. bituberosus* (female daily) determined in this study were comparable to what has been reported in the literature for other predatory mites feeding on *F. occidentalis*. Rates determined by Berndt et al. (2004b) for *Gaeolaelaps aculeifer* Canestrini and by Castilho et al. (2009) for *Protogamasellopsis zaheri* Abo-Schnaf, Castilho & Moraes (cited as *P. posnaniensis* Wisniewski & Hirschmann, according to Castilho et al. 2009), respectively 3.5 and 4.3 thrips, were similar to those determined in this study. Only recently has the net reproductive rate (C_o) been reported in works concerning predation by mites (Moghadasi et al. 2014; Saemi et al. 2017; Ajvad et al. 2018). This new index provides an interesting new insight, as it integrates predation by both sexes and throughout their life cycle, differently from most literature information, in which predation is evaluated separately for each developmental stage (e.g. Berndt et al. 2004b; Castilho et al. 2009). Thus, C_o provides a better perspective of the potential of a given predator at the population level. However, none of the previous publications providing this index refer to *F. occidentalis* as prey.

In conclusion, the predation capacity and r_m of *P. bituberosus* are relatively high, implying that the predator could have an important impact on the pest population. The predation capacity is comparable and r_m is higher than that of *G. aculeifer* (Rueda-Ramirez et al. in preparation), commercially used for the control of this pest. The fact that the development and fecundity of this species can be supported by free living nematodes raises the possibility for using it in a strategy of conservation biological control, as free-living nematodes are ubiquitous organisms in the soil (Neher 2010). The encouraging results of this study warrants further investigation of *P. bituberosus*, to evaluate methods for its mass

production, inclusion in conservation biological control programs, and its performance against the pest at larger scale.

Acknowledgements

To COLCIENCIAS (Departamento Administrativo de Ciencia, Tecnología e Innovación, Colombia) for the scholarship to the first author (Process No. 617-2013, Chapter 3), Pontificia Universidad Javeriana-COLCIENCIAS-SENA (Servicio Nacional de Aprendizaje, Colombia) for the support to the second author through the program JÓVENES INVESTIGADORES E INNOVADORES EN ALIANZA SENA (Process 738- 2015). To Hsin Chin (Department of Plant Production and Technologies, Faculty of Agricultural Sciencies and Technologies, Nigde University, Turkey) for the valuable suggestions, comments and teaching about the data preparation and analysis. To Augusto Ramirez-Godoy, Universidad Nacional de Colombia, for granting space for the experiments. To Luz Stella Fuentes, Centro de Bio-Sistemas Universidad Jorge Tadeo Lozano, and Alexander Escobar, Bichopolis, for providing the initial stock of *F. occidentalis* to be used in this study. To Everth Ebratt Ravelo for confirming the thrips identification. To Eric Palevsky for reviewing the previous version of this manuscript and his valuable suggestions and comments.

References

Abbatiello MJ (1965) A Culture Chamber for Rearing Soil Mites. Turtox News 43:162–164

Abrams PA, Hiroyuki M (1996) Positive indirect effects between prey species that share predators. Ecology 77:610–616. doi: 10.2307/2265634

Ajvad FT, Madadi H, Michaud JP, et al (2018) Life table of *Gaeolaelaps aculeifer* (Acari: Laelapidae) feeding on larvae of *Lycoriella auripila* (Diptera: Sciaridae) with stage-specific estimates of consumption. Biocontrol Sci Technol 28:157–171. doi: 10.1080/09583157.2018.1434613

Al-Amidi AHK, Downes MJ (1990) *Parasitus bituberosus* (Acari: Parasitidae), a possible agent for biological control of *Heteropeza pygmaea* (Diptera: Cecidomyiidae) in mushroom compost. Exp Appl Acarol 8:13–25. doi: 10.1007/BF01193378

Al-Amidi AHK, Dunne R, Downes MJ (1991) *Parasitus bituberosus* (Acari: Parasitidae): An agent for control of *Lycoriella solani* (Diptera: Sciaridae) in mushroom crops. Exp Appl Acarol 11:159–166. doi: 10.1007/BF01246088

Attavian B (2014) Cut Flowers and Greenery Import Manual Cut Flowers and Greenery, First Ed. United States Department of Agriculture - USDA

Axtell R., Rutz D. (1986) Role of parasites and predators as biological fly control agents in poultry production facilities. In: Patterson RS, Rutz DA (eds) Biological control of muscoid flies. Entomological Society of America. Miscellaneous Publications No. 61, pp 88–100

Axtell RC (1986) Fly Management in Poultry Production: Cultural, Biological, and Chemical1. Poult Sci 65:657–667

Azevedo LH de, Emberson RM, Esteca F de CN, Moraes GJ de (2015) Macrochelid Mites (Mesostigmata: Macrochelidae) as Biological Control Agents. In: Carrillo D, de Moraes GJ, Peña JE (eds) Prospects for Biological Control of Plant Feeding Mites and Other Harmful Organisms. Springer International Publishing, Switzerland, pp 103–132

Berndt O, Meyhöfer R, Poehling HM (2004a) The edaphic phase in the ontogenesis of *Frankliniella occidentalis* and comparison of *Hypoaspis miles* and *Hypoaspis aculeifer* as predators of soil-dwelling thrips stages. Biol Control 30:17–24. doi: 10.1016/j.biocontrol.2003.09.009

Berndt O, Poehling HM, Meyhöfer R (2004b) Predation capacity of two predatory laelapid mites on soil-dwelling thrips stages. Entomol Exp Appl 112:107–115. doi: 10.1111/j.0013-8703.2004.00185.x

Berry RE (1973) Biology of the predaceous mite, *Pergamasus quisquiliarum* on the garden Symphylan, *Scutigerella immaculata* in the laboratory. Ann Entomol Soc Am 66:1354–1356

Bhattacharyya SK (1963) A revision of the british mites of the genus *Pergamasus* Berlese S. Lat. (Acari: Mesostigmata). Trustees of the British Museum (Natural History), London

Buitenhuis R, Shipp JL (2008) Influence of plant species and plant growth stage on *Frankliniella occidentalis* pupation behaviour in greenhouse ornamentals. J Appl Entomol 132:86–88. doi: 10.1111/j.1439-0418.2007.01250.x

Calixto (2005) Trips del suborden Terebrantia (Insecta: Thysanoptera) en la Sabana de Bogotá. Rev. Colomb. Entomol. 31:207–213

Castilho RC, de Moraes GJ, Silva ES, Silva LO (2009) Predation potential and biology of *Protogamasellopsis posnaniensis* Wisniewski & Hirschmann (Acari: Rhodacaridae). Biol Control 48:164–167. doi: 10.1016/j.biocontrol.2008.10.004

Castilho RC, Venancio R, Narita JPZ (2015) Mesostigmata as biological control agents, with emphasis on Rhodacaroidea and Parasitoidea. In: Carrillo D, de Moraes GJ, Peña JE (eds) Prospects for biological control of plant feeding mites and other harmful organisms. Springer International Publishing, Cham, pp 1–31

Chi H (1988) Life-table analysis incorporating both sexes and variable development rates among individuals. Environ Entomol 17:26–34. doi: 10.1093/ee/17.1.26

Chi H (2016a) TWOSEX-MSCHART. A computer program for age stage, two-sex life table analysis

Chi H (2016b) CONSUME-MSChart (version 04.22): A computer program for the predation rate analysis based on age-stage, two-sex life table.

Chi H, Huang Y-B, Allahyari H, et al (2011) Finite predation rate: a novel parameter for the quantitative measurement of predation potential of predator at population levelno. Nat Preced 1–11

Chi H, Yang T-C (2003) Two-sex life table and predation rate of *Propylaea japonica* Thunberg (Coleoptera: Coccinellidae) fed on *Myzus persicae* (Sulzer) (Homoptera: Aphididae). Environ Entomol 32:327–333. doi: 10.1603/0046-225X-32.2.327

Evans OE, Till WM (1979) Mesostigmatic mites of Britain and Ireland: An introduction to their external morphology and classification. Trans Zool Soc London 35:139–270

Freire RAP, Moraes GJ de (2007) Description of a new species of *Cosmolaelaps* Berlese (acari: Laelapidae, Hypoaspidinae) from Brazil and its biological cycle. Int J Acarol 33:353–358. doi: 10.1080/01647950708683697

Hennessey MK, Farrier MH (1989) Mites of the family Parasitidae inhabiting forest soils of North and South Carolina. 78

Hofstetter RW, Moser JC, Mcguire R (2009) Observations on the mite *Schizosthetus lyriformis* (Acari: Parasitidae) preying on bark beetle eggs and larvae. Entomol News 120:397–400. doi: 10.3157/021.120.0408

Holt RD (1977) Predation, apparent competition, and the structure of prey communities. Theor Popul Biol 12:197–229. doi: https://doi.org/10.1016/0040-5809(77)90042-9

Hyatt KH (1980) Mites of the subfamily Parasitinae (Mesostigmata: Parasitidae) in the British Isles. Bull Br Museum Nat Hist Zool 38:237–378

Ito Y (1977a) Predatory activity of mesostigmatid mites (Acarina : Mesostigmata) for house fly eggs and larvae under feeding of nematodes. Med Entomol Zool 28:167–173. doi: 10.7601/mez.28.167

Ito Y (1971) Predation by manure-inhabiting mesostigmatids (Acarina: Mesostigmata) on some free-living nematodes. Appl Entomol Zool 6:51–56

Ito Y (1973) Effect of isolation on the moult of *Parasitus* sp.: deutonymphs (Acarina : Mesostigmata). Appl Entomol Zool 8:1–7. doi: 10.1303/aez.8.1

Ito Y (1977b) Contact stimulation between intact and amputated deutonymphs of *Parasitus gregarius* for induction of molting (Acarina : Parasitidae). Appl Entomol Zool 12:290–291. doi: 10.1303/aez.12.290

Ito Y (1976) Contact stimulation by crowding for induction of molting in *Parasitus gregarius* deutonymphs (Acarina : Parasitidae). Appl Entomol Zool 11:295–301. doi: 10.1303/aez.11.295

Janssen A, Sabelis MW (2015) Alternative food and biological control by generalist predatory mites: the case of *Amblyseius swirskii*. Exp Appl Acarol 65:413–418. doi: 10.1007/s10493-015-9901-8

Karg W (1972) Zur kenntnis der gattung *Parasitus* Latreille, 1795 (Acarina, Parasitiformes) aus komposterden und gurkenkulturen. Dtsch Entomol Zeitschrift 19:55–63. doi: 10.1002/mmnd.19720190108

Kazemi S, Arjomandi E, Ahangaran Y (2013) A review of the Iranian Parasitidae (Acari: Mesostigmata). Persian J Acarol 2:159–180

Keum E, Kaczmarek S, Jung C (2016) New records of Parasitidae mites (Acari; Mesostigmata) in Korea. J Species Res 5:300–308. doi: 10.12651/JSR.2016.5.3.300

Kiers E, De Kogel WJ, Balkema-Boomstra A, Mollema C (2000) Flower visitation and oviposition behavior of *Frankliniella occidentalis* (Thysan., Thripidae) on cucumber plants. J Appl Entomol 124:27–32. doi: 10.1046/j.1439-0418.2000.00433.x

Kinn DN (1971) The life cycle and behavior of *Cercoleipus coelonotus* (Acarina: Mesostigmata) Including a survey of phoretic mite associates of California Scolytidae. Univ Calif Publ Entomol 65:

Koulianos S, Schwarz HH (1999) Reproduction, development and diet of *Parasitellus fucorum* (Mesostigmata: Parasitidae), a mite associated with bumblebees (Hymenoptera: Apidae). J Zool 248:267–269. doi: DOI: undefined

Laakso J, Seta H (1999) Population- and ecosystem-level effects of predation on microbial-feeding nematodes. Oecologia 120:279–286. doi: 10.1007/s004420050859.

Lesna I, Sabelis MW, Bolland HR, Conijn CGM (1995) Candidate natural enemies for control of *Rhizoglyphus robini* Claparède (Acari: Astigmata) in lily bulbs: exploration in the field and pre-selection in the laboratory. Exp Appl Acarol 19:655–669. doi: 10.1007/BF00145254

McMurtry JA, Moraes GJ De, Sourassou NF (2013) Revision of the lifestyles of phytoseiid mites (Acari: Phytoseiidae). Syst Appl Acarol 18:297–320. doi: 10.11158/saa.18.4.1

Micherdziński W (1969) Die Familie Parasitidae Oudemans 1901 (Acarina, Mesostigmata), Polska Aka. Państwowe Wydawnictwo Naukowe

Moghadasi M, Saboori A, Allahyari H, Zahedi Golpayegani A (2014) Life table and predation capacity of *Typhlodromus bagdasarjani* (Acari: Phytoseiidae) feeding on *Tetranychus urticae* (Acari: Tetranychidae) on rose. Int J Acarol 40:501–508. doi: 10.1080/01647954.2014.962084

Moreira GF, de Morais MR, Busoli AC, de Moraes GJ (2015) Life cycle of *Cosmolaelaps jaboticabalensis* (Acari: Mesostigmata: Laelapidae) on *Frankliniella occidentalis* (Thysanoptera: Thripidae) and two factitious food sources. Exp Appl Acarol 65:219–226. doi: 10.1007/s10493-014-9870-3

Muñoz-Cárdenas K, Ersin F, Pijnakker J, et al (2017) Supplying high-quality alternative prey in the litter increases control of an above-ground plant pest by a generalist predator. Biol Control 105:19–26. doi: https://doi.org/10.1016/j.biocontrol.2016.11.004

Muraoka M, Ishibashi N (1976) Nematode-feeding mites and their feeding behavior. Appl Entomol Zool 11:1–7. doi: 10.1303/aez.11.1

Neher DA (2010) Ecology of plant and free-living nematodes in natural and agricultural soil. Annu Rev Phytopathol 48:371–394. doi: 10.1146/annurev-phyto-073009-114439

Norton RA, Kethley JB, Johnston DE, O'Connor BM (1993) Phylogenetic perspectives on genetic systems and reproductive modes of mites. In: Wrensch DL, Ebbert MA (eds) Evolution and diversity of sex ratio in insects and mites. Chapman & Hall Publ., New York, pp 8–99

Peel MC, Finlayson BL, McMahon TA (2007) Updated world map of the Köppen-Geiger climate classification. Hydrol Earth Syst Sci 11:1633–1644. doi: 10.5194/hess-11-1633-2007

Sabelis MW (1985) Reproduction. In: Helle W, Sabelis MW (eds) Spider mites: their biology, natural enemies and control. Volume 1B. Part 2 Natural enemies of the Tetranychidae. Elsevier, Amsterdam, pp 73–82

Saemi S, Rahmani H, Kavousi A, Chi H (2017) Group-rearing did not affect the life table and predation rate of *Phytoseiulus persimilis* (Acari: Phytoseiidae) fed on *Tetranychus urticae*. Syst Appl Acarol 22:1698–1714. doi: 10.11158/saa.22.10.11

Schousboe C (1987) Deutonymphs of *Parasitellus* phoretic on Danish bumblebees (Parasitidae, Mesostigmata; Apidae, Hymenoptera). Acarologia 28:37–41

Schwarz HH, Walzl MG (1996) Pairing, oviposition and development in two sibling species of phoretic mites (Acari: Mesostigmata: Parasitidae: Poecilochirus spp.) associated with burying beetles (Coleoptera: Silphidae: *Nicrophorus* spp.). J Nat Hist 30:1337–1348. doi: 10.1080/00222939600771251

Sokolow I (1934) Untersuchungen über die Spermatogenese bei den Arachniden. V. Uber die Spermatogenese der Parasitidae. Zeitschrift für Zellforsch und Mikroskopische Anat 21:42–109. doi: https://doi.org/10.1007/BF00668270

Szafranek P, Lewandowski M, Kozak M (2013) Prey preference and life tables of the predatory mite *Parasitus bituberosus* (Acari: Parasitidae) when offered various prey combinations. Exp Appl Acarol 61:53–67. doi: 10.1007/s10493-013-9701-y

Szlendak E, Lewandowski M (2009) Development and reproductive capacity of the predatory mite *Parasitus consanguineus* (Acari: Parasitidae) reared on the larval stages of *Megaselia halterata* and *Lycoriella ingenua*. Exp Appl Acarol 47:285–292. doi: 10.1007/s10493-008-9218-y

Tuan S-J, Yeh C-C, Atlihan R, Chi H (2016) Linking life table and predation rate for biological control: a comparative study of *Eocanthecona furcellata* (Hemiptera: Pentatomidae) fed on *Spodoptera litura* (Lepidoptera: Noctuidae) and *Plutella xylostella* (Lepidoptera: Plutellidae. J Econ Entomol 109:13–24. doi: 10.1093/jee/tov265

van Baalen M, Křivan V, van Rijn PCJ, Sabelis MW (2001) Alternative food, switching predators, and the persistence of predator-prey systems. Am Nat 157:512–524. doi: 10.1086/319933

Walter DE (2009) Reproduction and embryogenesis. In: Krantz GW, Walter DE (eds) Manual of Acarology, Third. Texas Tech University Press, Lubbock, Texas, pp 54–56

Walter DE, Proctor HC (2013) Mites: ecology, evolution & behaviour. life at a microscale, Second. Springer, Dordrecht

Wise GUU, Hennessey MKK, Axtell RCC (1988) A new species of manure-inhabiting mite in the genus *Poecilochirus* (Acari: Mesostigmata: Parasitidae) predacious on house fly eggs and larvae. Ann Entomol Soc Am 81:209–224

Yasui Y (1997) Sperm competition and the significance of female multiple mating in the predatory mite *Parasitus fimetorum*. Exp Appl Acarol 21:651–664. doi: 10.1023/A:1018456618435

Zhang Z-QQ (2003) Mites of Greenhouses: Identification, Biology and Control. CABI Pub.

7. CONCLUSIONS

The results of the studies reported in the different chapters of this thesis allow the following conclusions:

1) Diversity of non-Uropodina mesostigmatid mites in very high in soils of rose fields and of patches of the natural vegetation is high of the Bogota plateau, Cundinamarca, Colombia;

2) Diversity is much higher in patches of the natural vegetation than in rose fields;

3) Dominant non-Uropodina mesostigmatid families of that region resemble those reported in other temperate areas of the world, with a predominance of species of the families Parasitidae, Veigaiidae and Laelapidae;

4) A significant and positive relation exist between the the densities of those mites in the soil and the levels of organic matter and of pH;

5) *Parasitus bituberosus* Karg cannot complete immature development when only pre-pupae and pupae of *Frankliniella occidentalis* (Pergande) are available as prey;

6) The presence of individuals of opposite sexes can allow normal deutonymphal development of *P. bituberosus*;

7) The Colombian populations of *Geaolaelaps aculeifer* Canestrini and *P. bituberosus* are promising as biological control agents of *F. occidentalis*, given their high predation capacity;

8) Free living nematodes of the family Rhabditidae and mites *A. ovatus* are acceptable as alternative food for mass rearing or as complementary food in periodic releases of *P. bituberosus* and *G. aculeifer*.