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Dirección de Nuevas Creaciones
E. S. D.

Ref: Expediente No. NC2022/0002532.

Solicitud de Patente de Invención denominada «NUEVOS MÉTODOS PARA LA CRIANZA Y LIBERACIÓN CONTROLADA DE ÁCAROS DEPREDADORES».

Fase nacional de la solicitud PCT/IL2019/050982.

Solicitante: BIO-BEE SDE ELIYAHU LTD.

Luz Helena Adarve, identificada como aparece al pie de mi firma, y obrando en mi condición de apoderada de **BIO-BEE SDE ELIYAHU LTD.,** solicitante de la patente en referencia, a continuación, doy respuesta al Oficio **No. 351** del 09 de enero de 2025.

1. **Respecto a la patentabilidad de la materia de la solicitud (Artículos 14, 15 y 20 de la Decisión 486)**

En los numerales 4, 5, 6 y 7 del Oficio No. **351**, se presentan varias objeciones sobre la patentabilidad de los objetos de las anteriores reivindicaciones 1 a 22, 27 a 34 y 36 a 56.

Por lo tanto, con el fin de superar las objeciones presentadas respecto a la patentabilidad de dichas reivindicaciones, **es deseo del solicitante presentar un capítulo reivindicatorio modificado compuesto por 22 reivindicaciones**, que encuentran su debido sustento en las reivindicaciones y la descripción originalmente presentadas, sin que ello conlleve ampliación de la invención.

Sobre las modificaciones presentadas en dicho capítulo reivindicatorio modificado, la expresión de «*huevos que no eclosionan*» encuentra su sustento en la anterior

reivindicación 57, y el sustento a la expresión «*hospedero artificia*l» se encuentra por lo menos en las páginas 59 y 63 de la descripción de la presente solicitud. Adicionalmente la definición de «*hospedero artificial*» se encuentra en la página 69 de la descripción de la presente solicitud.

1.1. Sobre los objetos que no se consideran una invención (Artículo 15 de la Decisión 486, literal b)

Sobre los objetos que no se consideran una invención según el Artículo 15 de la Decisión 486, el Oficio indica lo siguiente en su numeral 4:

> «*Debido a lo anterior, esta oficina establece que el objeto de las reivindicaciones 1 a 20 y 57 no se consideran como una invención, toda vez que, en sus preámbulos hacen alusión a "población de ácaros depredadores", lo que corresponde al todo de seres vivos como se encuentran en la naturaleza, puesto que en la descripción no se evidencia que dichos ácaros hayan sido modificados, ni presenten características que los distingan de los ácaros naturales.*
>
> *Adicionalmente las reivindicaciones 27 a 33 no se consideran una invención porque se refieren a procesos biológicos naturales, toda vez que reclaman métodos de crianza de individuos depredadores del género Phytoseiulus, donde esencialmente estos se alimentan de ácaros presas, lo cual se relaciona con la actividad predadora del ácaro depredador sobre el ácaro presa, lo que constituye un proceso biológico natural*».

El oficio en referencia manifiesta que las anteriores reivindicaciones 1 a 20 y 57 no corresponden a invenciones bajo la sección b) del artículo 15 de la Decisión 486, ya que sus preámbulos se refieren a «*población de ácaros depredadores*», que corresponde a todos los seres vivos tal como se encuentran en la naturaleza, ya que la descripción de los mismos no muestra que dichos ácaros hayan sido modificados o tengan características que los diferencien de los ácaros que se encuentran en la naturaleza.

Sobre esto el solicitante, sin conceder la exactitud de esta objeción y para agilizar el enjuiciamiento de la solicitud, las anteriores reivindicaciones 1 a 20, han sido

canceladas y, por lo tanto, las objeciones a estas reivindicaciones ya no son procedentes.

Respecto a la anterior reivindicación 57, correspondiente a la actual reivindicación 22 del capítulo reivindicatorio modificado que ahora se presenta, dicha reivindicación se modificó para que se refiera a una *composición*, que no corresponde a seres vivos como se encuentran en la naturaleza según se define en la sección b) del Artículo 15 de la Decisión 486. La composición reclamada comprende una combinación de componentes que abarca individuos de *Phytoseiulus* junto con una mezcla de huevos incapaces de eclosionar y etapas móviles inmovilizadas de un hospedero artificial artrópodo no tetraníquido, y un material portador. Por lo tanto, el objeto de la actual reivindicación 22, correspondiente a la anterior reivindicación 57, se considera una invención de acuerdo con el Artículo 15 de la Decisión 486 de la Comisión de la Comunidad Andina, año 2000.

El oficio indica además que las reivindicaciones 27 a 33 presentadas anteriormente no se consideran una invención porque se refieren a procesos biológicos naturales, ya que reivindican métodos para la crianza de individuos depredadores del género *Phytoseiulus*, donde estos se alimentan esencialmente de ácaros presa, lo que está relacionado con la actividad depredadora del ácaro depredador sobre el ácaro presa, lo que constituye un proceso biológico natural. Sobre esta objeción el solicitante respetuosamente discrepa por las razones expuestas más adelante.

Las anteriores reivindicaciones 27, 32 y 33 presentadas anteriormente han sido canceladas, y, por lo tanto, las objeciones a estas reivindicaciones ya no son procedentes.

Respecto a las anteriores reivindicaciones 28 a 31 presentadas anteriormente, correspondientes actuales reivindicaciones 9 a 14 del capítulo reivindicatorio modificado que ahora se presenta, *no* se refieren a un proceso biológico natural, sino que se refieren a un método artificial para obtener la composición *no natural* reclamada, con un grado sustancial de intervención humana.

El solicitante indica que el objeto de la actual reivindicación 9, correspondiente a la anterior reivindicación 28, ahora comprende un método para obtener la composición según se reclama en la actual reivindicación 1, correspondiente a la anterior

reivindicación 21. Se indica que la actual reivindicación 1 corresponde claramente a materia que es patentable y define una invención según la ley de patentes colombiana. Se afirma adicionalmente que el objeto de la actual reivindicación 1 modificada no corresponde a la «*totalidad o parte de un ser vivo tal como se encuentra en la naturaleza*» según el artículo 15 de la Decisión 486 de la Comisión de la Comunidad Andina, año 2000. La materia reclamada actualmente se refiere a una composición que comprende una combinación de los siguientes componentes: (1) individuos de ácaros depredadores *Phytoseiulus*, (2) una fuente de alimento para los individuos de ácaros depredadores que comprende una mezcla de huevos incapaces de eclosionar y etapas móviles inmovilizadas de un hospedero artificial artrópodo no tetraníquido, y (3) un material portador.

El solicitante afirma que esta composición reclamada, que asocia ácaros depredadores *Phytoseiulus* con una **mezcla de huevos incapaces de eclosionar y etapas móviles inmovilizadas de un hospedero artificial artrópodo no tetraníquido** como fuente de alimento para los ácaros depredadores, junto con un **material portador**, y el método para obtener la composición, NO es una materia tal como se encuentra en la naturaleza, o un proceso biológico natural, respectivamente. Esto se sustenta y demuestra con los siguientes argumentos:

1. Al momento de la presentación de la presente solicitud, la persona del oficio medianamente versada en la materia sabía que el género *Phytoseiulus* NO depreda naturalmente especies de artrópodos no tetraníquidos (por ejemplo, especies de ácaros presas Astigmata). Esto se describe en la revisión de «*Life-styles of Phytoseiid mites and their roles in biological control*» (McMurtry JA, Croft BA, Annu Rev Entomol, 1997, 42:291-321), que se anexa a este memorial. En esta revisión, el género *Phytoseiulus* se analiza en las páginas 292 a 294 en relación con el estilo de vida y los hábitos alimentarios de sus especies, en la sección «*Type I.* ***Specialized Predators of Tetranychus Species***» (ver páginas 292 a 294 de dicha revisión).

   Lo anterior se refuerza por la publicación del mismo autor titulada «*Revision of the lifestyles of phytoseiid mites (Acari: Phytoseiidae) and implications for biological control strategies*» (McMurtry et al, Systematic and Applied Acarology, Volumen 18, No 4: 24, diciembre de 2013) que también se anexa junto con este memorial y que respalda que las especies de *Phytoseiulus* (depredadores de tipo Ia) solo se alimentan y reproducen en sus presas

naturales. Por ejemplo, esta publicación, en el último párrafo de la página 298 recita que el «*Subtipo I-a—Depredadores [es] especializados de Tetranychus (Tetranychidae)*» y, en su primer párrafo de la página 299, además indica lo siguiente:

> *«Corresponde a las especies incluidas en el estilo de vida **Tipo I** de McMurtry & Croft (1997), que **contiene especies de Phytoseiulus**. Estos depredadores podrían haber coevolucionado con especies de Tetranychus, que tienen distribuciones muy agrupadas (véase McMurtry & Croft 1997).*
>
> ***Existe una vasta literatura que indica la asociación de Phytoseiulus con especies de Tetranychus** en condiciones de campo. Varios estudios nuevos en condiciones de laboratorio confirman la capacidad de Phytoseiulus para desarrollarse y reproducirse cuando se alimenta de especies de Tetranychus».*

Otras referencias ejemplares que apuntan hacia la dependencia de las especies de *Phytoseiulus* de los Tetraniquidos son los documentos de patente WO2013/103295 (véase desde la página 4, línea 28, hasta la página 5, línea 9), y EP2415356 (véase el párrafo [0003]). Por lo tanto, la persona del oficio medianamente versada en la materia comprobará por las referencias anteriores que las especies de *Phytoseiulus* no se alimentan de **especies de artrópodos no tetraníquidos** (véase desde la página 4, línea 33 hasta la página 5, línea 6, del documento WO2013/103295; y los párrafos [0034] y [0035] del documento EP2415356). Por ejemplo, el documento WO2013/103295, en sus páginas 4 y 5, divulga lo siguiente (énfasis añadido):

> *«Como sabe el experto en la materia, **las especies de Phytoseiulus requieren tetraníquidos, preferiblemente huevos de tetraníquidos, más preferiblemente huevos de Tetranichus urticae como fuente de alimento**.*
>
> *Para Phytoseiidae (**con excepción de las especies de Phytoseiulus**), las presas de cría Ascidae, Laelapidae, Macrochelidae, Parasitidae, Cheyletidae, Cunaxidae, Erythraeidae o Stigmaeidae pueden seleccionarse del suborden Astigmata.*

Por lo tanto, la persona del oficio, que conozca la técnica anterior de al menos McMurtry y Croft (1997), McMurtry et al. (2013) y WO2013/103295, sabría que **la invención reivindicada no podría encontrarse en la naturaleza**.

2. Además, estas poblaciones de especies de ácaros (género *Phytoseiulus* y **especies de artrópodos no tetraníquidos**) NO están en estrecha asociación en la naturaleza.

   Se debe enfatizar que las reivindicaciones actuales 1 y 9, correspondientes respectivamente a las anteriores reivindicaciones 21 y 28, se relacionan con una composición y un método para obtener la composición, lo que implica que sus constituyentes están en asociación íntima/funcional. Nunca se ha encontrado ni se ha reportado que se haya encontrado en la naturaleza una asociación de este tipo entre las especies de *Phytoseiulus* y la mezcla reclamada de huevos incapaces de eclosionar y etapas móviles inmovilizadas de hospederos artificiales artrópodos no tetraníquidos.

   Por el contrario, el experto en la materia sabe que los géneros Astigmatid, como ejemplo de hospedero artificial artrópodo no tetraníquido, infestan productos almacenados y pueden alimentarse directamente del sustrato alimentario. También se reporta que la dieta habitual de estos ácaros son hongos.

   Por tanto, el solicitante afirma que no se presenta ni se encuentra ninguna divulgación concreta de una asociación entre el género *Phytoseiulus* y un hospedero artificial artrópodo no tetraníquido (como la especie Astigmata) ni hechos que apunten inevitablemente hacia dicha asociación. Obvia y específicamente, la asociación reclamada entre los ácaros *Phytoseiulus* y una mezcla de **huevos incapaces de eclosionar y etapas móviles inmovilizadas de hospedero artificial artrópodo no tetraníquido, junto con un material portador, no podría encontrarse de forma natural o su producción no podría considerarse como un proceso biológico natural**.

Por lo tanto, la materia de las actuales reivindicaciones 9 a 14 y reivindicaciones 1 a 4, debe ser considerada como una invención de conformidad con el Artículo 15 de la Decisión 486 de la Comisión de la Comunidad Andina, año 2000.

1.2. Sobre los objetos que no se consideran patentables (Artículo 20 de la Decisión 486, literal c)

Sobre los objetos que no se consideran patentables según el Artículo 20 de la Decisión 486, el Oficio indica lo siguiente en su numeral 5:

> «*Debido a lo anterior, esta oficina establece que el objeto de las reivindicaciones 21, 22, 34 y 36 a 56 no es patentable, toda vez que, en sus preámbulos se refieren a "composición de control biológico" las cuales comprenden poblaciones de ácaros depredadores del género Phytoseiulus, y especies de ácaros astigmátidos de los géneros, Carpoglyphus, Dermatophagoides, Diamesoglyphus, Ctenoglyphus, Blomia, Glycyphagus, Lepidoglyphus, Austroglycyphagus, Aëroglyphus, Gohieria, Coproglyphus, Chortoglyphus, Glycyphagus, Lepidoglyphus, Tyrophagus, Acarus, Lardoglyphus, Thyreophagus, Aleuroglyphus, o Suidasia*».

El Examinador indicó en el oficio en referencia que la materia de las anteriores reivindicaciones 21, 22, 34 y 36 a 56 no es patentable, ya que sus preámbulos se refieren a «*composiciones de control biológico*» que incluyen poblaciones de ácaros depredadores del género *Phytoseiulus*, y especies de ácaros astigmátidos de los géneros Carpoglyphus, Dermatophagoides, Diamesoglyphus., Ctenoglyphus, Blomia, Glycyphagus, Lepidoglyphus, Austroglycyphagus, Aëroglyphus, Gohieria, Coproglyphus, Chortoglyphus, Glycyphagus, Lepidoglyphus, Tyrophagus, Acarus, Lardoglyphus, Thyreophagus, Aleuroglyphus o Suidasia.

El solicitante no está de acuerdo con este rechazo y afirma que las reivindicaciones tal como se han presentado actualmente son patentables como se explica a continuación.

El objeto de las reivindicaciones 1, 2, 15, 18, 20 y 21 tal como se han presentado actualmente (anteriores reivindicaciones 21, 22, 34, 36, 55 y 56), abarca una composición que comprende una combinación de los siguientes componentes (1) individuos de ácaros depredadores *Phytoseiulus*, (2) <u>una mezcla de huevos incapaces de eclosionar y etapas móviles inmovilizadas</u> de un <u>hospedero artificial</u> artrópodo no tetraníquido como fuente de alimento para los individuos de ácaros depredadores, y (3) un <u>material portador</u>. El solicitante afirma que esta composición

reivindicada, que asocia ácaros depredadores *Phytoseiulus* con una mezcla específica de etapas de desarrollo inmovilizadas seleccionadas de huevos incapaces de eclosionar y etapas móviles inmovilizadas del hospedero artificial artrópodo no tetraníquido y un material portador, es, de hecho, una materia patentable según la definición del Artículo 20 de la Decisión 486. La materia reivindicada en su totalidad NO está dirigida a animales *per se*, sino a una composición producida por los inventores de la presente solicitud mezclando los componentes de ácaros depredadores *Phytoseiulus* junto con huevos incapaces de eclosionar y etapas móviles inmovilizadas de la especie de artrópodo no tetraníquido como una dieta alternativa artificial para los ácaros depredadores, y un material portador. Se observa respetuosamente que la prueba para determinar si la materia es patentable debe realizarse sobre la totalidad de la combinación de características de las reivindicaciones y no sobre características individuales dentro de dichas reivindicaciones.

Además, como se explicó anteriormente de forma extensa (ver sección 1.1 de esta respuesta), la combinación de componentes de la composición reivindicada en las actuales reivindicaciones 1, 2, 15, 18 y 19 no se encontraría naturalmente ni sería considerada por una persona con conocimientos ordinarios en la materia como presente en la naturaleza.

En vista de lo anterior, el solicitante respetuosamente sostiene que las reivindicaciones 1, 2, 15, 18, 20 y 21 tal como se presentan actualmente (anteriores reivindicaciones 21, 22, 34, 36, 55 y 56), y las reivindicaciones dependientes de las mismas, deberían ser patentables de conformidad con el Artículo 20 de la Decisión 486 de la Comisión de la Comunidad Andina, año 2000.

1.3. Sobre los objetos que no se consideran un producto o procedimiento (Artículo 14 de la Decisión 486)

Sobre los objetos que no se consideran correspondientes a las dos únicas formas patentables de producto o procedimiento según el Artículo 14 de la Decisión 486, el oficio en referencia indica lo siguiente en su numeral 6:

> «*En consecuencia, las reivindicaciones 23, 24 y 26 no se consideran patentables, teniendo en cuenta que hacen referencia a "El uso de una*

especie de artrópodo no tetraníquido", "uso comprende aplicar individuos de una especie de artrópodo no tetraníquido a una planta objetivo" y "uso de una población de ácaros depredadores", lo que está reclamando el uso de la población de ácaros depredadores y composiciones para la protección de cultivos».

Según el oficio en referencia, las anteriores reivindicaciones 23, 24 y 26 no se consideran patentables, ya que se refieren al «*Uso de una especie de artrópodo no tetraníquido*», «*el uso comprende la aplicación de individuos de una especie de artrópodo no tetraníquido a una planta objetivo*» y «*uso de una población de ácaros depredadores*», que reivindica el uso de la población de ácaros depredadores y composiciones para la protección de cultivos. De acuerdo con lo establecido en el Artículo 14 de la Decisión 486 de la Comisión de la Comunidad Andina, año 2000, sólo son patentables las invenciones de producto o procedimiento.

En respuesta, se indica que la anterior reivindicación 24 fue cancelada y por lo tanto sus objeciones yo no son procedentes; y que la materia de las anteriores reivindicaciones 23 y 26 (correspondientes a las actuales reivindicaciones 5 y 7, respectivamente) se ha reorientado para reivindicar un *método* para criar una población de ácaros de individuos depredadores de *Phytoseiulus* mediante los pasos de proporcionar una mezcla de etapas de desarrollo inmovilizadas que comprenden huevos incapaces de eclosionar y etapas móviles inmovilizadas de una especie de artrópodo no tetraníquido, como fuente de alimento de un hospedero artificial para la población de ácaros depredadores de individuos depredadores de *Phytoseiulus*, junto con un material portador.

Así, las actuales reivindicaciones 5, y 7, tal como se encuentran actualmente presentadas, deben considerarse como conformes con el Artículo 14 de la Decisión 486 de la Comisión de la Comunidad Andina, año 2000.

2. <u>Respecto a las Objeciones a la Claridad y Concisión de las reivindicaciones (Artículo 30 de la Decisión 486)</u>

En el numeral 6.1 del Oficio No. **351**, se presentan las siguientes objeciones a la claridad de las reivindicaciones:

- «*Esta oficina informa que, las reivindicaciones 25 y 35 no son claras porque definen el dispositivo para la liberación de individuos, en términos de lo que contiene y no por sus características estructurales esenciales (partes y configuración). Además, el término "preferentemente" no es limitativo y hace opcional la característica de "una salida adecuada". Se sugiere hacer las aclaraciones necesarias*».

- «*De igual forma la reivindicación 35 no es clara, porque la expresión "un liberación sostenida" no tiene concordancia gramatical en el uso del pronombre, se sugiere hacer las correcciones*».

Según el oficio en referencia, las reivindicaciones 25 y 35, tal como se presentaron anteriormente, no son claras porque definen el dispositivo para liberar individuos en términos de lo que contiene y no por sus características estructurales esenciales (partes y configuración). Además, el término «*preferentemente*» no es limitativo y hace opcional la característica «*una salida adecuada*». Asimismo, la anterior reivindicación 35 no es clara, porque la expresión «*un liberación sostenida*» no tiene concordancia gramatical en el uso del pronombre.

En respuesta, el solicitante sostiene que las anteriores reivindicaciones 25 y 35 (correspondientes a las actuales reivindicaciones 6 y 17, respectivamente) se han modificado para definir el dispositivo con las características estructurales de una salida para la liberación sostenida de una serie de etapas móviles del ácaro depredador *Phytoseiulus*, que no estaba disponible antes de la invención actual (ya que estos ácaros depredadores se cultivaban y reproducían en su hospedero natural, que es la plaga de la planta, véase las páginas 63 y 64 de la descripción presentada).

Por lo tanto, las anteriores reivindicaciones 25 y 35 (correspondientes a las actuales reivindicaciones 6 y 17, respectivamente) deben considerarse conformes con el artículo 30 de la Decisión 486 de la Comisión de la Comunidad Andina, año 2000.

3. Respecto a la Determinación del Estado de la Técnica y al Examen de Patentabilidad

En los numerales 8, 9 y 10 del oficio citado, ese Despacho concluye que las anteriores reivindicaciones 25 y 35 (correspondientes a las actuales

reivindicaciones 6 y 17) de la presente solicitud de patente carecen de novedad frente a las enseñanzas de los documentos **NC2020/0010470** (D1) y **EP3527072** (D2).

3.1. Novedad y nivel inventivo

Aunque el oficio en referencia haya citado los documentos D1 y D2 para objetar la novedad de la presente invención, es posible afirmar que la materia actualmente reivindicada es diferente y no obvia a la vista de los documentos D1 y D2 como se explica a continuación y, por lo tanto, el solicitante rechaza respetuosamente esta objeción.

La actual reivindicación 1 (correspondiente a la anterior reivindicación 21) se modificó para que defina lo siguiente:

1. *Una composición que comprende una población de ácaros depredadores de individuos Phytoseiulus junto con una fuente de alimento para los individuos depredadores que comprende una mezcla de etapas de desarrollo inmovilizadas seleccionadas de huevos incapaces de eclosionar y etapas móviles inmovilizadas de un hospedero artificial artrópodo no tetraníquido, y un material portador.*

Se afirma que ninguna de los documentos citados, D1 y/o D2, divulgan o enseñan la materia que actualmente se reclama en la presente solicitud.

Respecto al documento D1, dicho documento no divulga ni sugiere una fuente de alimento para los individuos depredadores *Phytoseiulus* que comprende un artrópodo <u>no tetraníquido</u>. Por ejemplo, la presente solicitud, a diferencia de lo divulgado en el documento D1, divulga y demuestra el uso de *Artemia* como fuente de alimento para individuos de ácaros depredadores *Phytoseiulus*.

Además, se afirma que la materia objeto de las actuales reivindicaciones 3 y 4 (correspondientes a las anteriores reivindicaciones 3 y 5, respectivamente) no está divulgada o enseñada por el documento D1. Por otra parte, el porcentaje de individuos hembras que ponen huevos y las tasas diarias de oviposición es descrita y demostrada en la presente solicitud, por ejemplo, en el Ejemplo 7, Tabla 1.

Por lo tanto, la presente invención tal como se reclama actualmente es novedosa e inventiva con respecto al documento D1.

Respecto al documento D2, dicho documento describe métodos y dispositivos para distribuir artrópodos a un cultivo mediante la pulverización de una mezcla de medio líquido y artrópodos al cultivo objetivo.

Se aclara que el documento D2 NO recita ni enseña la materia actualmente reivindicada.

Aunque los ácaros que se distribuyen en el método descrito en dicho documento D2 incluyen ácaros *Phytoseiulus* (párrafos [0040] y [0063]; reivindicaciones 7 y 12), el documento D2 NO divulga ni menciona la cría de ácaros *Phytoseiulus* con una fuente de alimento para los individuos depredadores *Phytoseiulus* que comprende un artrópodo <u>no tetraníquido</u>, ni que la fuente de alimento requerida <u>sea una</u> mezcla de huevos incapaces de eclosionar y etapas móviles inmovilizadas del hospedero artificial artrópodo no tetraníquido.

El solicitante señala que el documento D2 fue citado en la Opinión Escrita Europea de la Autoridad de Búsqueda Internacional (WOSA) de PCT/IL2019/050982 (que corresponde a la fase internacional de la presente solicitud). En el informe de la WOSA PCT (Punto V, puntos 3 y 4 relativos a la novedad y la actividad inventiva, respectivamente) se afirma que los documentos del estado de la técnica *«se han citado para ilustrar que el uso de ácaros depredadores del género Phytoseiulus ya estaba bien establecido en la técnica».*

Se afirma además en dicha opinión escrita del PCT que «***<u>ninguno de los documentos del estado de la técnica sugiere que los ácaros depredadores Phytoseiulus puedan criarse en artrópodos no tetraníquidos</u>***», por lo que se considera que las reivindicaciones de «composición» presentadas implican una actividad inventiva.

En vista de lo anterior, la presente invención según el nuevo conjunto de reivindicaciones se considera novedosa e inventiva con respecto al estado de la técnica citado.

4. <u>Conclusión</u>

Las modificaciones realizadas a las reivindicaciones de la presente solicitud de patente y las aclaraciones presentadas a lo largo del presente escrito permiten superar completamente las objeciones realizadas a la claridad de las reivindicaciones, por lo cual, la presente solicitud cumple a cabalidad las exigencias establecidas por el artículo 30 de la Decisión 486 según los requerimientos del de oficio en referencia.

De otra parte, los argumentos expuestos en el numeral 3 del presente escrito ponen de manifiesto de una manera clara y contundente que lo revelado en las nuevas reivindicaciones de la presente solicitud resulta completamente novedoso e inventivo sobre las enseñanzas del estado del arte más cercano representado por los documentos D1 y D2, toda vez que nada dentro de dichos documentos revela en forma directa o al menos llega a sugerir todas las características de la materia que se reclama actualmente en la solicitud. Por consiguiente, no se puede derivar la inexistencia de los requisitos de ley para la concesión del privilegio de patentabilidad.

En consecuencia, me permito solicitar a ese Despacho, proceder con la revisión de las modificaciones y de los argumentos aquí presentados, para conceder el privilegio de patente solicitado para la materia objeto de las 22 reivindicaciones ahora presentadas en el capítulo reivindicatorio modificado, y que de subsistir alguna duda o inquietud respecto a la patentabilidad de la presente invención, a pesar de las modificaciones y argumentos técnicos ahora presentados, sin apartarse del espíritu inventivo originalmente revelado en la solicitud internacional, se le brinde la oportunidad al solicitante de aclararla o de limitar aún más la invención, mediante la emisión de un segundo examen de fondo, teniendo en cuenta el nuevo capítulo reivindicatorio que se somete a revisión, antes de que se emita una decisión definitiva por parte de ese Despacho, de conformidad con lo dispuesto en 1.2.2.5.1 del artículo primero de la Resolución 54093 de 2012.

5. Anexos

Junto con este escrito se incluye lo siguiente:

- Capítulo reivindicatorio modificado, en donde se han llevado a cabo las modificaciones mencionadas anteriormente.

- Evidencia correspondientea «*Life-styles of Phytoseiid mites and their roles in biological control*», McMurtry JA, Croft BA, Annu Rev Entomol, 1997, 42:291-321.

- Evidencia correspondiente a «*Revision of the lifestyles of phytoseiid mites (Acari: Phytoseiidae) and implications for biological control strategies*», McMurtry et al, Systematic and Applied Acarology, Volumen 18, No 4: 24, diciembre de 2013.

6. Pagos

Junto con esta respuesta se paga la tasa correspondiente a la modificación del capítulo reivindicatorio.

7. Petición

Solicito al Despacho, y en el evento que el examinador considere que pese a las modificaciones presentadas aún existen objeciones, que proceda a emitir un segundo examen de fondo sobre el nuevo capítulo reivindicatorio presentado.

En este sentido requiero se me comunique a través del SIPI o cualquier otro medio la existencia de estas objeciones para, de esta manera, si procede, realizar el nuevo pago del examen de patentabilidad de la solicitud de la referencia.

Atentamente,

LUZ HELENA ADARVE GÓMEZ.
C.C 41.575.435 de Bogotá.
T.P. 14.884 C.S.J.

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FJG
P-1203

REIVINDICACIONES (con marcas de modificación)

~~1. Población de ácaros depredadores que comprende individuos depredadores *Phytoseiulus*, en donde al menos el 10% de los individuos hembra de la población es capaz de reproducirse sobre una presa artrópoda no tetraníquida, preferentemente sobre una presa artrópoda no tetraníquida inmovilizada, tal como sobre una presa no fitófaga, preferentemente sobre una presa astigmátida, lo más preferentemente sobre una presa astigmátida inmovilizada, tal como una presa astigmátida inmovilizada, en particular una presa *Carpoglyhus*, con etapas de desarrollo inmovilizadas que comprenden huevos inmovilizados.~~

~~2. Población de ácaros depredadores según la reivindicación 1, en donde al menos el 15%, al menos el 20%, al menos el 25%, al menos el 30%, al menos el 35%, al menos el 40%, al menos el 45%, al menos el 50%, al menos el 55%, al menos el 60%, al menos el 65%, al menos el 70%, al menos el 75%, al menos el 80%, al menos el 85%, al menos el 90%, al menos el 95% o al menos el 99 % de los individuos hembra de la población son capaces de reproducirse sobre una presa artrópoda no tetraníquida, preferentemente sobre una presa artrópoda no tetraníquida inmovilizada, tal como sobre una presa no fitófaga, preferentemente sobre una presa astigmátida, más preferentemente sobre una presa astigmátida inmovilizada, tal como una presa astigmátida inmovilizada con etapas de desarrollo inmovilizadas que comprenden huevos inmovilizados.~~

~~3. Población de ácaros depredadores según cualquiera de las reivindicaciones 1-2, en donde al menos el 10% de los individuos hembra de la población son capaces de oviponer sobre presas artrópodas no tetraníquidas, preferentemente sobre presas astigmátidas inmovilizadas con etapas de desarrollo inmovilizadas que comprenden huevos.~~

~~4. Población de ácaros depredadores según cualquiera de las reivindicaciones 1-3, en donde la población tiene una tasa de oviposición diaria de al menos 0,50, tal como ≥ 0,60; ≥ 0,65; ≥ 0,70; ≥ 0,75; ≥ 0,80; ≥ 0,90; ≥ 0,95 ; ≥ 1,00; ≥ 1,05; ≥ 1,10; ≥ 1,15; ≥ 1,20; ≥ 1,25; ≥ 1,30; ≥ 1,35; ≥ 1,40; ≥ 1,45; ≥ 1,50; ≥ 1,55; ≥ 1,60; ≥ 1,65; ≥ 1,70; ≥ 1,75;~~

~~≥ ≥ 1,75; ≥ 1,80; ≥ 1,85; ≥ 1,90; ≥ 1,95 o al menos 2,00 huevos/día/hembra sobre presas artrópodas no tetraníquidas, preferentemente sobre presas astigmátidas inmovilizadas con etapas de desarrollo inmovilizadas que comprenden huevos inmovilizados.~~

~~5. Población de ácaros depredadores según cualquiera de las reivindicaciones 1-4, en donde la población tiene una tasa de oviposición diaria de al menos 0,55, tal como ≥ 0,60; ≥ 0,65; ≥ 0,70; ≥ 0,75; ≥ 0,80; ≥ 0,90; ≥ 0,95 ; ≥ 1,00; ≥ 1,05; ≥ 1,10; ≥ 1,15; ≥ 1,20; ≥ 1,25; ≥ 1,30; ≥ 1,35; ≥ 1,40; ≥ 1,45; ≥ 1,50; ≥ 1,55; ≥ 1,60; ≥ 1,65; ≥ 1,70; ≥ 1,75; ≥ ≥ 1,75; ≥ 1,80; ≥ 1,85; ≥ 1,90; ≥ 1,95 o ≥ 2,00 huevos/día/hembra, cuando se utilizan artrópodos no tetraníquidos como presas y como única fuente de alimento.~~

~~6. Población de ácaros depredadores según cualquiera de las reivindicaciones 1-5, en donde al menos el 10% de los individuos hembra son capaces de completar un ciclo ontogenético completo, cuando se utiliza la presa artrópoda no tetraníquida como única fuente de alimento.~~

~~7. Población de ácaros depredadores según cualquiera de las reivindicaciones 1-6, en donde la población se caracteriza por una tasa de supervivencia juvenil y/o de hembras de al menos 40%, preferentemente al menos 45%, 50%, 60%, 65%, 70%, 75%, 80%, 85%, 90% o al menos 95% sobre presas que no son tetraníquidas.~~

~~8. Población de ácaros depredadores según cualquiera de las reivindicaciones 1-7, en donde al menos el 10% de los individuos hembra de la población se caracterizan por la capacidad de producir descendencia de hembras en varias generaciones subsecuentes, en donde el número de generaciones subsecuentes es de al menos 1, tal como al menos 2, tal como durante al menos 3, 4, 5, 6, 7, 8, 9 al menos 10 generaciones.~~

~~9. Población de ácaros depredadores según cualquiera de las reivindicaciones 1-8, en donde la población se caracteriza por una tasa de reproducción diaria en el rango de alrededor de 1,10-1,40, tal como 1,15-1,40, 1,20-1,40, 1,25-1,40, 1,30- 1,40, o 1,10-1,35, 1,10-1,30, 1,10-1,25, 1,10-1,20 sobre presas artrópodas no tetraníquidas, preferentemente sobre presas astigmátidas inmovilizadas con etapas de desarrollo inmovilizadas que comprenden huevos inmovilizados.~~

~~10. Población de ácaros depredadores según cualquiera de las reivindicaciones 1-9, en donde los individuos hembra tienen un comportamiento depredador hacia individuos de una especie de tetraníquidos, preferentemente un comportamiento depredador caracterizado por una tasa de oviposición diaria de al menos 10, preferentemente al menos 15, más preferentemente al menos 19 huevos por hembra durante 5 días.~~

~~11. Población de ácaros depredadores según cualquiera de las reivindicaciones 1-10, en donde la población tiene una tasa de reproducción aumentada en comparación con una población depredadora *Phytoseiulus* de control de la misma especie criada con presas tetraníquidas como única fuente de alimento.~~

~~12. Población de ácaros depredadores que comprende individuos depredadores *Phytoseiulus*, en donde la población se caracteriza por una tasa de oviposición diaria de al menos 0,55 huevos/día/hembra; tal como ≥ 0,60; ≥ 0,65; ≥ 0,70; ≥ 0,75; ≥ 0,80; ≥ 0,90; ≥ 0,95; ≥ 1,00; ≥ 1,05; ≥ 1,10; ≥ 1,15; ≥ 1,20; ≥ 1,25; ≥ 1,30; ≥ 1,35; ≥ 1,40; ≥ 1,45; ≥ 1,50; ≥ 1,55; ≥ 1,60; ≥ 1,65; ≥ 1,70; ≥ 1,75. ; ≥ 1,80; ≥ 1,85; ≥ 1,90; ≥ 1,95 o ≥ 2,00 huevos/día/hembra, mientras se alimenta de presas artrópodas no tetraníquidas, preferentemente de presas artrópodas no tetraníquidas inmovilizadas, tal como presas no fitófagas, preferentemente de una presa astigmátida, más preferentemente de una presa astigmátida inmovilizada, tal como una presa astigmátida inmovilizada con etapas de desarrollo inmovilizadas que comprenden huevos inmovilizados.~~

~~13. Población de ácaros depredadores según la reivindicación 12, en donde la población se caracteriza por una tasa de supervivencia juvenil y/o de hembras de al menos un 40% sobre las presas no tetraníquidas.~~

~~14. Población de ácaros depredadores según cualquiera de las reivindicaciones 12-13, en donde al menos el 10% de los individuos hembra de la población se caracterizan por la capacidad de producir descendencia de hembras en varias generaciones subsecuentes, en donde el número de generaciones subsecuentes es de al menos 1, tal como al menos 2, tal como durante al menos 3, 4, 5, 6, 7, 8, 9 al menos 10 generaciones.~~

~~15. Población de ácaros depredadores según cualquiera de las reivindicaciones 12-14, en donde la población se caracteriza por una tasa de reproducción diaria en el rango de alrededor de 1,10 -1,40, tal como 1,15-1,40, 1,20-1,40, 1,25-1,40, 1,30- 1,40, o 1,10-1,35, 1,10-1,30, 1,10-1,25, 1,10-1,20.~~

~~16. Población de ácaros depredadores según cualquiera de las reivindicaciones 12-15, en donde al menos el 15%, al menos el 20%, al menos el 25%, al menos el 30%, al menos el 35%, al menos el 40%, al menos el 45%, al menos el 50%, al menos el 55%, al menos el 60%, al menos el 65%, al menos el 70%, al menos el 75%, al menos el 80%, al menos el 85%, al menos el 90%, al menos el 95%, o al menos el 99% de las hembras de la población son capaces de reproducirse sobre una presa artrópoda no tetraníquida, preferentemente sobre una presa artrópoda no tetraníquida inmovilizada, tal como sobre una presa no fitófaga, preferentemente sobre una presa astigmátida, lo más preferentemente sobre una presa astigmátida inmovilizada, tal como una presa astigmátida inmovilizada con etapas de desarrollo inmovilizadas que comprenden huevos inmovilizados.~~

~~17. Población de ácaros depredadores que comprende individuos depredadores *Phytoseiulus*, en donde la población se caracteriza por una reproducción aumentada sobre presas artrópodas no tetraníquidas, preferentemente sobre presas artrópodas no tetraníquidas inmovilizadas, tal como sobre presas no fitófagas, preferentemente sobre presas astigmátidas, lo más preferentemente sobre una presa astigmátida inmovilizada, tal como una presa astigmátida inmovilizada con etapas de desarrollo inmovilizadas que comprenden huevos inmovilizados, en comparación con una población depredadora de *Phytoseiulus* de control de la misma especie, criada sobre presas tetraníquidas como única fuente de alimento.~~

~~18. Población de ácaros depredadores *Phytoseiulus persimilis* según la reivindicación 17, en donde la reproducción aumentada sobre una presa artrópoda no tetraníquida se caracteriza por al menos uno de: mayor tasa de reproducción diaria, mayor tasa de oviposición diaria, mayor tasa de supervivencia, mayor porcentaje de individuos hembra reproduciéndose sobre dicha presa, y mejor comportamiento depredador hacia Tetranychidae.~~

~~19. Población de ácaros depredadores según cualquiera de las reivindicaciones 1-18, en donde los individuos depredadores son de una especie seleccionada de *Phytoseiulus fragariae, Phytoseiulus longipes, Phytoseiulus macropilis, Phytoseiulus persimilis* y *Phytoseiulus robertsi*.~~

~~20. Población de ácaros depredadores según cualquiera de las reivindicaciones 1-19, en donde la reproducción sobre una presa no tetraníquida es la reproducción sobre una especie de ácaro astigmátido seleccionada entre:~~

~~i) *Carpoglyphidae* tales como del género Carpoglyphus, por ejemplo, *Carpoglyphus lactis*;~~

~~ii) *Pyroglyphidae* tales como del género *Dermatophagoides*, por ejemplo, *Dermatophagoides pteronysinus*, *Dermatophagoides farinae*; del género *Euroglyphus*, por ejemplo, *Euroglyphus longior, Euroglyphus maynei*; del género *Pyroglyphus*, por ejemplo, *Pyroglyphus africanus*;~~

~~iii) *Glycyphagidae* tales como de la subfamilia *Ctenoglyphinae*, tales como del género *Diamesoglyphus*, por ejemplo, *Diamesoglyphus intermediusor* del género *Ctenoglyphus*, por ejemplo, *Ctenoglyphus plumiger, Ctenoglyphus canestrinii, Ctenoglyphus palmifer*; la subfamilia *Glycyphaginae*, tal como del género Blomia, por ejemplo, *Blomia freemani* o del género *Glycyphagus*, por ejemplo, *Glycyphagus ornatus*, *Glycyphagus bicaudatus*, *Glycyphagus privatus*, *Glycyphagus domesticus*, o del género *Lepidoglyphus*, por ejemplo, Lepidoglyphus michaeli, Lepidoglyphus fustifer, *Lepidoglyphus destructor*, o del género *Austroglycyphagus*, por ejemplo, Austroglycyphagus geniculatus; de la subfamilia Aëroglyphinae, tal como del género *Aëroglyphus*, por ejemplo, *Aëroglyphus robustus*; de la subfamilia *Labidophorinae*, tal como del género *Gohieria*, por ejemplo, *Gohieria* fusca; o de la subfamilia *Nycteriglyphinae* tal como del género *Coproglyphus*, por ejemplo *Coproglyphus stammeri* o de la subfamilia *Chortoglyphidae*, tal como el género *Chortoglyphus* por ejemplo *Chortoglyphus arcuatus* y más preferentemente se selecciona de la subfamilia *Glycyphaginae*, más preferentemente se selecciona del género *Glycyphagus* o el género~~

~~*Lepidoglyphus* seleccionado más preferentemente de *Glycyphagus domesticus* o *Lepidoglyphus destructor*;~~

~~iv) *Acaridae* tales como del género *Tyrophagus*, por ejemplo, *Tyrophagus putrescentiae*, *Tyrophagus tropicus*, del género *Acarus*, por ejemplo, *Acarus siro, Acarus farris, Acarus gracilis*; del género *Lardoglyphus*, por ejemplo, *Lardoglyphus konoi*, del género *Thyreophagus*, tal como *Thyreophagus entomophagus*; del género *Aleuroglyphus*, por ejemplo, *Aleuroglyphus ovatus*;~~

~~v) *Suidasiidae* tales como del género *Suidasia*, tales como *Suidasia nesbiti, Suidasia pontifica* o *Suidasia medanensis*.~~

~~21.~~1. Una c~~C~~omposición ~~de ácaros~~ que comprende una población de ácaros depredadores de individuos *Phytoseiulus* ~~según cualquiera de las reivindicaciones 1-20~~ junto con una fuente de alimento para los individuos depredadores que comprende una mezcla de etapas de desarrollo inmovilizadas seleccionadas de huevos que no eclosionan y etapas móviles inmovilizadas de un hospedero artificial artrópodo no tetraníquido, y un material portador~~, tal como un material portador seleccionado entre aserrín, salvado de trigo, cáscaras de trigo sarraceno, cáscaras de arroz o cáscaras de mijo, o que comprende una mezcla de los mismos, preferentemente un portador que tiene elementos portadores que comprenden alojamientos para ácaros~~.

2. La c~~C~~omposición ~~de ácaros~~ según la reivindicación 1~~21~~, en donde el material portador es seleccionado de aserrín, salvado de trigo, cáscaras de trigo sarraceno, cáscaras de arroz, cáscaras de mijo, una mezcla de los mismos, y un portador que tiene elementos portadores que comprenden alojamientos para ácaros~~que comprende una fuente de alimento para los individuos depredadores *Phytoseiulus*, en donde la fuente de alimento comprende una presa artrópoda no tetraníquida, preferentemente presa artrópoda no tetraníquida inmovilizada, tal como una presa no fitófaga, preferentemente un presa astigmátida, lo más preferentemente una presa astigmátida inmovilizada, tal como una presa astigmátida inmovilizada, en particular una especie *Carpoglyhus*, con etapas de desarrollo inmovilizadas que comprenden huevos inmovilizados~~.

3. La composición según cualquiera de las reivindicaciones 1-2, en donde al menos el 10 % de los individuos hembra de la población depredadora son capaces de oviponer sobre el hospedero artificial artrópodo no tetraníquido.

~~22.~~4. La composición según cualquiera de las reivindicaciones 1-3, en donde la población de *Phytoseiulus* tiene una tasa de oviposición diaria de al menos 0,55; tal como ≥ 0,60; ≥ 0,65; ≥ 0,70; ≥ 0,75; ≥ 0,80; ≥ 0,90; ≥ 0,95; ≥ 1,00; ≥ 1,05; ≥ 1,10; ≥ 1,15; ≥ 1,20; ≥ 1,25; ≥ 1,30; ≥ 1,35; ≥ 1,40; ≥ 1,45; ≥ 1,50; ≥ 1,55; ≥ 1,60; ≥ 1,65; ≥ 1,70; ≥ 1,75; ≥ 1,80; ≥ 1,85; ≥ 1,90; ≥ 1,95, o ≥ 2,00 huevos/día/hembra, cuando se usa el hospedero artificial artrópodo no tetraníquido como la única fuente de alimento.

~~23.~~5. Un método para criar una población de ácaros de individuos depredadores de *Phytoseiulus* que comprende los pasos de proporcionar~~El uso de una especie de artrópodo no tetraníquido, preferentemente~~ una mezcla de etapas de desarrollo inmovilizadas seleccionadas de huevos que no eclosionan y etapas móviles inmovilizadas de un~~especie~~ hospedero artificial~~ de~~ artrópodo no tetraníquido~~ inmovilizado, tal como una presa no fitófaga, preferentemente una especie de astigmátido, lo más preferentemente una especie de astigmátido inmovilizado, como lo más preferentemente una especie de astigmátido inmovilizado, en particular una especie *Carpoglyhus*, con etapas de desarrollo inmovilizadas que comprenden huevos inmovilizados~~, como fuente de alimento~~, ~~preferentemente como presa de crianza,~~ para ~~una~~ la población de ácaros depredadores de individuos depredadores *Phytoseiulus*~~ según cualquiera de las reivindicaciones 1-20~~, junto a un material portador.

~~24. El uso de acuerdo con la reivindicación 23, en donde dicho uso comprende aplicar individuos de una especie de artrópodo no tetraníquido a una planta objetivo, preferentemente una especie de artrópodo no tetraníquido inmovilizado, tal como una presa no fitófaga, preferentemente una especie de astigmátido, más preferentemente una especie de astigmátido inmovilizado, tal como lo más preferentemente una especie de astigmátido inmovilizado, en particular una especie *Carpoglyhus*, con etapas de desarrollo inmovilizadas que comprenden huevos inmovilizados, o una mezcla de etapas de desarrollo inmovilizadas que comprenden huevos y etapas móviles de la especie de artrópodo no tetraníquido.~~

~~25.~~6. Dispositivo para liberar individuos de una especie de ácaro depredador *Phytoseiulus*, comprendiendo dicho dispositivo un recipiente que contiene ~~una~~ la ~~población de ácaros depredadores según cualquiera de las reivindicaciones 1-20, preferentemente en una~~ composición según cualquiera de las reivindicaciones 1-4~~21-22~~, en donde el dispositivo comprende una salida para las etapas de desarrollo móviles de la especie de ácaro depredador *Phytoseiulus*, ~~preferentemente una salida~~ adecuada para proporcionar ~~una~~ liberación sostenida de varias etapas de desarrollo móviles.

7. Un método para controlar una plaga de cultivos, que comprende los pasos de aplicar ~~Uso de una población de ácaros depredadores según cualquiera de las reivindicaciones 1-20, o~~ una composición de ácaros según cualquiera de las reivindicaciones 1-4~~21-22, preferentemente en un dispositivo según la reivindicación 24, para la protección de~~ a un cultivo~~s~~.

~~26.~~8. El método para controlar una plaga de cultivos según la reivindicación 7, que comprende los pasos de aplicar la composición de ácaros según cualquiera de las reivindicaciones 1-4, en un dispositivo según la reivindicación 6, a un cultivo.

~~27. Método para criar individuos depredadores *Phytoseiulus*, comprendiendo dicho método proporcionar una población de ácaros depredadores según cualquiera de las reivindicaciones 1-20, preferentemente en una composición según cualquiera de las reivindicaciones 21-22 y permitir que los individuos depredadores *Phytoseiulus* se alimenten de la presa artrópoda no tetraníquida.~~

9. Método para la obtención de la composición~~una población de ácaros depredadores~~ según cualquiera de las reivindicaciones 1-4, comprendiendo dicho método los pasos de:

(a) proporcionar una población de crianza de una especie de ácaro depredador seleccionado del género *Phytoseiulus*, comprendiendo dicha población de crianza individuos de la especie *Phytoseiulus* junto con una fuente de alimento adecuada para los individuos *Phytoseiulus*, comprendiendo dicha fuente de alimento una especie presa seleccionada de *Tetranychidae*;

(b) proporcionar una mezcla de etapas de desarrollo inmovilizadas seleccionadas de huevos que no eclosionan y etapas móviles inmovilizadas de una especie hospedera artificial artrópoda no tetraníquida preseleccionada junto con un material portador;

(c) proporcionar la mezcla de especies hospederas artificiales de artrópodos no tetraníquidos inmovilizados y preseleccionados junto con un material portador a los individuos *Phytoseiulus* como fuente de alimento;

(d) seleccionar individuos *Phytoseiulus* que sean capaces de reproducirse mientras se usa la mezcla de los individuos artrópodos no tetraníquidos inmovilizados y preseleccionados, seleccionados de huevos que no eclosionan y etapas móviles inmovilizadas como una fuente de alimento; y

(e) criar individuos *Phytoseiulus* seleccionados con una fuente de alimento que comprenda la mezcla de especies hospederas artificiales de artrópodos no tetraníquidos preseleccionadas, seleccionadas de huevos que no eclosionan y etapas móviles inmovilizadas.

10. El método según la reivindicación 9, que además comprende, criar alternativamente individuos *Phytoseiulus* seleccionados en la siguiente secuencia:

- criar durante al menos 2, incluyendo entre 5 y 50, generaciones utilizando una fuente de alimento que comprenda la mezcla de especies hospederas artificiales de artrópodos no tetraníquidos inmovilizadas y preseleccionadas, seleccionadas de huevos que no eclosionan y etapas móviles inmovilizadas;
- criar durante al menos 2, incluyendo entre 5 y 50, generaciones usando una fuente de alimento que comprenda las especies presa seleccionadas de *Tetranychidae*.

~~28. era de las reivindicaciones 1-20, comprendiendo dicho método los pasos de:~~

~~(a) proporcionar una población de crianza de una especie de ácaro depredador seleccionado del género *Phytoseiulus*, comprendiendo dicha población de crianza individuos de la especie *Phytoseiulus* preferentemente junto con una fuente de alimento adecuada para los individuos *Phytoseiulus*, comprendiendo dicha fuente de alimento una especie presa seleccionada de *Tetranychidae*;~~

~~(b) proporcionar una especie de artrópodo preseleccionada que no sea *Tetranychidae*, preferentemente una especie de ácaro astigmátido, lo más preferentemente una especie de ácaro astigmátido inmovilizado con etapas de desarrollo inmovilizadas que comprenden huevos inmovilizados;~~

~~(c) proporcionar la especie de artrópodo no tetraníquido preseleccionado a los individuos *Phytoseiulus* como fuente de alimento;~~

~~(d) seleccionar individuos *Phytoseiulus* que sean capaces de reproducirse mientras se usan los individuos artrópodos no tetraníquidos preseleccionados como fuente de alimento;~~

~~(e) criar individuos *Phytoseiulus* seleccionados con una fuente de alimento que comprenda las especies de artrópodos no tetraníquidos preseleccionadas;~~

~~(f) opcionalmente, criar alternativamente individuos *Phytoseiulus* seleccionados en la siguiente secuencia:~~

~~- criar durante al menos 2, por ejemplo entre 5 y 50, generaciones utilizando una fuente de alimento que comprenda las especies de artrópodos no tetraníquidos preseleccionadas;~~

~~- -criar durante al menos 2, por ejemplo, entre 5 y 50, generaciones usando una fuente de alimento que comprenda las especies presa seleccionadas de *Tetranychidae*.~~

~~29.~~11. El método según cualquiera de las reivindicaciooónes 9 y 10~~28~~, en donde el método comprende además los pasos de

(a) separar los huevos de las especies de artrópodos no tetraníquidos preseleccionadas;

(b) mezclar los huevos separados con un material portador ~~, tal como un material portador seleccionado de aserrín, salvado de trigo, cáscaras de trigo sarraceno, cáscaras de arroz o cáscaras de mijo, o que comprende una mezcla de los mismos~~ y agua, para recubrir el material portador con una capa de huevos;

(c) congelar la mezcla; y

(d) criar los individuos *Phytoseiulus* en la mezcla como fuente de alimento.

12. El método según la reivindicación 11, en donde el material portador es seleccionado de aserrín, salvado de trigo, cáscaras de trigo sarraceno, cáscaras de arroz, cáscaras de mijo, o que comprende una mezcla de los mismos.

~~30.~~13. Método según cualquiera de las reivindicaciones ~~28~~9-12~~29~~, en donde la población de crianza de *Phytoseiulus* proporcionada es una población compuesta por una serie de subpoblaciones, en donde dichas subpoblaciones proceden de distintas fuentes, ~~tales como~~ de distintas poblaciones de producción y/o de poblaciones naturales aisladas de distintas ubicaciones geográficas.

~~33.~~ Método según cualquiera de las reivindicaciones 9~~28~~-13~~30~~, en donde la población de crianza proporcionada comprende al menos 100 individuos, ~~tal como~~incluyendo entre 200 y 5000 individuos, o~~preferentemente~~ entre 500 y 1500 individuos.

14.

~~31. Método para obtener una población de ácaros depredadores capaz de reproducirse sobre una presa artrópoda no tetraníquida, preferentemente sobre una presa artrópoda no tetraníquida inmovilizada, tal como sobre una presa no fitófaga, preferentemente sobre una presa astigmátida, más preferentemente sobre una presa astigmátida inmovilizada, tal como una presa astigmátida inmovilizada con etapas de desarrollo inmovilizadas que comprenden huevos inmovilizados, comprendiendo dicho método los pasos de:~~

~~(a) proporcionar una población de crianza de una especie de ácaro depredador seleccionado del género *Phytoseiulus*, comprendiendo dicha población de crianza individuos de la especie *Phytoseiulus*, criados sobre una fuente de alimento adecuada para los individuos *Phytoseiulus*, comprendiendo dicha fuente de alimento una especie presa seleccionada de la especie Tetranychidae del género *Phytoseiulus*;~~

~~(b) proporcionar una población de individuos de especies de artrópodos no tetraníquidos preseleccionadas, preferentemente una especie de ácaro astigmátido, lo más preferentemente una especie de ácaro astigmátido inmovilizado con etapas de desarrollo inmovilizadas que comprenden huevos inmovilizados;~~

~~(c) criar individuos *Phytoseiulus* sobre las especies de artrópodos no tetraníquidos preseleccionadas como fuente de alimento.~~

~~32. Método según la reivindicación 32, que comprende además los pasos de:~~

~~(d) seleccionar individuos *Phytoseiulus* que sean capaces de reproducirse mientras se usan los individuos artrópodos no tetraníquidos preseleccionados como fuente de alimento;~~

~~(e) criar individuos de *Phytoseiulus* seleccionados sobre una fuente de alimento que comprende las especies de artrópodos no tetraníquidos preseleccionadas;~~

~~(f) opcionalmente, criar alternativamente individuos *Phytoseiulus* seleccionados en la siguiente secuencia:~~

~~- criar durante al menos 2, por ejemplo entre 5 y 50, generaciones utilizando una fuente de alimento que comprenda las especies de artrópodos no tetraníquidos preseleccionadas;~~

~~- criar durante al menos 2, por ejemplo, entre 5 y 50, generaciones usando una fuente de alimento que comprenda las especies presa seleccionadas de *Tetranychidae*.~~

15. Composición de ácaros ~~que comprende una población de ácaros depredadores~~ según cualquiera de las reivindicaciones 1-~~20~~ 4 ~~junto con una presa artrópoda no tetraníquida inmovilizada, preferentemente una presa artrópoda no tetraníquida inmovilizada que comprende huevos inmovilizados, tal como una especie de ácaro astigmátido inmovilizado con etapas de desarrollo inmovilizadas que comprenden huevos congelados,~~ en donde los huevos que no eclosionan son huevos congelados que se recubren con un material portador~~, como un material portador seleccionado entre aserrín, salvado de trigo, cáscaras de trigo sarraceno, cáscaras de arroz o cáscaras de mijo, o que comprenden una mezcla de los mismos, preferentemente un portador que tiene elementos portadores que comprenden alojamientos para ácaros~~, o en donde el material portador~~, tal como un material portador seleccionado entre aserrín, salvado de trigo, cáscaras de trigo sarraceno, cáscaras de arroz o cáscaras de mijo, o que comprende una mezcla de los mismos, preferentemente un portador que tiene elementos portadores que comprenden alojamientos para ácaros que~~ está recubierto por la mezcla de etapas de desarrollo inmovilizadas seleccionadas de huevos que no eclosionan y etapas móviles inmovilizadas del hospedero artificial ~~presa~~ artrópodo~~a~~ no tetraníquido~~a~~.

~~34.~~ La composición de ácaros según la reivindicación 15, en donde el material portador es seleccionado de aserrín, salvado de trigo, cáscaras de trigo sarraceno, cáscaras de arroz, cáscaras de mijo, una mezcla de los mismos, y un portador que tiene elementos portadores que comprenden alojamientos para ácaros.

16.

~~35.~~ Dispositivo para la liberación de individuos de una especie de ácaro depredador *Phytoseiulus*, comprendiendo dicho dispositivo un recipiente que contiene la composición según cualquiera de las reivindicaci~~o~~ones 15-16~~34~~, en donde el recipiente comprende una salida para las etapas de desarrollo móviles de la especie de ácaro depredador *Phytoseiulus*, ~~preferentemente una salida~~ adecuada para proporcionar ~~un~~ liberación sostenida de una serie de etapas de desarrollo móviles.

17.

~~36.~~18. Una composición de control biológico, en donde la composición comprende

(a) una población de ácaros depredadores de ~~que comprende individuos de al menos una especie de ácaro del género~~ individuos de *Phytoseiulus* ~~capaz de reproducirse sobre una presa artrópoda no tetraníquida, preferentemente sobre una presa artrópoda no tetraníquida inmovilizada, tal como sobre una presa no fitófaga, preferentemente sobre una presa astigmátida, lo más preferentemente sobre una presa astigmátida inmovilizada, tal como una presa astigmátida inmovilizada, en particular una presa *Carpoglyhus*, con etapas de desarrollo inmovilizadas que comprenden huevos inmovilizados; y~~,

(b) una fuente de alimento para los individuos depredadores que comprende una mezcla de etapas de desarrollo inmovilizadas seleccionadas de huevos que no eclosionan y etapas móviles inmovilizadas de un hospedero artificial artrópodo no tetraníquido~~población de ácaros presa que comprende individuos presa artrópodos no tetraníquidos, preferentemente una presa artrópoda no tetraníquida inmovilizada, tal como una presa no fitófaga, preferentemente una presa astigmátida, más preferentemente una presa astigmátida inmovilizada, tal como una presa astigmátida~~

~~inmovilizada, en particular, una presa *Carpoglyhus*, con etapas de desarrollo inmovilizadas que comprenden huevos inmovilizados~~, y

(c) ~~opcionalmente un portador, tal como~~ un material de portador seleccionado de aserrín, salvado de trigo, cáscaras de trigo sarraceno, cáscaras de arroz o cáscaras de mijo, ~~o que comprende~~ una mezcla de los mismos, o~~preferentemente~~ un portador que tiene elementos portadores que comprenden alojamientos para ácaros.

~~37. La composición de control biológico de acuerdo con la reivindicación 36, en donde al menos el 10% de los individuos hembra de la población es capaz de reproducirse sobre una presa artrópoda no tetraníquida, preferentemente sobre una presa artrópoda no tetraníquida inmovilizada, tal como en una presa fitófaga, preferentemente sobre una presa astigmátida, lo más preferentemente sobre una presa astigmátida inmovilizada, tal como una presa astigmátida inmovilizada, en particular una presa *Carpoglyhus*, con etapas de desarrollo inmovilizadas que comprenden huevos inmovilizados.~~

~~38. La composición de control biológico según cualquiera de las reivindicaciones 36-37, en donde al menos 15%, al menos el 20%, al menos el 25%, al menos el 30%, al menos el 35%, al menos el 40%, al menos el 45%, al menos el 50%, al menos el 55%, al menos el 60%, al menos el 65%, al menos el 70%, al menos el 75%, al menos el 80%, al menos el 85%, al menos el 90%, al menos el 95%, o al menos el 99% de las hembras de la población son capaces de reproducirse sobre una presa artrópoda no tetraníquida, preferentemente sobre una presa artrópoda no tetraníquida inmovilizada, tal como sobre una presa no fitófaga, preferentemente sobre una presa astigmátida, lo más preferentemente sobre una presa astigmátida inmovilizada, tal como una presa astigmátida inmovilizada, en particular una presa *Carpoglyhus*, con etapas de desarrollo inmovilizadas que comprenden huevos inmovilizados.~~

~~39. La composición de control biológico según cualquiera de las reivindicaciones 36-38, en donde al menos el 10% de los individuos hembra de la población son capaces de oviponer sobre presas astigmátidas inmovilizadas con etapas de desarrollo inmovilizadas que comprenden huevos inmovilizados.~~

~~40. La composición de control biológico según cualquiera de las reivindicaciones 36-39, donde la población tiene una tasa de oviposición diaria de al menos 0,50, tal como ≥ 0,55; ≥ 0,60; ≥ 0,65; ≥ 0,70; ≥ 0,75; ≥ 0,80 ; ≥ 0,90; ≥ 0,95; ≥ 1,00; ≥ 1,05; ≥ 1,10; ≥ 1,15; ≥ 1,20; ≥ 1,25; ≥ 1,30; ≥ 1,35; ≥ 1,40; ≥ 1,45; ≥ 1,50; ≥ 1,55; ≥ 1,60; ≥ 1,65; ≥ 1,65; ≥ 1,70; ≥ 1,75; ≥ 1,80; ≥ 1,85; ≥ 1,90; ≥ 1,95 o al menos 2,00 huevos/día/hembra.~~

~~41.~~ La composición de control biológico según ~~cualquiera de~~ las reivindicaciones 18~~36-40~~, donde la población de *Phytoseiulus* tiene una tasa de oviposición diaria de al menos 0,50, tal como ≥ 0,55; ≥ 0,60; ≥ 0,65; ≥ 0,70; ≥ 0,75; ≥ 0,80 ; ≥ 0,90; ≥ 0,95; ≥ 1,00; ≥ 1,05; ≥ 1,10; ≥ 1,15; ≥ 1,20; ≥ 1,25; ≥ 1,30; ≥ 1,35; ≥ 1,40; ≥ 1,45; ≥ 1,50; ≥ 1,55; ≥ 1,60; ≥ 1,65; ≥ 1,65; ≥ 1,70; ≥ 1,75; ≥ 1,80; ≥ 1,85; ≥ 1,90; ≥ 1,95, o al menos 2,00 huevos/día/hembra, cuando se utilizan ~~presas~~ hospederos artificiales artrópodo~~a~~s no tetraníquido~~a~~s como única fuente de alimento.

19.

20. La composición de control biológico según cualquiera de las reivindicaciones 18-19, donde los individuos depredadores son de una especie seleccionada de *Phytoseiulus fragariae, Phytoseiulus longipes, Phytoseiulus macropilis, Phytoseiulus persimilis y Phytoseiulus robertsi*.

~~42. La composición de control biológico según cualquiera de las reivindicaciones 36-41, en donde al menos el 10% de los individuos hembra son capaces de completar un ciclo ontogenético completo sobre la presa artrópoda no tetraníquida, cuando se utiliza la presa artrópoda no tetraníquida como la única fuente de alimento.~~

~~43. La composición de control biológico según cualquiera de las reivindicaciones 36-42, en donde la población se caracteriza por una tasa de supervivencia juvenil y/o de hembras de al menos 40%, preferentemente al menos 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90% o al menos 95% sobre presas no tetraníquidas.~~

~~44. La composición de control biológico según cualquiera de las reivindicaciones 36-43, en donde al menos el 10% de los individuos hembra de la población se caracterizan por la capacidad de producir una progenie de hembras en varias generaciones subsecuentes, en donde el número de generaciones subsecuentes es al menos 1, tal como al menos 2, tal como durante al menos 3, 4, 5, 6, 7, 8, 9 al menos 10 generaciones.~~

~~45. La composición de control biológico según cualquiera de las reivindicaciones 36-44, en donde la población se caracteriza por una tasa de reproducción diaria en el rango de alrededor de 1,10-1,40, tal como 1,15-1,40, 1,20-1,40, 1,25-1,40, 1,30 -1,40, o 1,10-1,35, 1,10-1,30, 1,10-1,25, 1,10-1,20 sobre la presa no tetraníquida.~~

~~46. La composición de control biológico según cualquiera de las reivindicaciones 36-45, donde los individuos hembra tienen un comportamiento depredador hacia los individuos de una especie de tetraníquidos, preferentemente un comportamiento depredador caracterizado por una tasa de reproducción diaria de al menos 10, preferentemente al menos 15, más preferentemente al menos 19 huevos por hembra durante 5 días.~~

~~47. La composición de control biológico según cualquiera de las reivindicaciones 36-46, en donde la población tiene una tasa de reproducción aumentada en comparación con una población depredadora *Phytoseiulus* de control de la misma especie criada con presas tetraníquidas como única fuente de alimento.~~

~~48. Composición de control biológico que comprende individuos depredadores *Phytoseiulus*, en donde la población se caracteriza por una tasa de oviposición diaria de al menos 0,50; tal como ≥ 0,55; ≥ 0,60; ≥ 0,65; ≥ 0,70; ≥ 0,75; ≥ 0,80; ≥ 0,90; ≥ 0,95 ; ≥ 1,00; ≥ 1,05; ≥ 1,10; ≥ 1,15; ≥ 1,20; ≥ 1,25; ≥ 1,30; ≥ 1,35; ≥ 1,40; ≥ 1,45; ≥ 1,50; ≥ 1,55; ≥ 1,60; ≥ 1,65; ≥ 1,70; ≥ 1,75; ≥ ≥ 1,75; ≥ 1,80; ≥ 1,85; ≥ 1,90; ≥ 1,95, o al menos 2,00 huevos/día/hembra mientras se alimenta sobre presas artrópodas no tetraníquidas, preferentemente sobre presas artrópodas no tetraníquidas inmovilizadas, tal como sobre presas no fitófagas, preferentemente sobre una presa astigmátida, lo más preferentemente sobre una presa astigmátida~~

~~inmovilizada, tal como una presa astigmátida inmovilizada, en particular una presa *Carpoglyphus*, con etapas de desarrollo inmovilizadas que comprenden huevos inmovilizados.~~

~~49. La composición de control biológico según la reivindicación 48, en donde la población se caracteriza por una tasa de supervivencia juvenil y/o de hembras de al menos 40%, preferentemente al menos 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90% o al menos 95% sobre la presa no tetraníquida.~~

~~50. La composición de control biológico según cualquiera de las reivindicaciones 48-49, en donde al menos el 10% de los individuos hembra de la población se caracterizan por la capacidad de producir una progenie de hembras en varias generaciones subsecuentes, en donde el número de generaciones subsecuentes es al menos 1, tal como al menos 2, tal como durante al menos 3, 4, 5, 6, 7, 8, 9 al menos 10 generaciones.~~

~~51. La composición de control biológico según cualquiera de las reivindicaciones 48-50, en donde la población se caracteriza por una tasa de reproducción diaria en el rango de alrededor de 1,10-1,40, tal como 1,15-1,40, 1,20-1,40, 1,25-1,40, 1,30 -1,40, o 1,10-1,35, 1,10-1,30, 1,10-1,25, 1,10-1,20.~~

~~52. La composición de control biológico según cualquiera de las reivindicaciones 48-51, en donde al menos 15%, al menos el 20%, al menos el 25%, al menos el 30%, al menos el 35%, al menos el 40%, al menos el 45%, al menos el 50%, al menos el 55%, al menos el 60%, al menos el 65%, al menos el 70%, al menos el 75%, al menos el 80%, al menos el 85%, al menos el 90%, al menos el 95%, o al menos el 99% de las hembras de la población son capaces de reproducirse sobre una presa artrópoda no tetraníquida, preferentemente sobre una presa artrópoda no tetraníquida inmovilizada, tal como sobre una presa no fitófaga, preferentemente sobre una presa astigmátida, lo más preferentemente sobre una presa astigmátida inmovilizada, tal como una presa astigmátida inmovilizada, en particular una presa *Carpoglyphus,* con etapas de desarrollo inmovilizadas que comprenden huevos inmovilizados.~~

~~53. Composición de control biológico que comprende individuos depredadores *Phytoseiulus*, en donde la población se caracteriza por una~~

~~reproducción aumentada sobre presas artrópodas no tetraníquidas, preferentemente sobre presas artrópodas no tetraníquidas inmovilizadas, tal como sobre presas no fitófagas, preferentemente sobre presas astigmátidas, lo más preferentemente sobre una presa astigmátida inmovilizada, como una presa astigmátida inmovilizada, en particular una presa *Carpoglyphus*, con etapas de desarrollo inmovilizadas que comprenden huevos inmovilizados, en comparación con una población depredadora *Phytoseiulus* de control de la misma especie, criada sobre presas tetraníquidas como única fuente de alimento.~~

~~54. La composición de control biológico de acuerdo con la reivindicación 53, en donde la reproducción aumentada sobre una presa artrópoda no tetraníquida se caracteriza por al menos uno de: mayor tasa de reproducción diaria, mayor tasa de oviposición diaria, mayor tasa de supervivencia, mayor porcentaje de individuos hembra que se reproducen sobre dicha presa, y un mejor comportamiento depredador hacia Tetranychidae.~~

~~55. La composición de control biológico según cualquiera de las reivindicaciones 36-54, donde los individuos depredadores son de una especie seleccionada de *Phytoseiulus fragariae, Phytoseiulus longipes, Phytoseiulus macropilis, Phytoseiulus persimilis y Phytoseiulus robertsi*.~~

~~56.~~21. La composición de control biológico según cualquiera de las reivindicaciones ~~36~~18-20~~55~~, en donde la ~~reproducción sobre una~~ presa no T~~t~~etraníquida es ~~la reproducción sobre~~ una especie de ácaro astigmátido seleccionado ~~entre~~de:

i) *Carpoglyphidae* tales como del género Carpoglyphus, por ejemplo, *Carpoglyphus lactis*;

ii) *Pyroglyphidae* tales como del género *Dermatophagoides*, por ejemplo, *Dermatophagoides pteronysinus*, *Dermatophagoides farinae*; del género *Euroglyphus*, por ejemplo, *Euroglyphus longior, Euroglyphus maynei*; del género *Pyroglyphus*, por ejemplo, *Pyroglyphus africanus*;

iii) *Glycyphagidae* tales como de la subfamilia *Ctenoglyphinae*, tales como del género *Diamesoglyphus*, por ejemplo, *Diamesoglyphus intermediusor* del género *Ctenoglyphus*, por ejemplo, *Ctenoglyphus plumiger, Ctenoglyphus canestrinii, Ctenoglyphus palmifer*; la subfamilia *Glycyphaginae*, tal como del género Blomia, por

ejemplo, *Blomia freemani* o del género *Glycyphagus*, por ejemplo, *Glycyphagus ornatus*, *Glycyphagus bicaudatus*, *Glycyphagus privatus*, *Glycyphagus domesticus*, o del género *Lepidoglyphus*, por ejemplo, Lepidoglyphus michaeli, Lepidoglyphus fustifer, *Lepidoglyphus destructor*, o del género *Austroglycyphagus*, por ejemplo, Austroglycyphagus geniculatus; de la subfamilia Aëroglyphinae, tal como del género *Aëroglyphus*, por ejemplo, *Aëroglyphus robustus*; de la subfamilia *Labidophorinae*, tal como del género *Gohieria*, por ejemplo, *Gohieria* fusca; o de la subfamilia *Nycteriglyphinae* tal como del género *Coproglyphus*, por ejemplo *Coproglyphus stammeri* o de la subfamilia *Chortoglyphidae*, tal como el género *Chortoglyphus* por ejemplo *Chortoglyphus arcuatus* ~~y más preferentemente se selecciona de la subfamilia *Glycyphaginae*, más preferentemente se selecciona del género *Glycyphagus* o el género *Lepidoglyphus* seleccionado más preferentemente de *Glycyphagus domesticus* o *Lepidoglyphus destructor*~~;

iv) *Acaridae* tales como del género *Tyrophagus*, por ejemplo, *Tyrophagus putrescentiae*, *Tyrophagus tropicus*, del género *Acarus*, por ejemplo, *Acarus siro, Acarus farris, Acarus gracilis*; del género *Lardoglyphus*, por ejemplo, *Lardoglyphus konoi*, del género *Thyreophagus*, tal como *Thyreophagus entomophagus*; del género *Aleuroglyphus*, por ejemplo, *Aleuroglyphus ovatus*;

v) *Suidasiidae* tales como del género *Suidasia*, tales como *Suidasia nesbiti, Suidasia pontifica* o *Suidasia medanensis*.

~~33.~~22. La ~~población de ácaros depredadores *Phytoseiulus persimilis* según cualquiera de las reivindicaciones 1-20, o la~~ composición según cualquiera de las reivindicaciones ~~2~~1-4~~22~~ y ~~34~~15-16, o la composición de control biológico según cualquiera de las reivindicaciones ~~36~~18-21~~56~~, en donde la mezcla de~~presa astigmátida~~ etapas de desarrollo no Tetraníquidas inmovilizadas se selecciona del grupo que consiste en ácaros inmovilizados, ácaros no viables, huevos incapaces de eclosionar, huevos no viables y una combinación de los mismos.

REIVINDICACIONES

1. Una composición que comprende una población de ácaros depredadores de individuos *Phytoseiulus* junto con una fuente de alimento para los individuos depredadores que comprende una mezcla de etapas de desarrollo inmovilizadas seleccionadas de huevos que no eclosionan y etapas móviles inmovilizadas de un hospedero artificial artrópodo no tetraníquido, y un material portador.

2. La composición según la reivindicación 1, en donde el material portador es seleccionado de aserrín, salvado de trigo, cáscaras de trigo sarraceno, cáscaras de arroz, cáscaras de mijo, una mezcla de los mismos, y un portador que tiene elementos portadores que comprenden alojamientos para ácaros.

3. La composición según cualquiera de las reivindicaciones 1-2, en donde al menos el 10 % de los individuos hembra de la población depredadora son capaces de oviponer sobre el hospedero artificial artrópodo no tetraníquido.

4. La composición según cualquiera de las reivindicaciones 1-3, en donde la población de *Phytoseiulus* tiene una tasa de oviposición diaria de al menos 0,55; tal como ≥ 0,60; ≥ 0,65; ≥ 0,70; ≥ 0,75; ≥ 0,80; ≥ 0,90; ≥ 0,95; ≥ 1,00; ≥ 1,05; ≥ 1,10; ≥ 1,15; ≥ 1,20; ≥ 1,25; ≥ 1,30; ≥ 1,35; ≥ 1,40; ≥ 1,45; ≥ 1,50; ≥ 1,55; ≥ 1,60; ≥ 1,65; ≥ 1,70; ≥ 1,75; ≥ 1,80; ≥ 1,85; ≥ 1,90; ≥ 1,95, o ≥ 2,00 huevos/día/hembra, cuando se usa el hospedero artificial artrópodo no tetraníquido como la única fuente de alimento.

5. Un método para criar una población de ácaros de individuos depredadores de *Phytoseiulus* que comprende los pasos de proporcionar una mezcla de etapas de desarrollo inmovilizadas seleccionadas de huevos que no eclosionan y etapas móviles inmovilizadas de un hospedero artificial artrópodo no tetraníquido, como fuente de alimento para la población de ácaros depredadores de individuos depredadores *Phytoseiulus*, junto a un material portador.

6. Dispositivo para liberar individuos de una especie de ácaro depredador *Phytoseiulus*, comprendiendo dicho dispositivo un recipiente que contiene la

composición según cualquiera de las reivindicaciones 1-4, en donde el dispositivo comprende una salida para las etapas de desarrollo móviles de la especie de ácaro depredador *Phytoseiulus*, adecuada para proporcionar liberación sostenida de varias etapas de desarrollo móviles.

7. Un método para controlar una plaga de cultivos, que comprende los pasos de aplicar una composición de ácaros según cualquiera de las reivindicaciones 1-4 a un cultivo.

8. El método para controlar una plaga de cultivos según la reivindicación 7, que comprende los pasos de aplicar la composición de ácaros según cualquiera de las reivindicaciones 1-4, en un dispositivo según la reivindicación 6, a un cultivo.

9. Método para la obtención de la composición según cualquiera de las reivindicaciones 1-4, comprendiendo dicho método los pasos de:

(a) proporcionar una población de crianza de una especie de ácaro depredador seleccionado del género *Phytoseiulus*, comprendiendo dicha población de crianza individuos de la especie *Phytoseiulus* junto con una fuente de alimento adecuada para los individuos *Phytoseiulus*, comprendiendo dicha fuente de alimento una especie presa seleccionada de *Tetranychidae*;

(b) proporcionar una mezcla de etapas de desarrollo inmovilizadas seleccionadas de huevos que no eclosionan y etapas móviles inmovilizadas de una especie hospedera artificial artrópoda no tetraníquida preseleccionada junto con un material portador;

(c) proporcionar la mezcla de especies hospederas artificiales de artrópodos no tetraníquidos inmovilizados y preseleccionados junto con un material portador a los individuos *Phytoseiulus* como fuente de alimento;

(d) seleccionar individuos *Phytoseiulus* que sean capaces de reproducirse mientras se usa la mezcla de los individuos artrópodos no tetraníquidos inmovilizados y preseleccionados, seleccionados de huevos que no eclosionan y etapas móviles inmovilizadas como una fuente de alimento; y

(e) criar individuos *Phytoseiulus* seleccionados con una fuente de alimento que comprenda la mezcla de especies hospederas artificiales de artrópodos no tetraníquidos

preseleccionadas, seleccionadas de huevos que no eclosionan y etapas móviles inmovilizadas.

10. El método según la reivindicación 9, que además comprende, criar alternativamente individuos *Phytoseiulus* seleccionados en la siguiente secuencia:

- criar durante al menos 2, incluyendo entre 5 y 50, generaciones utilizando una fuente de alimento que comprenda la mezcla de especies hospederas artificiales de artrópodos no tetraníquidos inmovilizadas y preseleccionadas, seleccionadas de huevos que no eclosionan y etapas móviles inmovilizadas;
- criar durante al menos 2, incluyendo entre 5 y 50, generaciones usando una fuente de alimento que comprenda las especies presa seleccionadas de *Tetranychidae*.

11. El método según cualquiera de las reivindicaciones 9 y 10, en donde el método comprende además los pasos de

(a) separar los huevos de las especies de artrópodos no tetraníquidos preseleccionadas;

(b) mezclar los huevos separados con un material portador y agua, para recubrir el material portador con una capa de huevos;

(c) congelar la mezcla; y

(d) criar los individuos *Phytoseiulus* en la mezcla como fuente de alimento.

12. El método según la reivindicación 11, en donde el material portador es seleccionado de aserrín, salvado de trigo, cáscaras de trigo sarraceno, cáscaras de arroz, cáscaras de mijo, o que comprende una mezcla de los mismos.

13. Método según cualquiera de las reivindicaciones 9-12, en donde la población de crianza de *Phytoseiulus* proporcionada es una población compuesta por una serie de subpoblaciones, en donde dichas subpoblaciones proceden de distintas fuentes, de distintas poblaciones de producción y/o de poblaciones naturales aisladas de distintas ubicaciones geográficas.

14. Método según cualquiera de las reivindicaciones 9-13, en donde la población de crianza proporcionada comprende al menos 100 individuos, incluyendo entre 200 y 5000 individuos, o entre 500 y 1500 individuos.

15. Composición de ácaros según cualquiera de las reivindicaciones 1-4 en donde los huevos que no eclosionan son huevos congelados que se recubren con un material portador, o en donde el material portador está recubierto por la mezcla de etapas de desarrollo inmovilizadas seleccionadas de huevos que no eclosionan y etapas móviles inmovilizadas del hospedero artificial artrópodo no tetraníquido.

16. La composición de ácaros según la reivindicación 15, en donde el material portador es seleccionado de aserrín, salvado de trigo, cáscaras de trigo sarraceno, cáscaras de arroz, cáscaras de mijo, una mezcla de los mismos, y un portador que tiene elementos portadores que comprenden alojamientos para ácaros.

17. Dispositivo para la liberación de individuos de una especie de ácaro depredador *Phytoseiulus*, comprendiendo dicho dispositivo un recipiente que contiene la composición según cualquiera de las reivindicaciones 15-16, en donde el recipiente comprende una salida para las etapas de desarrollo móviles de la especie de ácaro depredador *Phytoseiulus*, adecuada para proporcionar liberación sostenida de una serie de etapas de desarrollo móviles.

18. Una composición de control biológico, en donde la composición comprende

(a) una población de ácaros depredadores de individuos de *Phytoseiulus*,

(b) una fuente de alimento para los individuos depredadores que comprende una mezcla de etapas de desarrollo inmovilizadas seleccionadas de huevos que no eclosionan y etapas móviles inmovilizadas de un hospedero artificial artrópodo no tetraníquido, y

(c) un material de portador seleccionado de aserrín, salvado de trigo, cáscaras de trigo sarraceno, cáscaras de arroz o cáscaras de mijo, una mezcla de los mismos, o un portador que tiene elementos portadores que comprenden alojamientos para ácaros.

19. La composición de control biológico según las reivindicaciones 18, donde la población de *Phytoseiulus* tiene una tasa de oviposición diaria de al menos 0,50, tal como ≥ 0,55; ≥ 0,60; ≥ 0,65; ≥ 0,70; ≥ 0,75; ≥ 0,80 ; ≥ 0,90; ≥ 0,95; ≥ 1,00; ≥ 1,05; ≥ 1,10; ≥ 1,15; ≥ 1,20; ≥ 1,25; ≥ 1,30; ≥ 1,35; ≥ 1,40; ≥ 1,45; ≥ 1,50; ≥ 1,55; ≥ 1,60; ≥ 1,65; ≥ 1,65; ≥ 1,70; ≥ 1,75; ≥ 1,80; ≥ 1,85; ≥ 1,90; ≥ 1,95, o al menos 2,00 huevos/día/hembra, cuando se utilizan hospederos artificiales artrópodos no tetraníquidos como única fuente de alimento.

20. La composición de control biológico según cualquiera de las reivindicaciones 18-19, donde los individuos depredadores son de una especie seleccionada de *Phytoseiulus fragariae, Phytoseiulus longipes, Phytoseiulus macropilis, Phytoseiulus persimilis y Phytoseiulus robertsi*.

21. La composición de control biológico según cualquiera de las reivindicaciones 18-20, en donde la presa no Tetraníquida es una especie de ácaro astigmátido seleccionado de:

i) *Carpoglyphidae* tales como del género Carpoglyphus, por ejemplo, *Carpoglyphus lactis*;

ii) *Pyroglyphidae* tales como del género *Dermatophagoides*, por ejemplo, *Dermatophagoides pteronysinus*, *Dermatophagoides farinae*; del género *Euroglyphus*, por ejemplo, *Euroglyphus longior, Euroglyphus maynei*; del género *Pyroglyphus*, por ejemplo, *Pyroglyphus africanus*;

iii) *Glycyphagidae* tales como de la subfamilia *Ctenoglyphinae*, tales como del género *Diamesoglyphus*, por ejemplo, *Diamesoglyphus intermediusor* del género *Ctenoglyphus*, por ejemplo, *Ctenoglyphus plumiger, Ctenoglyphus canestrinii, Ctenoglyphus palmifer*; la subfamilia *Glycyphaginae*, tal como del género Blomia, por ejemplo, *Blomia freemani* o del género *Glycyphagus*, por ejemplo, *Glycyphagus ornatus*, *Glycyphagus bicaudatus*, *Glycyphagus privatus*, *Glycyphagus domesticus*, o del género *Lepidoglyphus*, por ejemplo, Lepidoglyphus michaeli, Lepidoglyphus fustifer, *Lepidoglyphus destructor*, o del género *Austroglycyphagus*, por ejemplo, Austroglycyphagus geniculatus; de la subfamilia Aëroglyphinae, tal como del género

Aëroglyphus, por ejemplo, *Aëroglyphus robustus*; de la subfamilia *Labidophorinae*, tal como del género *Gohieria*, por ejemplo, *Gohieria* fusca; o de la subfamilia *Nycteriglyphinae* tal como del género *Coproglyphus*, por ejemplo *Coproglyphus stammeri* o de la subfamilia *Chortoglyphidae*, tal como el género *Chortoglyphus* por ejemplo *Chortoglyphus arcuatus*;

iv) *Acaridae* tales como del género *Tyrophagus*, por ejemplo, *Tyrophagus putrescentiae*, *Tyrophagus tropicus*, del género *Acarus*, por ejemplo, *Acarus siro, Acarus farris, Acarus gracilis*; del género *Lardoglyphus*, por ejemplo, *Lardoglyphus konoi*, del género *Thyreophagus*, tal como *Thyreophagus entomophagus*; del género *Aleuroglyphus*, por ejemplo, *Aleuroglyphus ovatus*;

v) *Suidasiidae* tales como del género *Suidasia*, tales como *Suidasia nesbiti, Suidasia pontifica* o *Suidasia medanensis*.

22. La composición según cualquiera de las reivindicaciones 1-4 y 15-16, o la composición de control biológico según cualquiera de las reivindicaciones 18-21, en donde la mezcla de etapas de desarrollo no Tetraníquidas inmovilizadas se selecciona del grupo que consiste en ácaros inmovilizados, ácaros no viables, huevos incapaces de eclosionar, huevos no viables y una combinación de los mismos.

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LIFE-STYLES OF PHYTOSEIID MITES AND THEIR ROLES IN BIOLOGICAL CONTROL

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ABSTRACT

This review categorizes the diversity of life-styles in the Phytoseiidae, based primarily on food habits and related biological and morphological traits. The life-styles proposed are as follows: Type I, specialized predators of *Tetranychus* species represented by the *Phytoseiulus* species; Type II, selective predators of tetranychid mites (most frequently associated with species that produce dense webbing) represented by *Galendromus*, some *Neoseiulus*, and a few *Typhlodromus* species; Type III, generalist predators represented by some *Neoseiulus* species and most *Typhlodromus* and *Amblyseius* species, as well as species in all other genera about which information is available; Type IV, specialized pollen feeders/generalist predators represented by *Euseius* species. Consideration is given to the relative importance of each of these types in biological control and pest management programs.

INTRODUCTION

Mites of the family Phytoseiidae have received considerable attention for the last four decades because of their potential as biological control agents of phytophagous mites and, more recently, of thrips on various crops. The early part of

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the period saw considerable controversy about the effectiveness of these predators in suppressing and regulating populations of spider mites (Tetranychidae). As more studies were undertaken, there was increasing evidence to support the contention that phytoseiid mites can be important biological control agents and essential elements in some pest management programs (99). Knowledge of the great diversity of feeding habits and predatory behavior within the family is still unfolding. Early disagreements on the value of phytoseiids probably can be attributed partly to generalizations made by some workers on the basis of experience with one species on one crop without awareness of the extensive biological diversity within the family, and partly because many species seem to have few qualities that were considered to be necessary for an effective predator.

Our understanding of what constitutes an effective phytoseiid mite in biological control has changed considerably in the past 30 years. Most early studies and even the majority of current ones focus on the abilities of these predaceous mites to rapidly increase and to overcome outbreak populations of spider mites. In recent years the potential of phytoseiids to regulate spider mites at low equilibrium densities has become more widely appreciated, and studies have begun to examine some of the attributes that contribute to persistence of populations at low prey densities, such as the ability to survive when starved, use of alternate foods, cannibalism, and predation on other phytoseiid species.

This review is an attempt to categorize this diversity of life-styles, based primarily on food habits and related biological and morphological traits, mainly of adult females. We examine the possible correlation of these life-styles with taxonomic groupings and evolutionary trends, and we consider the relative importance and potential of each category of predator in biological control and pest management programs. Our use of phytoseiid genus names in this review follows Chant & McMurtry (23) for the subfamilies Typhlodrominae and Phytoseiinae and deMoraes et al (49) for the Amblyseiinae.

LIFE-STYLES IN RELATION TO FOOD HABITS

We hypothesize that different types of life-styles have evolved in the Phytoseiidae, based on differences in food utilization, and we propose four main types. We recognize that there may not always be discrete lines between types and that additional categories may become evident as knowledge increases.

Type I. Specialized Predators of Tetranychus *Species*

This category is considered genus-specific in regard to prey preference and is represented only by *Phytoseiulus* species. These species are mainly associated with spider mites in the genus *Tetranychus* having a web structure of the CW-u type (141), characterized by a highly dense, complicated, irregular web

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on which fecal pellets, eggs, and cast skins accumulate. Occasionally, they may be found in webbed-over colonies of spider mites of other genera, such as *Oligonychus*, probably as a result of arrival by passive aerial dispersal (J McMurtry, unpublished observations).

Reproduction of *Phytoseiulus* species seems to be dependent on tetranychid mites as prey and usually occurs at a higher rate on prey of the genus *Tetranychus* than on species in other genera (6, 7). In one study, the oviposition rate of *Phytoseiulus persimilis* on *Oligonychus pratensis* was similar to that on *Tetranychus urticae. O. pratensis* differs from other *Oligonychus* species in that it produces heavy webbing of the CW-u type on the undersides of leaves, similar to that of *Tetranychus* species (126). A repellent response was reported for *P. persimilis* to some other mite families (131). Various other parameters also suggest a high degree of specialization to tetranychid mites as prey, including a density-dependent response to *T. urticae* as measured by prey attacks, time spent in a prey patch, and oviposition rate (8, 9, 178, 181).

Although *P. persimilis* showed a random searching behavior at higher spatial levels (branches within a plant), it showed strong aggregation behavior at the lower spatial levels (leaflets within a leaf) (177). The aggregative response was found to be positively correlated with efficiency of biological control of *T. urticae* (87, 180). Of three predator species with different degrees of polyphagy, *P. persimilis* showed the strongest tendency to remain in prey patches, probably reflecting coevolution of this species with prey species having highly clumped distributions (181).

Phytoseiulus species all have a high potential for population increase, probably the highest in the Phytoseiidae (173). They have a short development time (139, 154), with a usually nonfeeding larval stage that takes up only a small percentage of the developmental period, along with high fecundity, resulting in intrinsic rate of increase (r) values sometimes exceeding 0.4. Mean oviposition rates obtained are often above 4/day (139). However, the rate of increase of *P. persimilis* can vary according to the plant on which the prey, *T. urticae*, are feeding (127). *Phytoseiulus* species are relatively large and both nymphs and adults have a high prey consumption rate compared to most species in other genera (68, 135).

Life functions of *Phytoseiulus* species are carried out almost exclusively in spider mite colonies. Thus, the living space of this group of predators is the prey colony itself, and there is less influence of leaf anatomy or leaf age on behavior than for phytoseiids in Groups III and IV, which use certain parts of the leaf rather than prey colonies for various life functions. Foraging responses of *P. persimilis* are not affected by leaf size or age (179). Eggs are mostly laid on the strands of webbing, and all of the active stages are able to move readily among the dense strands. Passive dispersal on air currents occurs as the prey

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population declines to low levels, but propensity to disperse is suppressed in the presence of prey (136).

Various studies have shown that *P. persimilis* and other phytoseiids respond to volatile chemicals emitted by infestations of spider mites on leaves and that they have the ability to discriminate between volatiles resulting from different tetranychid species (138). Under natural conditions, this response may induce arrestment in a prey patch more than attraction to the patch from a distance (140, 176).

A morphological character state correlated with specialized predators of *Tetranychus* species is the presence of long setae in the medial position of the dorsal shield, usually setae j4–j6 and J2, as well as some setae in the lateral position of the shield, i.e. the s-S series and occasionally Z1 (99, 135) [see (21) for setal notations]. These long setae might aid the predators in moving through the strands of webbing: Sabelis & Bakker (137) presented a protection hypothesis that proposes that species having the capacity to control *Tetranychus* species populations have long setae in these positions on the dorsal shield. Conversely, species usually considered ineffective predators of *Tetranychus* species have short setae in these positions and are usually hindered by the webbing.

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Type II. Selective Predators of Tetranychid Mites (Most Frequently Associated with Dense-Web–Producing Species)

This category is represented mainly by two genera, *Galendromus* and one group of *Neoseiulus*, and also (tentatively) a few species in *Typhlodromus*, subgenus *Anthoseius*, i.e. the *Typhlodromus rickeri* group (Table 1). Species in Type II are usually associated with *Tetranychus* species (CW-u type) or those in other genera having species that produce a "webnest" (141), varying from a loosely defined roof in a leaf depression or alongside the midrib or main leaf veins (WN-u type), to a very densely woven roof that is impenetrable to some phytoseiids (WN-c type). Compared to Type I, species in Type II show a broader range of prey on which they thrive within the Tetranychidae. For example, *Neoseiulus idaeus* and *Galendromus annectens* had a comparable reproductive potential on *T. urticae* and cassava green mite, *Mononychellus tanajoa*, which produces little webbing (112), although a strain of *N. idaeus* was reported that had a lower rate of increase on *M. tanajoa* (47). *Galendromus helveolus* does equally well on *Eotetranychus sexmaculatus*, *T. urticae*, *Oligonychus perseae*, and *Oligonychus punicae*, each of which has a different type of colonization behavior and web structure (15, 99, 158; J McMurtry & A Aponte, unpublished observations). On the other hand, *Neoseiulus californicus* (= *chilenensis*) had a higher oviposition rate on *Tetranychus cinnabarinus* than on *Eutetranychus*

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orientalis, a species that produces little webbing (153). *Panonychus ulmi*, another species that produces little webbing, was a less favorable food in terms of development and oviposition for both *Neoseiulus fallacis* and *Galendromus occidentalis* (66). These studies along with general observations suggest that predators in Group II may readily prey on tetranychids of the "little webbing" (LW) life types, but they are less likely to have a close association with them. Although the response of Type II predators to prey density may be less than that of *Phytoseiulus* species, some Type II species do show a strong aggregation response to leaves infested with *T. urticae* (37, 178, 181).

Species in Type II have been shown to reproduce on mites in other families. A tarsonemid mite was found to promote development and reproduction of *G. annectens*, *Galendromus porresi*, and *Typhlodromus rickeri* at a rate comparable to that of *T. urticae* (104). *G. occidentalis* feeds on eriophyids such as apple rust mite (*Aculus schlechtendali*), tydeids, and tarsonemids, some of which may be important alternate foods (109), but *G. helveolus* did not develop on the eriophyid *Phyllocoptruta oleivora* (15). *T. rickeri* reproduces at comparable rates on both tetranychid mites and *P. oleivora* (107). *Neoseiulus* species in this category are known to feed on eriophyids, but the presence of rust mites alone did not promote increases of *N. fallacis* (35). There are no records of associations with Tenuipalpidae, although feeding and oviposition in the laboratory on this prey has been reported for *G. occidentalis* and *Neoseiulus californicus* (156).

Some studies have shown that pollen promotes reproduction of certain species of *Neoseiulus* and *Galendromus*, but at a much lower rate than mite prey (3, 10, 109, 156, 159). However, there is no information on the consumption of pollen by these species under field conditions. Plant exudates may prolong survival. Cassava exudates sustained metabolism of *N. idaeus* in the absence of prey and allowed normal reproduction to resume when prey again became available (111).

Reproductive capacities and developmental rates could be classed as medium in species in *Galendromus* (15, 139) to high in most species of *Neoseiulus* in Type II, with r values of up to 0.4 reported for some species (20, 82, 139). The species in this category, especially in *Galendromus*, are smaller than *Phytoseiulus* species. They have a tendency toward a shorter deutonymphal stage and a lower prey requirement for completing development compared to species in Type I and also to many of those in Type III (135, 174). Most life functions are carried out in the heavily webbed colonies of *Tetranychus* and species in other genera that spin profuse webbing. The degree of intercolony movement in an abundant prey source may vary with the species. Adults of *Neoseiulus* species such as *N. fallacis* and *N. californicus* are more active than those of *G. occidentalis* (37, 46). There seems to be more influence by leaf condition or architecture on distribution compared to Type I species. For ex-

Table 1 Examples of genera and species of Phytoseiidae in each of four life-style types

Genus[a]	Species	Distribution[b]	Type of crop[c]	Strategy[d]	References
Type 1					
Phytoseiulus	*persimilis*	Nt, Pa, Na (I), Au (I), Et (I)	L, G	C, A, Im	24, 102, 160, 164; B Croft[g], D Penman[f]
	macropilis	Na, Nt, Et, Pa	L	A	76
	longipes	Et	L, G	A	99
Type II					
Galendromus	*annectens*	Na, Nt	T	C, A	J McMurtry[g]
	helveolus	Na, Nt	T	C, A	118; J McMurtry[g]
	occidentalis	Na, Pa (I), Or (I)	T, L, V	C, A, Im	79, 99, 146
Typhlodromus (Typhlodromus)	*rickeri*	Or, Na (I)	T	[e]	99
Neoseiulus	*bibens*	Et	L, Sh	C	99
	californicus	Pa, Na, Nt	T, L, V	C, A	30, 99
	fallacis	Pa, Na, Nt, Au (I), Or (I)	T, Sh, L	C, A, Im	30, 99
	idaeus	Nt, Et (I)	Sh, L	C, Im	171
	longispinosus	Or, Aus	T, Sh, L	C, A	96, 116
	tiki	Et	Sh, L	C	99
Type III					
Typhlodromus (Typhlodromus)	*pyri*	Pa, Na	T, V, Sh	C, A	30, 120, 148
	exhilaratus	Pa	T	C	99
Typhlodromus (Anthoseius)	*caudiglans*	Pa, Na, Au	T	C	99
	doreenae	Au	V	C	86
Metaseiulus	*arboreus*	Na	T	C	99
	citri	Na	T	C	98
	pomi	Na	T	C	4
Paraseiulus	*soleiger*	Pa, Na	T	C	94
Phytoseius	*macropilis*	Na	T	C	4
	spoofi[h]	Pa	T	C	94
Amblyseius	*andersoni*	Pa, Na	T	C, A	46, 56, 83, 99
	eharai	Or	T	C	99, 100
	swirskii	Pa	T	C	99, 100, 115
Neoseiulus	*barkeri*	Pa, Na, Or	G	A	78, 129, 130
	cucumeris	Pa, Na	L, G	C, A	67, 99, 130
	umbraticus	Pa, Na	L, T	[e]	92
Kampimodromus	*aberrans*	Pa, Na	T, V	C, A	59, 75
Typhlodromalus	*aripo*	Nt, Et (I)	Sh	C, Im	5, 171
	limonicus	Na, Nt	T, Sh	C	107
	manihoti	Nt, Et (I)	Sh	C, Im	5
Typhlodromips	*sessor*	Na	T	[e]	144
	newsami	Or	T	C, A	128
Iphiseius	*degenerans*	Pa, Et	T, Sh, G	C, A	L Tanigoshi[f]

Continues

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Table 1 *Continued*

Genus[a]	Species	Distribution[b]	Type of crop[c]	Strategy[d]	References
Type IV					
Euseius	*addoensis*	Et	T	C	73, 91
	elinae	Au	T	C	99
	finlandicus	Pa, Na	T	C	99, 128
	fructicolus	Nt	T	C	99
	sojaensis	Or	T	C	124
	tularensis	Na	T	C	70, 157
	stipulatus	Pa, Na (I)	T	C, Im	62, 108
	victoriensis	Au	T	C	85, 147

[a]Use of genus and subgenus names follow Chant & McMurtry (23) for the subfamilies Typhlodrominae and Phytoseiinae and de Moraes et al (49) for the Amblyseiinae.
[b]Pa, Palearctic; Et, Ethiopian; Or, Oriental; Au, Australian; Na, Nearctic; Nt, Neotropical; (I), introduced.
[c]L, low-growing; Sh, shrub; T, tree; V, grapevine; G, greenhouse.
[d]C, conservation; A, augmentation; Im, importation and establishment.
[e]No information available.
[f]Personal communication.
[g]Unpublished data.
[h]Referred to as *P. macropilis* in most European literature (172).

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ample, *G. occidentalis* spent more time in prey patches on young leaves than old (179), and this species frequents the midrib area more than the periphery of apple leaves, as compared to Type III species such as *Typhlodromus pyri* (97).

The Type II species, exemplified by *N. fallacis* and *G. occidentalis*, have high powers of aerial dispersal when *Tetranychus* prey becomes locally scarce (46, 53, 79, 88). To what extent these species persist by utilizing other foods or are locally displaced by generalist species may depend upon the phytoseiid species composition and the pesticide spray program in a given ecosystem (46, 80, 106, 134). In a stable system not disrupted by chemicals, Type III generalists often displace Type II species (40, 150). Both *Neoseiulus* and *Galendromus* species show responses to volatile chemicals produced from infestations of spider mites on foliage, with a preference for volatiles from infestations of *T. urticae* over those from other genera of spider mites (138).

Type II species also have long setae on the median and lateral surfaces of the dorsal shield, as described above. This character state occurs in all three genera mentioned, but those species in *Neoseiulus* and *Typhlodromus* that are known to be generalists (Type III) have shorter setae in these locations. This is consistent with the protection hypothesis (137).

Type III. Generalist Predators

With the exception of *Phytoseiulus* and *Galendromus*, generalist species occur in all genera for which some biological information is available (Table 1). Feed-

ing and reproduction occurs on various genera of tetranychids, but *Tetranychus* species may be inferior as prey to those in other tetranychid genera for species such as *Amblyseius swirskii* and *Typhlodromus exhilaratus* (156). Eriophyid mites vary as prey from unfavorable to highly favorable, depending on the predator species (109). Some species, such as *Kampimodromus aberrans, Amblyseius andersoni*, and *T. pyri* may have higher potential for increase on rust mites than on tetranychids (51, 115, 143), although the last two species showed preference for *P. ulmi* (50). Other families of mites preyed upon include tarsonemids, on which development and oviposition occurs (104); tydeids, which may be an important alternate food for *T. pyri* (17) and possibly a primary food for *Paraseiulus* species (109); tenuipalpids; acarids (109, 156); and pyroglyphids (18). Potential insect prey includes thrips, on which reproduction may be higher than on spider mites (13) or similar to that on pollen and spider mites (19), as well as whiteflies, mealybugs, and scale crawlers, which usually are not highly favorable (109, 156). Immature stages of psocids may be fed upon by some species (34).

Most generalist predators across the whole family can reproduce on pollen, some species at a rate at least as high as on prey (19, 57, 109, 143, 162). Various plant exudates as well as honeydew may serve as survival foods or important food supplements, which may increase the reproductive potential in the presence of prey (12, 103). Also, there is some evidence to support the hypothesis that leaf sap can be utilized (103). Cannibalism and interspecific predation on phytoseiids by adult and immature stages may be more common among the generalists than in the Type I and II specialists (33, 34, 38, 175).

The reproductive potential of Type III species varies. For example, *T. pyri* and *Phytoseius hawaiinsis* have mean oviposition rates below 1.0/day and r values under 0.1. Others, such as *Iphiseius degenerans, Amblyseius largoensis, Typhlodromalus limonicus*, and *Typhlodromalus peregrinus* have mean oviposition rates of 1.5 to over 2/day and r values of up to 0.25 when fed spider mites or pollen (65, 109, 139). Generalists in the Amblyseiinae have a higher mean reproductive potential than those in the Phytoseiinae or Typhlodrominae (173). Type III predators vary in size from large (*Amblyseius* and some *Typhlodromalus* species) to medium (most *Typhlodromus* species) to very small (*Phytoseius* species). More prey may be required to complete development than for species in Type II (135, 174).

Type III phytoseiids do not aggregate so extensively in mite prey colonies as do the Type I and Type II species (37, 95, 103, 120, 181). In fact, aggregation may be inversely density-dependent, i.e. fewer predators are found on leaves with high prey density than on leaves with low prey denisty (177). Many species are adversely affected by dense spider mite webbing (137). Oviposition sites generally have no correlation with the location of patches of mite prey (103), un-

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less feeding by a mite or insect infestation has produced a depression or mined-out area in the leaf, creating a sheltered area. Some generalists have been shown to respond to volatiles produced by infestations of spider mites, sometimes with a preference for *Panonychus* species that produce little webbing (138).

Behavior of generalist phytoseiids may be strongly influenced by leaf anatomy. It is well known that many species usually are found on the undersides of leaves along the midrib or in depressions, among leaf hairs, or in other protected areas, and eggs usually are laid in such places. Leaves with various types of domatia may harbor more phytoseiids than similar leaves without domatia or leaves from which domatia have been removed (166, 167). The presence of sheltered habitats, including leaf pubescence, may be more important than food availability in affecting the abundance of some phytoseiids (55, 89, 125, 132). Thus, it is hypothesized that generalists have evolved more in response to conditions of the plants they inhabit than to certain kinds of prey.

Restriction of phytoseiids to a narrow range of plants is uncommon, but several cases are known. *Typhlodromalus manihoti* is seldom found on plants other than cassava (48). The three known species of the genus *Eharius* from Europe and the Middle East have been collected almost entirely on plants in the mint family, and most often from *Marrubium vulgare*. *Eharius cherguii* could have been introduced with the plant to North America, where it was also collected on several other species in the mint family (49). *M. vulgare* has very hairy leaves, and the long hypostome and cheliceral shafts of *Eharius* species are probably an adaptation for obtaining food on such leaves. The food source of these mites is unknown. *K. aberrans* is known almost exclusively on *Corylus* species (hazelnuts/filberts) in North America, on which it has a close association with eriophyid mites as prey (75) and also with the alate form of the filbert aphid, which it apparently exploits for dispersal (93).

All generalists studied thus far have short mid-dorsal setae (j-J series), and many of these species are hindered by dense spider mite webbing (137). There seems to be a correlation between plants with glabrous leaves and phytoseiids with smooth dorsal shields and short to minute mid-dorsal setae. Collections of *Iphiseius*, *Iphiseiodes*, many *Typhlodromalus*, and *Amblyseius* species have been collected mainly from trees and shrubs with smooth leaves, such as citrus, avocado, and coffee, although leaves of these plants may contain sheltered sites along the midrib or other kinds of domatia (49, 137; J McMurtry, unpublished observations).

Species living on plants with highly pubescent leaves are generally small with narrow body shape. *Phytoseius* species usually occur on such plants (137, 165; G Moraes, personal communication). Species in this genus have thick, long setae in the lateral areas of the dorsal shield, as well as a reduction in the number of setae on the opisthosoma. Most *Kampimodromus* species and *Typhlodromus*

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species are also relatively small, and both *K. aberrans* and *T. pyri* were more abundant on grape varieties with hairy leaves. Suggested factors influencing this preference include a more favorable microclimate with higher humidity and lower temperature, increased number of oviposition sites, increased protection from macropredators, and increased capacity for trapping wind blown pollen grains (55). On the other hand, the searching activity of *Neoseiulus cucumeris* for thrips was thought to be hindered by the trichomes of cucumber, compared to pepper, which had fewer trichomes and on which biological control of thrips was more efficient (146).

Type IV. Specialized Pollen Feeders/Generalist Predators

This type presently comprises only the genus *Euseius*. The genus contains over 200 described species, found mostly in arboreal habitats in the tropics and subtropics (49). Species in this category are also polyphagous (109, 156), but the reproductive potential of many species is highest on pollen (1, 2, 61, 109, 123). Population increase of *Euseius* species often can be correlated with pollen fallout onto the foliage rather than the presence of any prey species (103). The reproductive potential of *Euseius* species is considered medium (139, 156). Spider mites alone may be unsuitable for development unless supplementary foods are present (2, 84, 109, 182). The rate of population increase has been shown to be lower on *Tetranychus* species compared to spider mites in other genera as prey (61, 145). Although some *Euseius* species may show preference for and reproduce better on eriophyid than tetranychid prey (51, 143), eriophyids are unsuitable food for other species (2, 107). A tarsonemid mite promoted development and oviposition of two *Euseius* species (104). *Euseius tularensis* preferred pollen, thrips and spider mites in that order (28). Some species of *Euseius* have been investigated for their potential as control agents of whiteflies (113, 114, 169).

Euseius species seem to be even less closely associated with patches of spider mite prey than the Type III generalists. Rather, they are active in foraging both sides of leaves, especially in shade or darkness, feeding on pollen grains or other food. Arrestment responses to extracts of pollen as well as to spider mites have been shown (105). *Euseius stipulatus* was observed to withdraw the contents of more than 100 pollen grains in 1 h, with an average handling time of less than 10 sec/pollen grain (63). Resting and oviposition usually occur in protected areas of the leaf, along the midrib or in depressions or various types of domatia. Although no studies have been designed to measure the rate of dispersal of *Euseius* species, relatively rapid colonization of an exotic species in citrus orchards has been observed (103, 108).

Euseius species appear to have a complex relationship with their host plants. *E. tularensis* reaches higher numbers on citrus trees that have been pruned

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and have an abundance of flush growth (71). Evidence suggests that *Euseius hibisci* withdraws fluids from avocado leaves, but the same tests were negative for citrus leaves (103). This species is common on both citrus and avocado, but the closely related *E. tularensis* does not occur on avocado, even in locations where it is abundant on citrus. This species had a lower fecundity on avocado leaves than on citrus leaves when fed the same food, whereas *E. hibisci* showed no differences in fecundity on the two substrates (27).

Most *Euseius* species are characterized by a smooth dorsal shield with short setae in the median as well as lateral areas of the shield. There are a few exceptions with long setae, such as *Euseius tutsi* and *Euseius scutalis*. It is unknown if such species are more closely associated with spider mites having clumped distributions and densely webbed colonies. *E. scutalis* (=*rubini*) developed and oviposited on eggs and larvae of *Tetranychus pacificus* and *T. cinnabarinus* (14, 60, 152), although some difficulty of immature stages moving in the webbing of the prey was observed (14). An anatomical feature unique to *Euseius* species and the monotypic *Iphiseius* (*degenerans*) is the shape of the chelicerae, which are small with convex inner surfaces and minute denticles only at the distal end of the fixed digit. This shape of chelicerae is accompanied by a wide deutosternal groove; both characters are possible adaptations for obtaining nourishment from pollen grains (64).

Possible Additional Types

An intriguing relationship is that of the close association between *Typhlodromus bambusae* and *Schizotetranychus celarius* on bamboo. This spider mite constructs webbing classed as the "webnest" (WN-c) type (141), consisting of a nest formed by a densely woven roof over depressions on the lower leaf surface and no other webbing inside. *T. bambusae* will accept other spider mite prey species living on bamboo, but the oviposition rate is lower on these foods (142). Coevolution of prey and predator seems likely. The habitat is a stable one on an evergreen host plant, both species can be classified as having a low reproductive potential, and the spider mite has evolved an unusual defensive strategy of driving away or actually killing immature predators (142). *T. bambusae* has short setae in the mid-dorsal position. This is not inconsistent with the protection hypothesis (137) because there are no strands of webbing inside the nest of *S. celarius.*

ROLES IN BIOLOGICAL CONTROL

This section reviews the research on and utilization of the four types of phytoseiids in strategies of conservation, augmentation, and importation (Table 1).

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Type I

The traits of *Phytoseiulus* species, which result in a rapid numerical response to increasing spider mite populations, make them logical candidates for augmentation strategies in biological control. However, this efficiency could have the drawback of possible overexploitation of the prey and the predator dying out because of inability to exist on alternate foods, especially in confined spaces, as in a greenhouse (168). Species in this category, mainly *P. persimilis*, and to a lesser extent *Phytoseiulus macropilis*, are used mostly in augmentation strategies. Programs have been in effect since the 1960s to control *T. urticae* on greenhouse vegetable crops with *P. persimilis*, mainly on cucumbers and peppers (102). Routine management programs use *P. persimilis* for control of *T. urticae* on field-grown strawberries in California (102) and more recently in Florida (160). Although the economic feasibility of this strategy has been proven on high value crops, the use of Type I predators has also been investigated for use on lower value crops, including *P. persimilis* releases on field crops by the use of aerial delivery systems (102) and on apple trees (149).

Importation of *P. persimilis* has resulted in extension of the distribution to new areas that include the United States, Australia, New Zealand, New Caledonia, Israel (99, 155), and South Africa (B Croft, unpublished observations). What have been the benefits from these establishments? There are few documented cases in which *Phytoseiulus* species have been successful in conservation strategies without the use of supplemental releases. For example, natural dispersal of *P. persimilis* into a crop as a *Tetranychus* species infestation develops usually occurs too late for effective suppression of mites on strawberry, thus necessitating the use of augmentation. However, this scenario should not be automatically assumed. A study in New Zealand indicated that resident *P. persimilis* could maintain *T. urticae* at acceptable levels in raspberry plantations (24). Contrary to most observations, *P. persimilis* remained on plants for several weeks after the spider mites were suppressed. This was attributed to a delayed dispersal induced by residual arrestment cues on the previously infested leaves (25). A study of *T. urticae–P. persimilis* interactions on roses in plastic tunnels in Australia for nearly three years showed that long-term stability at low population densities of predator and prey can occur without reintroduction of predators (69). *P. persimilis* also persisted at low levels over a three year period on bananas in Queensland, Australia, from which it dispersed into fruit crops and controlled *T. urticae* (163). All three of these cases involved complex ecosystems with relatively tall plants and dense foliage, and in the raspberry plantations, a ground cover around the fields and between rows contained weed species known to be hosts for *T. urticae* (24). Encouraging the growth of alternate hosts for *T. urticae* among and adjacent to strawberry fields increased off-season survival of *P. persimilis* (164). *P. persimilis* also has been observed

to move from cover crops into fruit trees infested with *Tetranychus* species in New Zealand (D Penman, personal communication), and South Africa (B Croft, unpublished observations). More effective biological control of *T. urticae* on cucumber compared to pepper was attributed to such aspects of cucumber culture such as adjacent plants touching and large individual leaves to increase the aggregative response of *P. persimilis* and make searching easier (87). Thus, the persistence of Type I predators in a system will vary according to the crop and to the cultural practices employed, as well as to differences in climatic conditions. Certainly the conditions described above are dramatically different from annually cropped strawberries in California, where large fields of plants growing on a plastic mulch in a nearly weed-free environment, sometimes near fields of vegetables receiving intensive pesticide applications, are hardly conducive to long term population stability.

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Type II

There are numerous documented cases of integrated pest management (IPM) programs employing conservation of *Galendromus* or *Neoseiulus* species. *G. occidentalis* probably is one of the most important species involved in mite management programs in western North America, on crops such as apple, prune, almond, and grape, mainly against *Tetranychus* species. It is also abundant on some low-growing crops such as strawberry and cotton (80, 99). On apple in western Oregon, *G. occidentalis* is complimentary to the generalist *T. pyri*, but it is commonly secondary in abundance to that species, or even disappears when *Tetranychus* species become scarce (40, 44, 53). The application of a selective pesticide (i.e. one that is slightly toxic to *T. pyri* but not to *G. occidentalis*) may be necessary to maintain *G. occidentalis* (46). In drier areas, such as central Oregon and the Wenatchee Valley in Washington on apple crops and the San Joaquin Valley of California on such crops as almond and grape, such competition from other resident phytoseiids apparently is less (43, 44), although this could be partly the result of exclusion of other competitors by spray programs (52, 106).

G. helveolus is considered important in regulation of *E. sexmaculatus* in Florida, but not of *Panonychus citri* or *Eutetranychus banksi*, which do not have clumped distributions and produce little webbing (15, 118). *G. annectens* was relatively uncommon in California and limited to coastal areas until the recent introduction of *O. perseae*, which produces a tightly woven nest on the undersides of leaves. At present, *G. annectens* occurs in all locations where *O. perseae* is found, including inland areas with greater temperature extremes and lower humidities (J McMurtry & A Aponte, unpublished observations). Agricultural acarology has many examples of species becoming either more or less abundant with a change in cultural practices. But a predaceous mite

changing from a rare to a common species as a result of the introduction of a new prey species seems noteworthy.

N. fallacis occurs more commonly on low-growing crops in temperate-humid areas of North America (49, 75), but it can be a major mortality factor of both *Tetranychus* species and *P. ulmi* on fruit trees, to which it moves from the ground cover. In the eastern United States and Canada, it is an important species in well-established IPM programs on apple, strawberry, corn, sorghum, soybean, and many others (30). In western North America, *N. fallacis* impacts pest mite populations on such crops as strawberry, caneberry, corn, mint, and hops. The use of groundcover or debris to increase shelter tends to increase its effectiveness in some regions and crops and not in others (42, 117, 122). *N. californicus* (= *chilenensis*) plays a role in conservation strategies on such crops as grape in coastal valleys of Central California and Chile, as well as apple and citrus in Chile (99) and many other parts of South America (30, 32). Its distribution extends to Europe on citrus, strawberry, and various low-growing plants (49). Other *Neoseiulus* species in other parts of the world, such as *N. longispinosus*, also should be promising for biological control programs (Table 1).

Phytoseiids in Type II have had increased use in augmentation programs. Releases of *G. occidentalis* are made on such crops as cotton, grape, and almond in California (G Scriven, personal communication) and hops in the Pacific Northwest United States (151). *G. helveolus* and *G. annectens* are released on avocado in California for suppression of *O. perseae* (J McMurtry & A Aponte, unpublished observations). Augmentation programs using *Neoseiulus* species include *N. californicus* on strawberry (99) and *N. fallacis* on hops (151), mint (117), strawberry (29, 133), and ornamentals (B Croft, unpublished observations). The high powers of dispersal of *N. fallacis* allowed for a remarkably low inoculative release rate (1500 adult females/2.5 ha field) to provide control of *T. urticae* on strawberry (29). The use of Type II phytoseiids in greenhouse situations has been limited. Such species appear to deserve more attention. Their low food requirements and low tendencies for cannibalism (so that they are cheaper to rear), broad range of foods on which reproduction is possible, and high activity of some species (such as *N. fallacis* and *N. californicus*) might contribute to stabilizing predator-prey systems at low average densities.

In importation programs, *G. occidentalis* represents a notable success story in the introduction and establishment of an organophosphate-resistant strain into Australia. The sole prey species in most orchards was *T. urticae* and an equilibrium was achieved with spider mites regulated at low levels (30, 134). *G. occidentalis* also has been introduced to Russia, New Zealand, and Taiwan (30). *G. helveolus*, introduced from Florida, is established in California, where its numbers are correlated with the presence of *O. perseae* on avocado (J Mc-

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Murtry & A Aponte, unpublished observations). *T. rickeri* was introduced from India to California in 1962, and it is occasionally collected in low numbers on citrus and avocado in coastal areas but is not a significant factor in mite control (99). Two *Neoseiulus* species have been established in other areas: *N. fallacis* from the United States to New Zealand and Taiwan on fruit trees (30) and *N. idaeus* on cassava from Brazil to Africa (5).

Type III

There is increasing evidence that generalists in various genera can maintain spider mites at low population densities. *Amblyseius* contains species that have an impact on *Panonychus* species on tree crops, such as *A. andersoni* (= *potentillae*) on deciduous fruits in both Europe and North America (46, 56, 83); *A. eharai* and other species in the *A. largoensis* group in Japan and Australia on citrus mites (100); and *A. swirskii* on citrus in Israel (99). Type III *Neoseiulus* species with relatively short mid-dorsal setae are exemplified by *N. aurescens* and *N. cucumeris*, which are important in control of cyclamen mite on strawberry crops (99). *K. aberrans* is widely distributed in Europe, where it is important in the control of *Eotetranychus carpini* on grapes (59) but of lesser importance to *Paraseiulus soleiger* in the suppression of *Eotetranychus tiliarum* on shade trees (94). In North America, *K. aberrans* seems to be limited to hazelnut (filbert), *Corylus avellanae*, on which it may play a role in control of eriophyid mites (75). This limited range of plants in North America suggests that the European and North American populations may represent different biotypes or even different species. *Typhlodromips newsami* reaches higher numbers in citrus orchards in China in which the wild plant *Ageratum conyzoides* is encouraged, which produces pollen as alternate food for the predators (128).

In *Typhlodromus*, subgenus *Typhlodromus*, *T. pyri* is probably the most studied and widely distributed species in any agroecosystem. Investigations on apple in various parts of the world (30, 120, 148) confirm that this predator can maintain *P. ulmi* at low levels (although it is not effective if pest mite populations reach high numbers), even though it does not track prey populations well, has a medium reproductive capacity, and shows no preference for spider mite prey. Some species of *Typhlodromus* in the subgenus *Anthoseius* may play roles similar to that of *T. pyri* in deciduous fruit ecosystems. Although there has been considerably less research on *Typhlodromus caudiglans*, it may have potential comparable to that of *T. pyri* in some situations (99). Although few studies have been designed to assess the impact of phytoseiids on populations of tenuipalpid mites, *Typhlodromus doreenae* was shown to have the potential to regulate populations of tenuipalpids on grapevines in Australia (86).

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The genus *Metaseiulus*, though known only from a few studies, consists of species that are found in bark crevices, under old scale insect coverings, or under buttons of citrus fruit as much as on foliage (98), and some species are common on conifers (26, 49). No response by *Metaseiulus citri* or *Metaseiulus johnsoni* to increasing populations of *P. ulmi* or *P. citri* was noted on walnuts or oranges, respectively (98, 106). On the other hand, *Metaseiulus arboreus* was rated as a factor in suppressing mites on unsprayed apple trees in Oregon and *M. citri* on peaches in California (99). *Metaseiulus flumenis* (= *mcgregori*) showed a preference for *Bryobia rubrioculus* over *Tetranychus urticae*, but it was considered of limited importance in control of *Bryobia rubrioculus* on apple in Utah (36). Although little information is available on the genus *Paraseiulus*, one species that is probably a generalist, *P. soleiger*, was considered the most likely of the phytoseiid species present to regulate populations of *E. tiliarum* on tilia trees in urban habitats in Poland (94). *Phytoseius* species, though common on fruit trees and some other crops, rarely have been considered significant in pest mite control (e.g. 94, 99).

Although it is usually assumed that phytoseiids of Types III and IV would be of value only in conservation strategies and not in augmentation, the latter is the strategy that is successful in biological control of thrips in greenhouse-grown cucumbers and peppers with either *Neoseiulus barkeri* or *N. cucumeris*. Various studies have shown the feasibility of controlling both *Frankliniella occidentalis* and *Thrips tabaci* by releasing large numbers (inundative releases) of predators when thrips are still scarce (67, 78, 129, 130). These are among the few phytoseiids that can be reared on mites of the family Acaridae, which can be cheaply produced (130). *N. cucumeris* can be introduced to peppers even before thrips are detected, as they can multiply on pollen from the blossoms (129, 161). *I. degenerans*, which can be reared on pollen, also has shown promise for thrips control (L Tanigoshi, personal communication). Releasing low numbers of *K. aberrans* on grapevines (25 predators/vine) for control of *E. carpini* also depends on the predator increasing on other foods (54, 58, 59).

Inundative releases have not yet been shown to be feasible for spider mite control, probably because of the greater expense of rearing spider mites, compared to acarid mites, required as food for most species of predators currently used for spider mite control. Releases of *A. andersoni* were suggested as a preventive measure to halt or slow the increase of *T. urticae*, with subsequent release of *P. persimilis* if a buildup of the pest occurred that A. andersoni could not control (77). It would be informative to investigate the potential of *Euseius* species or other pollen feeders to control spider mites in greenhouses, as these can be easily reared on pollen and pollen supplements could be dusted on the greenhouse plants to increase the predator populations.

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The use of Type III species in inoculative releases has been limited. A strategy for augmenting *T. pyri* is to collect it from orchard or hedgerow "nurseries" where it is abundant and to seed it into orchards to encourage predator buildup and dispersal (121, 148).

Both cases of Type III phytoseiids that have been successfully established in another region are *Typhlodromalus* species. Both are introductions from Brazil to sub-Saharan Africa on cassava in association with *M. tanajoa* (5). *T. manihoti* has been spreading from original release sites in Ghana for five years and reductions of *M. tanajoa* are attributed to this predator. *Typhlodromalus aripo*, a more recent introduction, has spread rapidly, and reduction in pest mite populations of up to 90% has been observed (5).

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Type IV

Euseius species are among the most common phytoseiids on citrus in most regions of the world (72, 100) and several studies have indicated that they can maintain citrus red mite, *P. citri*, at low levels (100). Two *Euseius* species present the intriguing situation of a phytoseiid mite playing a role in the control of both a mite and an insect pest. *E. tularensis*, besides preying on *P. citri*, possibly is more important in biological control of citrus thrips, *Scirtothrips citri*, in California (70, 157). *Euseius addoensis* was shown to lower populations of a similar thrips, *Scirtothrips aurantii* in South Africa (73), and also to suppress populations of *P. citri* (91). A *Euseius* species and a *Typhlodromalus* species often coexist in Southern Africa, and the combination of the two may result in better thrips control than either species alone (72). *Euseius victoriensis* showed potential for maintaining two species of eriophyid mites at low levels on citrus in Australia (147), and it was reported to prevent *T. urticae* from establishing a foothold on peaches even though it was unable to complete its development on this spider mite (85). Pollen from windbreaks has been suggested to be important for building up populations of *Euseius* species (74, 100, 147). *Euseius finlandicus*, a widespread species on deciduous fruits and one of the few *Euseius* species occurring in temperate climates, can be important in control of *P. ulmi* (99).

Releasing *Euseius* species can hasten their reestablishment in an orchard where resident species have been disrupted by pesticide applications. However, such a practice would not be useful on a routine basis (70, 108, 147). It appears more promising to increase population densities of *E. tularensis* by citrus tree pruning in order to induce a cycle of new foliage, which is more favorable for the predaceous mite (71). *E. stipulatus* from the Mediterranean area, the one Type IV species successfully established in another region, displaced the native *E. hibisci* on citrus and shows potential for regulation of populations of *P. citri* in some coastal areas of southern California (103, 108).

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BROADER PERSPECTIVES

Species across the family Phytoseiidae show various degrees of specialization on spider mites as a source of food (Table 1). Species that prefer spider mites producing profuse webbing, especially the CW types, are evident in only three rather disparate genera: the Type I *Phytoseiulus* and the Type II *Galendromus* and *Neoseiulus*. *Phytoseiulus* is a highly derivative genus that has just four described species, some with a wide distribution (155). These are large, globular mites, traits seemingly not conducive to living in densely webbed colonies of spider mites, but size may have the advantage of efficient prey capture and rapid food intake for conversion to eggs (135). *Galendromus*, with only 12 described species, are of New World origin, and their known distribution is confined to that region, except for *G. occidentalis* (referred to in some European literature as *Galendromus longipilis*), which is known from Europe. We suspect that its presence there is the result of an introduction (81). Plant associations of *Galendromus* species are broad, but the majority of collections are from arboreal habitats (49). *Galendromus* is in the New World tribe Metaseiulini (23) of 54 species, most of which are probably generalists. *Galendromus* species, especially *G. annectens*, show evidence of evolving smaller size, a possible adaptation for entering small openings in webbed "nests" of some tetranychids or small sheltered areas of the leaf. *Neoseiulus* is a very large cosmopolitan genus in which only some species are specialists. Collections from low-growing plants predominate in the records over those from arboreal situations (49). However, some species with long setae occur also on trees. Possibly their specialization as predators of spider mites has allowed them to colonize a greater range of habitats. Crops on all continents seem to have at least one representative of Type I and/or Type II. This specialization probably arose independently in these groups (99). Because studies are usually limited to predators of economically important pest mites, it is probable that there are other Type I or II specialists still undiscovered. *T. bambusae* may be another species independently evolving traits to exploit a prey with a specialized behavior.

There have yet to be discovered any specialized phytoseiid predators of spider mites that do not form discrete colonies and produce little webbing, such as species in *Bryobia*, *Eutetranychus*, and *Panonychus*. Known predators of these species all seem to be generalists or pollen feeders. Nor have any phytoseiids been found that specialize on other groups of Acari, although close associations between phytoseiids and eriophyids may occur. Because few detailed studies have focused on the relationships of phytoseiids with other Acari, the possible existence of specialists on other groups should not be ignored.

Extrapolating from the species about which we have biological information—well under 100 of the more than 1600 described species (23)—it seems likely

that the majority of phytoseiids are Type III generalists. It has been hypothesized (109) that the generalist feeding habit is the ancestral state in the Phytoseiidae and that the family may have evolved with the Ascidae from a common ancestor (22) that fed on small arthropods or microorganisms in protected habitats such as bark crevices, mosses, and surface litter and subsequently radiated in foliage habitats not occupied by other Mesostigmata. Another possible scenario is that the Phytoseiidae evolved from an edaphic group into species each adapted to a certain stratum in the habitat. Some species, such as *N. cucumeris*, occupy a wider stratum than others (90).

The diversity in the Type III generalists is great. They have evolved in several different paths, and it may be possible in the future to define subtypes based on food habits. Patterns have not emerged thus far, and research directed toward that end should produce important knowledge and hypotheses. Studies to solve pest control problems have not elucidated these relationships. For example, do the large, multidentate chelicerae predominant in the worldwide genus *Amblyseius* give them some advantage in feeding on a number of different foods or on one particular type? Pollen grains and spider mite prey seem to be manipulated with comparable efficiency (63). Similar types of chelicerae have evolved independently in a few genera of the Typhlodrominae as well as some other Amblyseiinae. *Chelaseius* species have extraordinarily large digits with few teeth, the function of which is probably to handle certain kinds of prey in the surface litter habitat.

Phytoseiid specialists on small insects have not been documented, but few studies have been designed to investigate this possibility. With the exception of some generalists showing a high rate of development and oviposition on thrips, most laboratory tests have indicated comparatively low reproduction on insects such as scale crawlers, mealybugs, aphids, and whiteflies (109, 156). The degree to which conditioning or adaptation to food sources affects field populations is unknown. For example, the reproduction of *N. cucumeris* reared on *T. tabaci* increased over three generations. Because of this phenomenon and the availability of a number of foods in the field, combinations of which may increase development and reproduction rates, short-term laboratory tests on a certain food could underestimate reproductive capacity (19).

There have been few studies investigating the suitability of nematodes as prey, although one, on *A. largoensis*, showed positive effects (156). The highly distinctive *Macroseius biscutatus* has been collected exclusively in pitcher plants and was shown to complete development on nematodes and mites of the family Histiostomatidae (Anoetidae), with the former possibly as the preferred prey (119). This might represent adaptation to a specialized habitat more than to a certain kind of food. Photoseiids have been noted to feed on microorganisms such as fungus spores (107), but no close association with such

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organisms has been shown. The Type IV *Euseius* species show a marked ability for foraging for and feeding on pollen grains. This group probably evolved from a line of generalist types.

A low rate of survival and oviposition on the target pest alone does not necessarily mean lack of potential for suppression or regulation of a pest species. In fact, studies testing only one food at a time can give misleading results (103). We know little about how many different foods and the proportion of each that phytoseiids, especially those in Types III and IV, consume under field conditions and how this might change with life stage or seasonal food abundance. Such studies, though expensive and time-consuming, can yield much insight into the biology of the predators and the dynamics of the system (50).

Different species in the generalist groups may each differ slightly in the primary or alternate foods they utilize, possibly allowing for resource partitioning. Although single phytoseiid species may dominate in some stable ecosystems (4, 101), some studies have revealed that dominance may change from year to year or from place to place. Factors affecting changes in dominance include abundance of small insects (thrips, psocids), ability to prey on other phytoseiids, and survival time without food (16, 31, 39, 45). Species that utilize the same primary and alternate foods may be able to coexist by having different foraging strategies or different distributions on the plant (11), and species dominance also may differ on different crop varieties (16, 55).

Although all four types of photoseiids have the potential for suppressing prey populations, the means by which suppression occurs may differ among groups. Specialists of Types I and II tend to aggregate and multiply in prey patches and exhibit a density-dependent response to increasing prey numbers (177, 179). In contrast, generalists of Types III and IV are less likely to aggregate in prey patches, and instead they will forage more randomly and pick off wandering prey before extensive colonization occurs (103). Among the generalists, predator:prey ratios often are greater than 1.0 because the predators usually build up on some other food, such as pollen or various small arthropods (103). However, there is evidence to indicate that populations of some generalists increase markedly in response to increase in populations of spider mites that spin little webbing (83, 110).

Few studies have addressed the possibility of manipulation of two or more species of predators to enhance pest control. A *P. persimilis–N. longispinosus* (Types I and II) species combination showed better results than either alone (116). The same type of combination (*P. persimilis–N. californicus*) sometimes is used on strawberry crops, although it has not been tested experimentally (G Scriven, personal communication). Releasing two Type II species (*N. fallacis* and *G. occidentalis*) had about the same effect as either alone in a study on hops (151). Release of two Type III species (*T. pyri* and *A. aberrans*) also

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had similar results as either one alone, and one species (*A. aberrans*) became dominant in a relatively short time (54). In studies on apple, a Type II species (*G. occidentalis*) and a Type III (*T. pyri*) controlled *P. ulmi* better than releases of either species alone; when a second Type III species (*A. andersoni*) was added, regulation of *P. ulmi* occurred at a lower level in seven-year plots than where only one or two species were present (31, 41, 45).

Although there has been relatively little effort toward importation strategies (170), establishment of eight species of Phytoseiidae in other regions has been documented, and all four types of phytoseiids are represented. Can any generalizations be made from these projects and results? Given that a climatic match probably is all-important (170, 171), the prey species may be an important factor in the establishment of Types I and II. Introduction of *G. helveolus* to California in 1992 and 1993 resulted in reproduction and spread of the species in nearly all release sites infested with *O. perseae*, a recent introduction to California. Yet, few or no recoveries were made when the same species was introduced and released in the 1970s on infestations of *O. punicae* in avocado orchards in the same areas. One explanation is that *G. helveolus* was able to exploit this new prey with little competition from *E. hibisci* and some insect species, which are consistently associated with the two indigenous spider mites *O. punicae* and *E. sexmaculatus* but do not enter the nests of *O. perseae*. The establishment of *G. occidentalis* and *N. fallacis* into other areas probably has been encouraged by their resistance to pesticides. Introduction of *E. stipulatus* from the Mediterranean region to California is a case of a nonnative Type IV species replacing an indigenous one on a single crop; this indicates that *E. stipulatus* had a competitive advantage over the native *E. hibisci* on citrus, with which *E. stipulatus* may have been associated for at least 2000 years, but not on avocado, with which it had no previous association (101). The same phenomenon may apply to *T. manihoti*, *T. aripo*, and *N. idaeus*, which could have an advantage over native African species not formerly exposed to either the cassava plant or the cassava green mite.

FUTURE CONSIDERATIONS

Evolution in the Phytoseiidae has been influenced by many factors. While we have emphasized feeding specialization, several other aspects on which research has recently commenced are also important and are likely to receive more attention in the future. Our awareness of these factors comes mostly from studies of species interactions at low prey densities.

Competition is one aspect that appears to influence patterns of interspecific predation among adult females and immatures. Generalist phytoseiids feed more on other phytoseiids than specialists do (34, 38). Cannibalism is a related

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behavior that similarly conserves resources. This behavior also is more common among generalists, but some specialists also have evolved ways to exploit it. When prey levels decline rapidly, *G. occidentalis*, for example, lays all of its remaining eggs and then feeds on many of them before it disperses. Generalists like *T. pyri* or *A. andersoni* lay eggs more slowly, show less egg predation, and disperse more slowly (38).

Another factor affecting phytoseiid evolution is predation by larger phytoseiids or by macropredators, such as mites in the Anystidae, Cheyletidae, Erythraeidae, Cunaxidae, and Bdellidae, as well as insects and spiders. Some phytoseiids use domatia and other features of leaf morphology to escape detection; some use avoidance behaviors when contacted. The generalist *T. pyri* spends much time in cover on leaves, is very mobile, and shows evasive behaviors when contacted by predators (34). In contrast, adult females of the specialist *G. occidentalis* show little if any avoidance behaviors and they are easily captured and consumed even by only slightly larger phytoseiids. Have phytoseiids evolved chemical adaptations to deter predation by larger species? Chemical cues possibly play a greater role in deterring macropredation than we have perceived. Although the behaviors associated with escaping predation have not been studied extensively, it is already clear that there are large differences in strategies within the family.

A related perspective that is emerging is the diversity that is present among immature phytoseiids. Fairly recent reviews gave little attention to the topic (e.g. 139). Recent studies have shown that immature stages differ greatly in activity, food requirements, feeding habits, and tendencies for intra- and interspecific predation. Although the data are scarce, some patterns may be emerging. Specialists have immatures that seem to develop more rapidly and require less food (especially Type II species), but they are less active in intra- and inter-specific predation than immatures of generalists. Just how adaptations of immatures relate to those of adults to create a species life-style needs more study.

Other factors influencing phytoseiid evolution are human-related. As with pests, there are phytoseiids (mostly Type II specialists) that are adapted to the highly disturbed conditions created by modern agriculture. These species usually have the ability to disperse and reproduce rapidly along with an inherent tolerance of or ability to adapt rapidly to changing conditions. These are often the dominant species in agricultural systems and are the ones we have studied most in the past. In more natural ecosystems, these species are not as common. Evolution of pesticide resistance is an example of such a response. In the future, we anticipate more studies on species that are less common but are key elements in the regulation of pests at low equilibrium levels. We expect that more of these species will be found in association with IPM and sustainable agricultural methods.

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Finally, there is growing interest in phytoseiid species complexes. Often these mites occur in groups or guilds of up to ten species in stable plant ecosystems. How do these complexes of species function? Have some species evolved beneficial associations (or mutualistic) associations? We have observed one phytoseiid species feeding on a prey that was captured by another species. Benefits may come to a less common species that overwinters in aggregations of a more common species. Surely other positive or negative relationships will be identified as phytoseiid life-styles and species complexes are studied in the future.

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Review

Revision of the lifestyles of phytoseiid mites (Acari: Phytoseiidae) and implications for biological control strategies

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ABSTRACT

A new classification of lifestyles of phytoseiid mites is proposed based on the findings and suggestions from many studies conducted in the fifteen years since the publication of the lifestyle system by McMurtry & Croft (1997). In this newly proposed classification, Type I (Specialized mite predators) is divided into three subtypes to highlight mite prey specificity: subtype I-a—Specialized predators of *Tetranychus* species (Tetranychidae); subtype I-b—Specialized predators of web-nest producing mites (Tetranychidae); subtype I-c—Specialized predators of tydeoids (Tydeoidea). Type II (Selective predators of tetranychid mites) remains essentially the same. Type III (Generalist predators) is a huge and diverse group of general feeders; predators in this category are now grouped into five subtypes based on the microhabitat occupied and morphology: subtype III-a—Generalist predators living on pubescent leaves; subtype III-b—Generalist predators living on glabrous leaves; III-c—Generalist predators living in confined spaces on dicotyledonous plants; III-d—Generalist predators living in confined spaces on monocotyledonous plants; III-e—Generalist predators from soil/litter habitats. Type IV (Pollen feeding generalist predators) also remains essentially the same. Two possible additional lifestyles include phytoseiids living on aquatic plants and phytoseiids able to pierce leaf cells. Behavioral and biological information is updated and implications for biological control strategies are discussed.

Key words: Ecology, predator, feeding habit, biological control

INTRODUCTION

Phytoseiid mites are important biological control agents of other mite groups, thrips and whiteflies. They have been extensively used in biological control programs (Helle & Sabelis 1985; Lindquist *et al.* 1996; Sabelis & Van Rijn 1997; McMurtry & Croft 1997; Gerson *et al.* 2003). The general biology of these mites has been thoroughly studied. Despite being known mainly as predators of small arthropods and nematodes, most phytoseiids also have other feeding habits, consuming food items such as fungi, plant exudates, pollen, etc. Some are even able to extract liquid from leaf cells.

Although apparently all phytoseiids avoid exposure to direct sunlight, they vary in relation to their preferred substrates. Some are often found in smooth microhabitats, where they find their food sources, resting near the main leaf veins or under non-plant structures, such as webbing produced by insects, spiders or mites, or particles carried by the wind and deposited on plant parts, especially leaves and fruits. Others are favoured by non-homogeneous microhabitats, such as pubescent leaves, natural plant structures (domatia, meristematic regions) or structures produced by plants because of exogenous determining factors (galls or erinea). Still others seem to commute regularly between plant microhabitats showing those two extreme characteristics while looking for food or protection. McMurtry (2010) diagrammed hypothetical pathways of evolution of phytoseiid food habits.

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This paper presents a revision of the lifestyle system of McMurtry & Croft (1997) as well as a summary of new behavioural and biological information related to this aspect (without intending to be an all-inclusive review). It also discusses the implication of this new information on the establishment of new biological control programs involving the use of phytoseiid species.

THE MODIFIED LIFESTYLE SYSTEM

An overview of the relation between the previous (McMurtry & Croft 1997) and the newly proposed systems is shown in Table 1. One of the main differences between them refers to the relation of some species to more than one lifestyle. McMurtry & Croft (1997) had already emphasized the absence of discrete lines between types.

TABLE 1: Old and proposed new system of lifestyles of Phytoseiidae.

Old (McMurtry and Croft 1997)	Proposed New System
TYPE I—Highly specific on *Tetranychus* spp	TYPE I—Subdivided according to mite prey specificity: I-a, b, c
TYPE II—Broadly specific—tetranychids most favoured	TYPE II—Nearly the same
TYPE III—Generalists—wide range of foods acceptable	TYPE III—Subdivided according to habitat: III-a, b, c, d, e
TYPE IV—Primarily pollen feeders Generalist predators	TYPE IV—Same, but with new information

Type I is now divided into subtypes to highlight the specificity of phytoseiid assemblages to different groups of mite prey. Type II remains essentially the same as defined previously. Type III is a huge and diverse group of generalists, now divided into subtypes according to microhabitat and morphology (McMurtry & Moraes 2012). Type IV also remains basically the same as previously defined.

Type I lifestyle—Specialized mite predators

Since the first attempt to classify the phytoseiids according to their feeding habits (McMurtry & Croft 1997), the specificity of certain phytoseiid assemblages to mite prey groups other than tetranychids was pointed out by different authors. Thus, Type I lifestyle is now considered to include phytoseiids that are specialized predators of different mite groups. This led to the need to divide this lifestyle type into three subgroups.

Subtype I-a—Specialized predators of *Tetranychus* (Tetranychidae)

This subtype contains phytoseiids that have adapted to attacking spider mites producing the so-called "complicated web" (CW-u life type of Saito 1985). Until now, the examples refer to phytoseiids associated with *Tetranychus* species. However, it is possible that these predators can also be effective as control agents of spider mites of other genera, also known to produce the CW-u web type. Saito (1985) mentioned some species of *Eotetranychus* as also producing that web type.

It corresponds to the species included in the Type I lifestyle of McMurtry & Croft (1997), containing *Phytoseiulus* species. These predators could have coevolved with *Tetranychus* species, which have highly clumped distributions (see McMurtry & Croft 1997).

There is a vast literature indicating the association of *Phytoseiulus* with *Tetranychus* species under field conditions. Several new studies under laboratory conditions confirm the ability of *Phytoseiulus* to develop and reproduce when feeding on *Tetranychus* species (e.g., Pratt *et al.* 2003; Kazak 2008; Abad-Moyano *et al.* 2009). *Phytoseiulus persimilis* (Athias-Henriot), *Phytoseiulus fragariae* Denmark & Schicha and *Phytoseiulus macropilis* (Banks) are the most comprehensively studied species. The first species has been extensively used commercially for the control of pest *Tetranychus* mites, especially *Tetranychus urticae* Koch, a major pest of many crops in temperate and tropical countries, but its performance seems to be limited on solanaceous plants, apparently because of the action of trichomes present on the aerial parts of those plants (Krips *et al.* 1999; Skirvin & Fenlon 2001; Sato *et al.* 2011).

A recent laboratory study has suggested that *P. macropilis* can be an effective predator of *T. urticae* on tomato (Sato *et al.* 2011). This predator may make use of the webbing produced by *T. urticae* to avoid contact with deterring glandular trichomes of tomato leaves (Sato *et al*. 2011).

Significant efforts have been dedicated in the last decade to the determination of prospective predators of *Tetranychus evansi* (Baker & Pritchard), an actual or potential pest of solanaceous plants in African, American, Asian and European countries that produces profuse webbing (Navajas *et al*. 2013). Despite that effort, only a single species of predator, *Phytoseiulus longipes* (Evans), was found as potentially useful for the control of that pest, showing preference for *T. evansi* over *T. urticae* as prey (Furtado *et al.* 2006, 2007; Ferrero *et al.* 2007; Silva *et al.* 2010).

Subtype I-b—Specialized predators of web-nest producing mites (Tetranychidae)

This subtype contains phytoseiids that have adapted to attacking *Schizotetranychus*, *Stigmaeopsis* and some *Oligonychus* spider mites producing the so-called web-nests (WN-u life type of Saito 1985). These phytoseiids also seem to show co-evolution with their prey (Saito 1990). *Typhlodromus* (*Anthoseius*) *bambusae* (Ehara) has been considered an effective biological control agent of *Schizotetranychus celarius* (Banks) in China (Zhang *et al.* 1999). This predator apparently evolved with that prey, having the ability to penetrate its web-nests.

Subtype I-c—Specialized predators of tydeoids (Tydeoidea)

This group was suggested by C. Duso (pers. comm. with JAM, 2009). It comprises representatives of *Paraseiulus* and *Typhlodromina*. It may also contain some species of *Proprioseiopsis* (Momen 2011).

Paraseiulus talbii (Athias-Henriot) is the most extensively studied member of this group. Camporese & Duso (1995) showed that it was closely associated with tydeoid mites in Italy, and that in laboratory studies it had a higher reproductive potential on *Tydeus caudatus* (Dugès) than on other food items. Of several phytoseiid species inhabiting European vineyards, only *P. talbii* has been mentioned to feed on tydeoids (Camporese & Duso 1995). Its impact on tydeoid population densities was determined to be moderate, but apparently insufficient to maintain these mites at low population levels in vineyards (Camporese & Duso 1995).

Typhlodromina eharai Muma & Denmark is associated with *Tydeus californicus* (Banks) on avocado trees in California, USA, on which it has been observed to prey (J.A. McMurtry pers. obs.). *Proprioseiopsis cabonus* (Schicha & Elshafie) was reported by Momen (2011) in association with the tydeoids *Neoapolorryia aegyptiaca* (El-Bagoury & Momen), *Lorryia aegyptiaca* (Rasmy & El-Bagoury) and *T. caudatus* in soils of Egypt. In a laboratory study, Momen (2011) showed the ability of *P. cabonus* to feed, develop and reproduce efficiently on *N. aegyptiaca* and *L. aegyptiaca*, but not

on pollen of *Ricinus communis* or *Phoenix dactylifera*, reported to be suitable for laboratory rearing (Abou-Setta *et al.* 1997) of *Proprioseiopsis cannaensis* (Muma) and *Proprioseiopsis rotundus* (Muma). Life table parameters of a Brazilian population of *Proprioseiopsis cannaensis* were calculated by Bellini *et al.* (2010) on four different food items, including species of Eriophyidae, Tenuipalpidae and Tetranychidae, as well as *Typha angustifolia* pollen. In that paper, the authors reported difficulties in maintaining a colony of this predator on a mixture of *Typha angustifolia* pollen and all stages of the mite *Tyrophagus putrescentiae* (Schrank) (Acaridae). The results suggested that neither of those items were adequate as food sources to the predator. Laboratory studies are needed to assess the possible preference of *P. cannaensis* for tydeoids as food sources.
The suitability of tydeoids as prey for some phytoseiids has been known for a long time. Knop & Hoy (1983) reported *Homeopronematus anconai* (Baker) as an important prey to maintain the population of *Galendromus occidentalis* (Nesbitt) under field conditions, when the population of *Tetranychus pacificus* (McGregor), a major pest of grape, was low. However, *G. occidentalis* should not be included in this group, given that it is not a specific predator of *H. anconai*.

Type II lifestyle—Selective predators of tetranychid mites

This category includes selective predators of tetranychid mites, most often associated with dense web producing species, such as *Oligonychus* and *Tetranychus* species. It includes species of *Neoseiulus*, *Galendromus* and apparently, the *rickeri* group of *Typhlodromus* (*Anthoseius*). These are associated with *Tetranychus* species (CW-u life type) or species of other genera producing other types of webbing (WN-u web and WN-c life types; see McMurtry & Croft 1997). Unlike Type I species, members of Type II have a preference for a broad range of tetranychid species, but they also feed and reproduce on mites of other groups, including Eriophyidae, Tarsonemidae and Tydeoidea, and also on pollen.

It has been questioned (Croft *et al*. 1998a) whether *Neoseiulus californicus* (McGregor), one of the main phytoseiids placed by McMurtry & Croft (1997) in this group, should not be better classified as a member of Type III group. However, it is kept here in the Type II group because it is nearly always associated with tetranychids producing heavy webbing; Type III phytoseiids do not do well on mite prey of this type, often getting stuck in their webbing. *Neoseiulus californicus* shows adaptations for living in spider mite colonies with heavy webbing; it has the ability to cut strands of webbing with the chelicerae (Shimoda *et al.* 2009) and to use the front legs to tear holes in web-nests of *Oligonychus perseae* (Tuttle, Baker & Abatiello) (Montserrat *et al.* 2008).

Because of the widely known efficiency of *N. californicus* as a control agent of tetranychid mites, many new publications have dealt with different aspects of its biology, ecology and practical use to control tetranychid mites (i.e, Jolly 2000; Zalom 2002; Nancy *et al.* 2005; Pringle & Heunis 2006; Walzer *et al.* 2007; Abad-Moyano *et al*. 2009; Elmoghzy *et al.* 2011; Toldi *et al.* 2013). It has also been evaluated as a predator of *T. evansi*, with poor performance (Escudero & Ferragut 2005). *Neoseiulus californicus* has been used for the biological control of *O. perseae* in the USA (Hoddle *et al.* 1999, Hoddle *et al.* 2000), and was recommended for the control of this pest in Spain (Montserrat *et al.* 2008). This predator has also been mentioned as potentially effective for the control of *Phytonemus pallidus* (Banks) on strawberry (Easterbrook *et al.* 2001) and *Polyphagotarsonemus latus* (Banks) on pepper (Jovicich *et al.* 2008), both Tarsonemidae, and for the control of thrips on pepper (Van Baal *et al.* 2007, Rahman *et al.* 2009).

Several studies on the closely related *N. fallacis* were also conducted in recent years. This phytoseiid was reported to feed on a wide range of mite pests of ornamentals (Pratt & Croft 2000). Minimum inoculations of this species were reported to provide successful control of *T. urticae* on strawberries in the USA (Croft & Coop 1998). In field experiments, *N. fallacis* was reported to be effective in controlling *T. urticae* on *Malus* rootstocks or *Acer* shade trees, as well as *Oligonychus*

ilicis (McGregor) on *Rhododendron* (Pratt & Croft 2000). Releases of *N. fallacis* provided effective control of *T. urticae* on apple seedlings in Oregon (Croft *et al.* 2004). It was also reported as effective for management of *Schizotetranychus longus* (Saito) on bamboo in the USA (Pratt & Croft 1999). *Neoseiulus fallacis* has been reported to be able to control *P. pallidus* on strawberry (Croft *et al.* 1998b), and to develop and reproduce adequately when offered *Aculops lycopersici* as prey (Brodeur *et al.* 1997).

As observed for *N. californicus* in the American and European continents, *Neoseiulus longispinosus* (Evans) has received extensive attention in Asia, according to Nusartlert *et al.* (2010), for the control of spider mites. These authors reported its development on species of the tetranychids *Eutetranychus*, *Oligonychus* and *Tetranychus*. This range of prey includes species that web profusely and species that produce little webbing. They did not observe the development of this predator on *Oligonychus mangiferus* (Rhaman & Sapra), a species that produces little webbing. Yet, the potential of this predator to control *Oligonychus coffeae* (Nietner), a serious pest of tea plantations that also produces little webbing, was reported by Vattakandy *et al.* (2013). *Neoseiulus longispinosus* was also observed to develop and reproduce on *Eotetranychus cendanai* (Rimando), so it might be used to control this spider mite pest in greenhouses (Tongtab *et al.* 2001).Works by Zhang *et al.* (1999) showed the potential of this predator as a biological control agent of *Stigmaeopsis nanjingensis* (Ma & Yuan) on bamboo in China. *Neoseiulus longispinosus* has also been observed to feed on the tenuipalpid *Raoiella indica* (Hirst), a serious pest of coconut, especially in the Caribbean area (Carrillo *et al*. 2012).

The preference of *Neoseiulus womersleyi* (Schicha) for *Amphitetranychus viennensis* (Zacher) over *T. urticae* was reported by Furuichi *et al*. (2005). The authors attributed this difference to the more favorable web produced by the former prey. The potential of *N. womersleyi* to control the spider mite *Tetranychus macfarlanei* (Baker & Pritchard) was recently evaluated under laboratory conditions by Ali *et al.* (2011). Reduced predation of *Tetranychus kanzawai* (Kishida) by *N. womersleyi* was attributed by Oku (2008) to the presence of the yellow excreted pellets deposited by the spider mite prey on its own web.

Galendromus occidentalis was found to be effective in the control of *O. perseae*, whereas the opposite was observed for *Galendromus annectens* (DeLeon) (Hoddle *et al.* 1999). *Galendromus helveolus* (Chant) was shown to be one of the most promising predators for that purpose, as it readily entered the nests of *O. perseae* to feed on the prey (Takano-Lee & Hoddle 2002).

Some *Neoseiulus* and *Galendromus* species have been found in association with web-net producing spider mites. However, they are not specific predators of those mites, and for that reason they are placed in Type II lifestyle, rather than in subtype I-b. *Neoseiulus fallacis* has shown some potential in controlling *S. longus* in the United States (Pratt & Croft 1999), being able to successfully invade the nests of this species, at least up to ten days after the beginning of nest building process by the mite. Zhang *et al*. (1999) showed the ability of *N. longispinosus* to consume *S. nanjingensis* in short duration laboratory experiments, but the authors pointed out that this predator is rarely found on bamboo, the host plant on which *S. nanjingensis* should be controlled. *Neoseiulus cucumeris* (Oudemans) has also been shown to feed and develop when offered *S. nanjingensis* as prey under laboratory trials (Zhang *et al.* 2000). However, they are only able to enter broken web-nests. *Neoseiulus californicus* and *G. helveolus* have been reported to provide effective control of *O. perseae* (Tuttle, Baker & Abatiello), also a web-nest producing mite (Kerguelen & Hoddle 1999; Takano-Lee & Hoddle 2002).

Type III lifestyle—Generalist predators

Species in this category feed and reproduce on a wide range of prey (at least under laboratory conditions), including mites of families belonging to Astigmata such as Acaridae and Pyroglyphidae,

and Prostigmata, particularly Eriophyidae, Tarsonemidae, Tetranychidae, Tenuipalpidae and Tydeidae, as well as thrips, whiteflies, mealybugs, nematodes, etc. Many species in Type III have been shown to be able to feed and reproduce well on pollen. They can utilize plant exudates and honeydew as survival food in the absence of prey, or as complementary food, which increase their reproductive capacity when prey is present (McMurtry & Croft 1997).

In addition, several phytoseiids of this group have the ability to feed on fungi. Association or actual development and/or reproduction have been reported for the following phytoseiids on different plant pathogenic fungi: *Typhlodromus* (*Typhlodromus*) *pyri* (Scheuten) by Chant (1959), Eichhorn & Hoos (1990), Zemek & Prenerova (1997) and Pozzebon & Duso (2008); *Ricoseius loxocheles* De Leon by Flechtmann (1976) and Oliveira (2012); *Amblydromalus manihoti* (Moraes) (mentioned as *Typhlodromalus limonicus* s.l.) by Bakker & Klein (1992); and *Amblyseius andersoni* (Chant) by Pozzebon & Duso (2008). Some phytoseiids have been found to consume the microcrustacean species *Artemia franciscana* (Kelogg) (Artemiidae) as factitious food (Vangansbeke *et al.* 2013). *Amblydromalus limonicus* (Garman & McGregor) and *Amblyseius swirskii* Athias-Henriot have been reported to feed and maintain themselves on those organisms when the latter are placed on plant leaves (Audenaert *et al.* 2013).

The subsequent grouping of these mites in subtypes is based on their preferred microhabitats.

Subtype III-a—Generalist predators living on pubescent leaves

Species of *Paraphytoseius*, *Phytoseius* as well as some *Kampimodromus*, *Typhlodromalus* and *Typhlodromus* species are commonly found on pubescent leaves (leaves with trichomes). The typically small and laterally compressed idiosoma of these species apparently aids them in moving between leaf trichomes (Duso 1992; Walter 1992; Karban *et al.* 1995; Kreiter *et al.* 2002; Kreiter *et al.* 2003; Tixier *et al.* 2007). Those phytoseiids characteristically have some of the dorsal shield setae stout and usually serrate. These morphological characteristics enable those mites to colonize microhabitats not occupied by larger phytoseiids, avoiding possible competition and escaping predation by the latter (Seelman *et al*. 2007), while taking advantage of the presence of prey which also prefer the same microhabitat.

Also, the elongate gnathosoma of *Eharius* phytoseiids seems to be an adaptation to aid them in reaching the leaf surface from the trichomes of *Marrubium vulgare* foliage. *Eharius chergui* (Athias-Henriot) has been observed on this plant in the apparent absence of any prey or pollen grains, possibly piercing leaf cells (D. Mahr pers. comm.).

Trichome shapes and structures are widely variable (Metcalfe & Chalk 1979). Some authors have pointed out their deleterious effect on some phytoseiid species, whereas others have reported the opposite (Sato *et al*. 2011). While the non-glandular trichomes conceivably affect the phytoseiids and other mites physically, glandular types may also cause chemical interference with them. Walter (1996) conducted a thorough revision about the effect of different types of trichomes on mites. The author referred to several studies showing that plants with pubescent leaves had a higher diversity and density of predatory mites than plants with glabrous leaves, which was especially true for the small phytoseiid species. Different authors mentioned by Walter (1996) reported the following phytoseiids to predominate on pubescent leaves: *Euseius victoriensis* Womersley, *G. occidentalis*, *Kampimodromus aberrans* Oudemans, *Phytoseius* species, *Typhlodromus* (*Anthoseius*) *caudiglans* Schuster and *T.* (*T.*) *pyri*. As explained elsewhere in this text, the first and the second species are not classified as Type III lifestyle. *Kampimodromus aberrans* has been widely known to occur mainly on plants with pubescent leaves (Kreiter *et al.* 2002; Kabicek 2008). Kreiter *et al.* (2003) observed that leaf characteristics (trichomes, domatia) as well as pollen densities and plant species influenced greatly the occurrence and abundance of this predator. Additional supporting information has been published about the importance of *K. aberrans* as a biological control agent of spider mites on some

grape varieties in Europe, especially in France and Italy (Duso *et al.* 2009; Kreiter *et al*. 2000; Ozman-Sullivan 2006). It has also been reported from hazelnut orchards in Turkey in association with the eriophyoid mites *Phytoptus avellanae* (Nalepa) and *Cecidophyopsis vermiformis* (Nalepa) (Ozman-Sullivan 2006). In a laboratory study, these authors reported the ability of *K. aberrans* to develop and reproduce on *P. avellanae*. This predator has also been reported to prey, develop and reproduce on *Cecidophyopsis vitis* (Nalepa) (Schausberger 1992). Higher density of *T. (T.) pyri* was reported by Duso *et al.* (2003) on an apple variety with highly pubescent leaves as compared to varieties with less pubescent leaves. The preference of *Typhlodromalus aripo* De Leon for cassava varieties with pubescent tips over varieties with glabrous tips was reported by Onzo *et al.* (2012).

Many studies have been published about the association of *Phytoseius* species with tetranychid, eriophyid, tarsonemid and tenuipalpid mites (e.g., El-Laithy & Fouly 1998; Tixier *et al.* 1998; Mailloux *et al.* 2010; Vassiliou *et al.* 2012). Differently from what was reported by McMurtry & Croft (2007) in relation to the potential of species of this genus as biological control agents, a species reported as *Phytoseius finitimus* (Ribaga) was mentioned by Duso & Vettorazzo (1999) as potentially useful for the control of *Panonychus ulmi* Koch on grape. In laboratory experiments, Pappas *et al.* (2013) observed phytoseiids identified as *P. finitimus* to feed and reproduce on larvae of *T. urticae*, as well as on crawlers of the greenhouse whitefly, *Trialeurodes vaporariorum* Westwood. Populations from Iran identified as *Phytoseius plumifer* (Canestrini & Fanzago) have been mentioned as predators of tetranychid and eriophyid mites on various crops (Hajizadeh *et al.* 2002; Kodayari *et al.* 2013; Nadimi *et al.* 2009).

Subtype III-b—Generalist predators living on glabrous leaves

This is probably the most diverse subgroup. It seems to contain most of the species of large genera, e.g. *Amblyseius* and *Neoseiulus*, but also species of smaller genera, such as *Amblydromalus*. This subtype contains phytoseiids that are not particularly small.

Amblyseius swirskii has been extensively used for thrips and whitefly control in greenhouses (e.g., Bolckmans *et al.* 2005; Messelink *et al.* 2005, 2006; Kutuk *et al.* 2011). It can be mass produced at relatively low cost on acarid mites. Provision of pollen to this predator in the field may enhance its efficiency in controlling whiteflies (Nomikou *et al.* 2010; Kutuk & Yigit 2011). This predator was mentioned by van Maanen *et al.* (2010) as useful for the control of *P. latus*.

Amblydromalus limonicus is often found on the glabrous leaves of citrus and other plant species (Moraes *et al.* 1986), whereas the closely related *A. manihoti* is a common predator on cassava plants in South America (Yaninek *et al.* 1998). The latter species is found mostly on leaves of the median section of cassava plants, where leaf pubescence is less than those of the apical section (Bonato *et al*. 1999). In the last few years, *A. limonicus* has been commercialized for the control of whiteflies and thrips in protected crops, following the discovery of successful off-plant rearing on factitious prey. *Amblydromalus manihoti* was reported (as *Amblyseius limonicus* s.l.) to feed on thrips (Noronha & Cobo 1990) and whiteflies (Noronha & Moraes 1992). *Amblydromalus lailae* (Schicha) was reported as potentially useful for the biological control of thrips, *A. lycopersici* and *P. latus* in Australia (Steiner *et al.* 2003b).

Amblyseius andersoni was observed to be abundant and more effective as a predator of spider mites on grape varieties with more glabrous leaves (Camporese & Duso 1995; Duso *et al.* 2003). Studies conducted under laboratory and greenhouse conditions also indicated the potential of *Transeius montdorensis* Schicha to control *A. lycopersici*, *P. latus* and thrips (Steiner *et al.* 2003a). It can be reared exclusively on *Typha* pollen. Given the successful adoption of off-plant rearing methods using factitious prey, this predator is now produced commercially in Europe and Australia mainly for thrips and whitefly control in greenhouses.

Studies in China (Wu *et al.* 2010) have shown *Amblyseius eharai* Amitai & Swirski and *Scapulaseius newsami* Evans to be effective natural enemies of *Panonychus citri* (McGregor). The potential of the former species to control thrips has been reported by Kakimoto *et al.* (2004).

Subtype III-c—Generalist predators living in confined space on dicotyledonous plants
Examples are phytoseiids (Walter 1996) on galled leaves of willow and poplar trees. Gall-forming eriophyids are often present as possible food sources, but so are spider mites (JAM, pers. obs.). Thus, these phytoseiids are apparently distinguished by the type of microhabitat they favour, represented by the galled leaf surface, rather than by the available prey type. They are elongate but not particularly small, comprising mostly the *desertus* group of *Neoseiulus* (Prischmann *et al.* 2005). Little is known about the potential of species of the *desertus* group of *Neoseiulus* as biological control agents of gall-forming eriophyid mites on willow and poplar trees.

Domatia are structures of different constitutions always corresponding to a confined space on leaves of some plants (O´Dowd & Willson 1989; Walter 1996). They have been reported on over 2000 plant species of nearly 300 families (Brouwer & Clifford 1990). As previously mentioned, domatia favor the survival and development of several mites, including phytoseiids. Pemberton & Turner (1989) hypothesized the existence of a widespread facultative mutualism between plants with leaf domatia and beneficial mites. The following phytoseiids have been noted to occur in domatia: *Amblyseius herbicolus* (Chant), *Euseius hibisci* (Chant), *Galendromus longipilus* (Nesbitt), *Phytoseius hawaiiensis* Prasad, *Typhlodromus* (*Anthoseius*) *haramotoi* Prasad and *Typhlodromus* (*Anthoseius*) *rhenanoides* (Athias-Henriot), by Pemberton & Turner (1989); *Euseius elinae* (Schicha) and *Typhlodromus* (*Anthoseius*) *dossei* Schicha, by Walter (1992); *Iphiseius degenerans* (Berlese), by Faraji *et al.* (2002) ; *Iphiseiodes zuluagai* Denmark & Muma, by Matos *et al.* (2004) ; *Typhlodromus* (*Anthoseius*) *doreenae* Schicha, by Rowles & O´Dowd (2009).

Although several other phytoseiids have been noted to occur in domatia, it does not seem appropriate to include them as part of this subtype because they are also often found on leaves (either pubescent or glabrous) of plants that do not have domatia. Thus, it seems that they may benefit from the presence of domatia, but that domatia are not essential for them (Ferreira *et al.* 2008). For example, *I. zuluagai* is one of the common predatory mites found in domatia of coffee leaves in Brazil (Matos *et al.* 2004). However, it has also been commonly reported on the glabrous leaves of several plant species, including citrus (Albuquerque & Moraes 2008) and other plant species that do not have domatia (Moraes *et al.* 1986). Thus, we do not consider it appropriate to include this species as a member of subtype III-c.

Similarly, *T. aripo* has been reported to spend the day between the unfolded leaves within the growing tips of cassava plants (Onzo *et al.* 2005, 2009). Growing tips of cassava could be considered as a confined space (Onzo *et al*. 2005), but *T. aripo* has also been reported from leaves of several plant species (Moraes *et al*. 1986). Even on cassava, this predator is found at night wandering on the upper leaves searching for its preferred prey, *Mononychellus tanajoa* (Bondar) (Tetranychidae). Thus, here it is considered as belonging to subtype III-a, given its preference for plants with pubescent tips (Onzo *et al*. 2012). The preference of *K. aberrans* and *Neoseiulella tiliarum* (Oudemans) to inhabit pubescent domatia has been reported (Kreiter *et al.* 2000, 2003; Kabicek 2008). However, these mites are commonly found on the surface of pubescent leaves, and are for this reason classified in subtype III-a.

Subtype III-d—Generalist predators living in confined spaces on monocotyledonous plants
This includes phytoseiids adapted to living in restricted spaces on monocotyledonous plants, between leaf sheaths or between bracts and subjacent fruit surfaces. The best known case refers to phytoseiids of the *paspalivorus* group of *Neoseiulus*, including *Neoseiulus baraki* (Athias-Henriot),

Neoseiulus neobaraki (Zannou, Moraes & Oliveira) and *Neoseiulus paspalivorus* (DeLeon). These species are small, flat, elongate, and short-legged, which allows them to move into the tiny spaces between the tightly appressed bracts and the subjacent fruit surface of coconut, in search of their eriophyid prey, *Aceria guerreronis* (Keifer) (Moraes *et al.* 2004).

Considerable effort was dedicated in the last decade to the development of a program for the biological control of *A. guerreronis*, a major pest of coconut. In this regard, several studies have been conducted in tropical countries of the American, African and Asian continents to search for prospective biological control agents. *Neoseiulus baraki*, *N. paspalivorus* and *N. neobaraki* have been found in association with *A. guerreronis* (Moraes *et al.* 2004; Lawson-Balagbo *et al.* 2008; Negloh *et al.* 2008; Navia *et al.* 2013). The first two species were most common in Africa, South America and Asia, while the last was only recorded in Africa. Their ability to feed and reproduce on *A. guerreronis* has been shown in studies conducted under laboratory conditions (Lawson-Balagbo *et al.* 2007; Negloh *et al.*, 2008). They have also been reported to develop and reproduce on *T. putrescentiae*, occasionally found in the same microhabitat (Moraes *et al.* 2004; Lawson-Balagbo *et al.* 2007). *Neoseiulus paspalivorus* was also shown to develop and reproduce on *Steneotarsonemus furcatus* (De Leon) and coconut pollen (Lawson-Balagbo *et al.* 2007), whereas *N. baraki* had poor development and reproduction when fed with *Steneotarsonemus concavoscutum* Lofego & Gondim Jr. as well as coconut pollen (Negloh *et al.* 2008; Domingos *et al.* 2012). *Neoseiulus baraki* and *N. paspalivorus* were originally described from grasses, on which they were probably occupying the leaf sheaths, as suggested by the confined microhabitat they occupy on coconuts.

Subtype III-e—Generalist predator from soil/litter habitats

Some species of this group periodically move up onto low-growing plants. These correspond to a diverse assemblage of species that may have secondarily moved from the aerial to the ground habitat (McMurtry 2010). It includes many *Neoseiulus* and *Arrenoseius*, some *Amblyseius* and most *Proprioseiopsis*, *Chelaseius* and *Graminaseius* (e.g., Salamane & Patrova 2002; Amano *et al.* 2011). The last three genera could have derived from *Amblyseius*. The *Neoseiulus* probably evolved in a separate event and they do not seem to be morphologically distinguishable as a group from the arboreal species.

Two species showing this lifestyle, *Neoseiulus barkeri* (Hughes) and *N. cucumeris*, have been extensively used commercially for the biological control of pest species, especially thrips (Gerson *et al.* 2003). *Neoseiulus barkeri* has also been used for the biological control of *P. latus* in protected crops (Fan & Petitt 1994). Laboratory and greenhouse experiments conducted by Messelink *et al.* (2012) have shown this predator to be potentially useful for the control of *Steneotarsonemus laticeps* (Halbert), a serious pest of amaryllis in Europe. Its ability to control the western flower thrips, *Frankliniella occidentalis* (Pergande), has also been suggested (Fan & Petitt 1994). *Neoseiulus cucumeris* is also known to feed on *P. latus*, *P. pallidus*, *T. urticae* and fungi (Gerson *et al.* 2003; Weintraub *et al.* 2003). Both *N. barkeri* and *N. cucumeris* are commercially produced using acarid mites as prey.

Species of *Proprioseiopsis* are commonly found in the soil/litter habitats. Despite being so common in different parts of the world (Moraes *et al.* 2004), very little has been reported about the biology of mites of this group. The few papers dealing with the biology of these mites refer to their ability to consume mites found on the aerial plant parts as prey (Ball 1980; Meshkov 1996; Fouly 1997; Abou-Setta *et al.* 1997; Momen 1999, 2009; Momen & El-Borolossy 1999; Navasero & Corpuz-Raros 2005).

Type IV lifestyle—Pollen feeding generalist predators

This category contains phytoseiid predators for which pollen constitute an important part of the diet. It includes the genera *Euseius*, with nearly 212 species (Demite *et al*. 2012), *Iphiseius* and *Iphiseiodes* (Reis & Alves 1997; Villanueva & Childers 2007), with a single and a few known species, respectively. These species generally have high reproductive capacity when feeding on pollen, and population increases often follow blossoming periods of the crop or adjacent plants.

Many of these mites prefer glabrous leaves, as inferred from an analysis of the plants on which they have been found (see Moraes *et al.* 1986). However, leaves of some of these plants are covered by trichomes over certain regions. *Euseius finlandicus* (Oudemans) has been reported mainly on glabrous substrates (Tuovinen 1994; Kabicek 2005, 2008). Kabicek (2008) reported the common occurrence of this species on the glabrous regions of the leaves of *Corylus avellana*, moving to pubescent patches when disturbed, where they are more protected. This predator is known to feed on eriophyoid and tetranychid species (Schausberger 1998; Broufas & Koveos 2000; Awad *et al.* 2001). Abundance of this predator was correlated with the presence of pollen on hedgerows adjacent to vineyards in northern Italy (Duso *et al*., 2004). A positive effect of pollen was also reported by Broufas & Koveos (2000) in some fruit tree orchards. *Euseius victoriensis* has been mentioned as a remarkable predator in Australia, playing an important role in the control of eriophyids (Smith & Papacek 1991), *T. urticae* as well as of *P. latus* (James 2001).

Field observations in Saudi Arabia indicated *Euseius* species, particularly *Euseius scutalis* (Athias-Henriot), to be important as predators of tetranychid mites, scale insects and whiteflies (Nomikou *et al.* 2001; Raza *et al.* 2005). A recent study conducted by Al-Shammery (2010) showed *E. scutalis* to be a promising control agent of those pests. *Euseius hibisci* is of some importance to management of the spider mite *Oligonychus punicae* (Hirst) in avocado orchards in California (McMurtry 1985), as is *E. scutalis* of *O. perseae* in avocado orchards in Israel (Maoz *et al.* 2011). In a study conducted by Abad-Moyano *et al.* (2010) in Spain, *Euseius stipulatus* (Athias-Henriot) was found to adversely affect the establishment of *N. californicus* and *P. persimilis*, thus negatively affecting control of *T. urticae* in Spanish Clementine orchards.

Iphiseius degenerans is a common predator on cassava plants in Africa (Yaninek *et al.* 1998; Zannou *et al.* 2005). This species was reported to feed and oviposit when diet consisted of pollen, *T. urticae*, larvae of the thrips *F. occidentalis* or eggs of *Ephestia kuehniella* (Zeller) (Vantornhout *et al.* 2005). Following the determination by van Houten *et al.* (2005) of its potential as a predator of *F. occidentalis*, this predator is now commercialized for thrips control.

Iphiseiodes quadripilis (Banks) could not complete its development when fed *Phyllocoptruta oleivora* (Ashmead) under laboratory conditions, while it could complete its development and reproduce on ice plant or oak pollens, or on *Eutetranychus banksi* (McGregor) and *P. citri* (Villanueva & Childers 2007). These results corroborate previous observations indicating availability of pollen on citrus leaves to be correlated with the abundance of *I. quadripilis* (Villanueva & Childers 2004). *Iphiseiodes zuluagai* is one of the most common phytoseiids in Brazil and a few other south American countries (Demite *et al*. 2012). Independently of its preference for pollen, *I. zuluagai* has also been mentioned as an important predator of *Brevipalpus phoenicis* (Geijskes) in Brazil, and to be able to develop and reproduce when offered eggs of *T. putrescentiae* as factitious food (Albuquerque & Moraes 2008).

Some phytoseiids placed in this group have been shown to be able to pierce leaf cells. This ability will be discussed in the following section of this publication.

POSSIBLE ADDITIONAL TYPES

Two possible new groups might be proposed in the future. However, the official establishment of those groups requires further investigations.

Aquatic phytoseiids

A distinct group of phytoseiids consisting of a single species in each of the genera *Evansoseius* and *Macrocaudus* (Neoseiulini) may constitute a new type (or subtype) of lifestyle. These mites live on floating plants and have similar primitive morphological phytoseiid features, especially the presence of some setae of uncommon occurrence on the posterior half of the dorsal shield. Otherwise they share common features with other Neoseiulini, a tribe considered by Chant & McMurtry (2003) to consist of primitive Amblyseiinae. Both genera were described from South America, and neither has been reported after the original description. Nothing is known about their biology. *Macrocaudus multisetatus* Moraes, McMurtry & Mineiro has been occasionally observed from its type locality and type host plant (unpublished observation). The only obvious arthropods found in association with this species were larvae of an unidentified species of chironomid fly. Attempts to rear that phytoseiid on *T. putrescentiae*, *Typha* pollen or the nematode *Rhabditella axei* (Cobbold) (Rhabditidae) as factitious food sources have not been successful (unpublished observation).

Phytoseiids with plant cell piercing abilities

A "cross type" was suggested by Adar *et al.* (2012) to contain phytoseiids that apparently complement their nutrition requirements by feeding on leaf cells. Although evidence suggests their ability to pierce leaf cells, the primary reason for this type of behaviour is still unknown. Given that the limiting factor for any organism is usually the availability of water, it seems that leaf cell piercing may be related to water uptake (from within cell cytoplasm), the uptake of nutrients being a consequence of their presence in the imbibed liquid.

This potential group contains mostly *Euseius* mites, but also species of *Kampimodromus*, *Phytoseius*, *Typhlodromalus*, *Typhlodromus* (*Anthoseius*), *Typhlodromus* (*Typhlodromus*) and probably some *Amblydromalus*. It is expected that many of the species included in this group are also pollen feeders. However, research suggested that some pollen feeders were unable to take up liquid from at least some of the plant species on which they were found (Porres *et al.* 1975; Adar *et al.* 2012).

Uptake of plant liquid by phytoseiid mites was first reported by Chant (1959) from laboratory experiments with *E. finlandicus*, *Typhlodromus* (*Anthoseius*) *rhenanus* (Oudemans) and *T.* (*T.*) *pyri*. It was later suggested by Porres et al. (1975) and Congdon & Tanigoshi (1983) for *E. hibisci*, Congdon & Tanigoshi (1983) for *Euseius tularensis* (Congdon), Kreiter *et al*. (2002) for *K. aberrans*, Magalhães & Bakker (2002) for *T. aripo* and Nomikou *et al*. (2003) for *E. scutalis*. Field studies by Grafton-Cardwell & Ouyang (1995, 1996) also provided indications that *E. tularensis* could consume the content of citrus leaf cells. Adar *et al*. (2012) conducted a detailed evaluation of the ability of *E. scutalis* and *A. swirskii* to pierce leaf cells, determining that the former was able to extract liquid from leaf cells but that the latter was not, although it ingested free water on the surface of the substrate. Nomikou *et al.* (2003) also did not find evidence of liquid uptake from leaves by *A. swirskii*. Adar *et al*. (2012) evaluated the cheliceral morphology of several phytoseiid species, including species reported and not reported as plant piercers, concluding that plant piercing phytoseiids had movable cheliceral digit shorter than fixed cheliceral digit and the latter less curved than the non-plant piercers.

Despite the ability of some phytoseiids to take up liquid from plants, economic damage by those mites has not been reported. Feeding scars have been mentioned by Sengonca *et al*. (2004) to be

caused by *T*. (*T*.) *pyri* on apple leaves and fruits, but even in total absence of other food items, the damage caused by those mites was minor, represented by few small scars. In addition to the reduced ability of each individual to cause damage, phytoseiid populations rarely attain high levels on plants under natural conditions. High phytoseiid population densities usually only occur when food is abundant, and that circumstance is less conducive to piercing of plant cells by phytoseiids (Sengonca *et al*. 2004).

Some authors have discussed the biological importance of plant piercing by phytoseiids. Grafton-Cardwell & Ouyang (1995) reported that pruning of citrus trees resulted in higher *E. tularensis* population densities. In a subsequent paper, the same authors (Grafton-Cardwell & Ouyang 1996) observed a positive correlation between the number of eggs laid by *E. tularenis* and the concentration of fertilizer supplied to the plants. These observations do not preclude the possibility of the effect being indirect, resulting basically from the effect of better plant nutrition on the prey. Magalhães & Bakker (2002) concluded that *T. aripo* feeds in cells of cassava leaves, suggesting that this habit could increase the survival of the phytoseiid in the absence of its main food source (*M. tanajoa*) on cassava. Gnanvossou *et al*. (2005) observed that males of this species were able to complete immature development when confined on a cassava leaf disk without any prey. It has often been observed under laboratory conditions that some phytoseiid species seem unable to develop and reproduce on non-leaf substrates, as reported by McMurtry & Scriven (1965) for *E. hisbisci* and by Bakker & Klein (1992) for *A. manihoti*. However, it is not known whether they really depend on plants for their survival, or whether other unaccounted factors could be involved. Omnivory is widespread in the animal kingdom, but many predators (canines, for example) are known to directly ingest plant material only under abnormal circumstances, although plant material is often taken by consuming the guts of their prey.

CONCLUSIONS

In this work, it was decided to deviate from the system of McMurtry & Moraes (2012) dividing type I lifestyle into three subtypes. Evolution of specialization to feed on tydeoids may be common to all *Paraseiulus* but not all *Proprioseiopsis.* It may also be common to *Typhlodromina* but not enough is known for most species of this genus. It is conceivable that many other phytoseiids prey on tydeoid mites, given the very common occurrence of the latter on plants and in the soil. The lack of information in this regard is apparently due to the low economic importance attributed to those mites. Other types of specialization may be detected in the future.

The very large Type III lifestyle could not be subdivided based on food habits, as was previously hoped by McMurtry & Croft (1997); therefore, subtypes based more on microhabitat and morphology were erected. Perhaps the majority of Type III species cannot be placed in a microhabitat subtype. This seems to stem from both lack of knowledge and the diversity of microhabitats that can be occupied by many of them. Can predictions be made based on this classification of species of the lifestyle? Type III-a contains species that are small and laterally compressed and/or with long gnathosoma to reach the plant surface from above. Species with these morphological features could be predicted to be adapted to living on pubescent leaves, and this seems largely to be the case. Considerable numbers of species seem to prefer glabrous leaves, mainly on trees (subgroup III-b). Species with smooth bodies (mostly minute setae and no ornamentation of dorsal shield) such as *Amblyseius* spp. as well as *Iphiseiodes* and *Iphiseius* inhabit smooth leaves. However, mites of the latter two genera were included in this paper in Type IV lifestyle, because of their apparent preference for pollen as food items. This is a clear case of overlapping of two different groups, which is not surprising, given the fact that Type IV species constitute a special group of

generalist predator (that has pollen as preferred food). Small and flattened species (subtype III-d), all in the *Neoseiulus paspalivorus* group, could be predicted to live in small spaces on monocotyledonous plants, and this also seems to be the case. Subtype III-c is probably insufficiently known at present and studies of more species may strengthen the constitution of this group. The soil/ litter habitat (Subgroup III-e) is difficult to characterize because of its complexity and wide array of potential foods.

The most consistent group in terms of morphology is still Type IV, with the characteristic shape of small chelicerae and shape of the gnathosoma.

Despite the extensive practical use of phytoseiids for the biological control of pest species, much remains to be known about microhabitat and food preference of the vast majority of the species. Several of the genera are known only from the original description of the corresponding type species, while very little is known about species of most genera. The large number of described phytoseiid species justifies further investigations to determine new prospective species for practical use. Precise determination of the feeding habit of phytoseiid species seems highly relevant for evaluation of their potential for practical use for different purposes. In the 15 years since the review by McMurtry & Croft (1997), the biology of only about 15 additional species (eight belonging to Type III) has been studied, even though the list of described species increased from about 1600 in 1997 to about 2800 today (Demite *et al*. 2012; Prasad 2013).

For better understanding of the behaviour of each phytoseiid group, studies on the factors driving preference for different microhabitats, seem particularly relevant. Some information is already available in this regard, but much more needs to be done. Are the driving factors physical, biological, biochemical or something else? For example, the assumption of many workers that the occupation of heterogeneous microhabitats is exclusively related to protection against predation could be an oversimplification or even misinterpretation of the real factor(s) involved. Similarly, why are some species restricted to or prefer inhabiting the soil? It would also be interesting to understand why some taxonomic groups, like the Neoseiulini for example, are much more diverse than others in terms of food or microhabitat preferences. Is that because it is the most primitive and oldest tribe, as proposed by Chant & McMurtry (2003)?

Because of the considerable attention that phytoseiids have received in the last few decades, this proposed lifestyle classification must be considered as a work in progress. Two possible additional types have been mentioned in this document. While preparing this document, F. Faraji (pers. comm. with the authors, 2013) called our attention to the apparent preference of *Typhlodromus* (*Anthoseius*) *bakeri* (Garman) for tree bark. An evaluation of the substrates onto which this species has been mentioned shows a strong predominance of tree hosts, although in most cases the authors do not refer to the exact plant part from which the specimens were collected; this preference is reported however by Faraji *et al.* (2006). Discovery of other species with similar behaviour will justify the creation of a new group for these predators. The growing interest for the study of phytoseiids around the world might lead in the future to a need for further updates of the lifestyles here defined.

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