Evaluation of biological control strategies for *Polyphagotarsonemus latus* (Banks) and *Phyllocoptruta oleivora* (Ashmead) in Valencia orange

Evaluación de estrategias de control biológico de *Polyphagotarsonemus latus* (Banks) y *Phyllocoptruta oleivora* (Ashmead) en naranja Valencia

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Abstract

The damage caused by *P. latus* and *P. oleivora* mites in the orange crop Valencia (*Citrus sinensis* L.) has an economical detrimental impact due to the external damage of the fruits. To evaluate the effect of biological control agents for these two pests, this work was carried out in a commercial crop in Caicedonia, Valle del Cauca, Colombia. The experimental design consisted of a randomized complete block, in which the following treatments were evaluated: (1) release of Phytoseiidae native species: *Neoseiulus anonymus*, *Neoseiulus californicus*, *Iphiseiodes zuluagai* and *Amblyseius herbicolus* (500 individuals / tree); (2) release of *Chrysoperla carnea* larvae (100 larvae/tree); (3) exclusion of beneficial agents (localized application of cypermethrin 2 cm^3/l) and (4) farmer control (localized application of abamectin, 1.5 cm^3/l). The releases and applications of the treatments were made on marked floral clusters and fruits in the middle third of each tree. Evaluations were made weekly until harvest time. For management of *P. latus* it was found that the treatments Phytoseiidae release, *C. carnea* release and abamectin application showed the least damage; exclusion of the beneficial agents demonstrated the importance of the natural control agents on this pest. For management of *P. oleivora*, *C. carnea* release and abamectin application showed the least damage. In release treatments of Phytoseiidae native species and the exclusion of beneficial agents, *P. oleivora* caused significant damage.

Key words: Beneficial agents exclusion, *Chrysoperla carnea*, citrus mite, Phytoseiidae.

Resumen

El daño ocasionado por los ácaros *Polyphagotarsonemus latus* (Banks) y *Phyllocoptruta oleivora* (Ashmead) en el cultivo de naranja Valencia (*Citrus sinensis* L.) es reconocido tanto por el impacto económico como por el dao externo de los frutos. En este trabajo se evaluó el efecto de agentes biológicos para el control de estas plagas en un cultivo comercial de naranja Valencia en el municipio de Caicedonia, Valle del Cauca, Colombia. Se usó un diseo de bloques completos al azar para evaluar los tratamientos siguientes: (1) liberación de especies de Phytoseiidae nativos (*Neoseiulus anonymus*,*Neoseiulus californicus*, *Iphiseiodes zuluagai* y *Amblyseius herbicolus* en poblaciones de 500 individuos/árbol; (2) liberación de larvas de

Chrysoperla carnea (100 larvas/árbol); (3) aplicación localizada de cipermetrina 2 cm^3/l como tratamiento de exclusión de agentes benéficos; y (4) testigo consistente en el tratamiento utilizado por los agricultores (aplicación localizada de abamectina, 1.5 cm^3/l). Las liberaciones de las especies benéficas y las aplicaciones de los tratamientos se realizaron sobre racimos florales y frutos marcados en el tercio medio de cada árbol. Las evaluaciones de daos se realizaron cada semana hasta la cosecha. Los tratamientos de liberación de Phytoseiidae, liberación de larvas de *C. carnea* y aplicación de abamectina presentaron el menor dao de *P. latus*; el tratamiento de exclusión de benéficos demostró la importancia de los agentes controladores naturales sobre la plaga. En el manejo de P. oleivora, los tratamientos de liberación de larvas de *C. carnea* y aplicación de abamectina presentaron los mejores resultados con el menor dao en frutos. La población de *P. oleivora* ocasionó daos significativos en el tratamiento de liberación de ácaros Phytoseiidae y exclusión de benéficos.

Palabras clave: Ácaros en cítricos, *Chrysoperla carnea*, exclusión de benéficos, Phytoseiidae.

Introduction

Valencia orange (*Citrus sinensis* L.) crops in the southwestern Colombia, that includes the departments of Quindío, Risaralda, Caldas, Antioquia, Valle del Cauca and Tolima, are affected by different phytosanitary problems, within which stand the ones caused by phytophagous mites *Polyphagotarsonemus latus* (Banks) of the Tarsonemidae family known as white mite and the roast mite *Phyllocoptruta oleivora* (Ashmead) of the Eriophydae family. Both cause mummifications, stains and deformations in fruits, which directly affect production and quality, and their look (Mesa and Rodríguez, 2012).

Polyphagotarsonemus latus is one of the most important pests in the citrus crops all over the world and their damages are characterized by malformations of young leaves, reproductive buds and flowers. The mite injects toxic saliva that causes growth rolling, hardening and distortion in the terminal tissues of the plant. When populations are high, attacked leaves lean and get a copper and purple color, that can be confused with the effect of herbicides on the crop, boron deficiency or physiological disorders. Internodes shorten, floral abortion happens and plant growth is suspended. Early attacks generate bud proliferation. Severe damage happens in just formed fruits. In three to four months old fruits attacked by mites the superficial layer of the epidermis is peeled, which stays in the fruit like a silvery gray fine layer (Smith and Peña, 2002; Peña and Campbell, 2005; Rogers *et al.*, 2009).

Phyllocoptruta oleivora is known as the citrus roast mite. It is distributed in regions of America, Asia, Africa, Europe and Australia. The damage caused by this mite in the upper leaf and fruits is due to the deterioration of the epidermal cells, which results on small yellow or brown spots. Due to reduction in photosynthetic capacity of the plant, production losses could be close to 30%; however, the greatest impact by *P. oleivora* attack is observed in fruits, because the damage is produced when the mite feeds on the epidermal cells of the peel and not by oxidation of the oils contained in oily cells. These damages negatively affect the cosmetic quality of the fruit, especially when the attack is on young fruits the epidermis becomes opaque and there is a reduction in size; whereas when the infestation happens in mature fruits, the color is dark and shiny giving the look of a tan with rough and rugged texture. The damage by this mite could reach 100% of the fruit (Smith and Peña, 2002; Rogers *et al.*, 2009).

Chemical control is the most used method for mite control in citrus. Rodríguez (2012) found that 95% of the citric farmers of the Southwestern Colombia use this method as control strategy and only 5% uses cultural measurements. In this region, abamectin is the most widely product used to control species like *P. latus*, *P. oleivora* and *B. phoenicis* and in lower percentage, chlorfenapyr, pyrethroids, and growth regulators such as sulfur, mixes of soap and oils, neonicotinoids, tetronic acids and *Phaecilomyces fumosoro-*

seus (Brown and Smith) and *Beauveria bassiana* (Bals.) entomopathogenic fungi. Rogers *et al.* (2009) confirmed the intensive use of acaricides in citric crops, especially in the control of the citrus leprosis vector *B. phoenicis* and of the roast mite *P. oleivora*.

The use of Phytoseiidae mites for biological control of other mites in citrus is scarce, although the potential of some species is known acting as natural regulators of the pest mites. Brown and Jobes (1983) introduced, with positive results, *Euseius stipulates* (Athias-Henriot) to control *P. latus* in lemon crops in California, especially during spring. Peña (1990) found that the Phytoseiidae *Neoseiulus californicus* (Mc Gregor) kept the *P. latus* population under the economic damage threshold in lime (*Citrus x aurantifolia* (Christm) Swingle) fruits. *Euseius victoriensis* (Womersley) showed an effective biological control of the *P. latus* mite in citrus of Queensland, Australia and, in the Antilles (Smith and Papacek, 1985). In Colombia is known the presence Phytoseiidae species and other families of predator habits, among them *Amblyseius aerealis* (Muma) and *Amblyseius herbicolus* (Chant), *Iphiseiodes zuluagai* (Denmark and Mumma) for their abundance in citric crops (Rodríguez, 2012). The only release of Phytoseiidae in the field that is known was done in cassava crops (Mesa and Duque, 1994). These researchers released three Phytoseiidae species in order to evaluate the impact on the population of cassava green mite *Mononychellus tanajoa* (Bondar) and to determine its establishment capacity and dispersion in the crop. After evaluating for two years they found that only one of the released species was established in the crop and while its population increased, the pest mite population decreased.

This research has as objective to gain information on how to release phytoseiids and other beneficals and to know if the population level of released predators has impact on the pest mites of Valencia orange.

Materials and methods

Field experiments were done in the San Pedro farm (4° 22' 8.8" N; 75° 48' 40.8" W), in Caicedonia, Valle del Cauca (Colombia), at 1150 MASL, relative humidity of 76.4% and average temperature of 23 °C.

Phytoseiidae mite breeding

Phytoseiidae used in the releases were collected in citric crops in Caicedonia and *C. carnea* larvae were obtained from a commercial breeder.

Massive breeding of Phytoseiidae were established on a chamber 25 ± 5 °C, RH 70 ± 5% and 12 hours light). For this, the breeding methodologies described by Mesa and Rodríguez (2012) were used. For *Neoseiulus anonymus* (Chant and Baker), *N. californicus* species the substrate used was common bean leaves and as food *Tetranychus urticae* (Koch), thus this mite was breed on common bean crops. To breed *I. zuluagai* and *A. herbicolus* species it was offered *Ricinus communis* L. pollen and *T. urticae* eggs.

Experimental design

A completely randomized block design was used. The experimental unit consisted of four trees and each treatment was repeated three times. Into each experimental unit was defined as observation (sampling) unit one tree and in each one of them were labelled three floral inflorescences with buds and flowers and three fruits of 3 to 4 months of development (5-6 cm diameter). Treatments consisted in: (T1) release of Phytoseiidae predators *N. anonymus*, *N. californicus*, *I. zuluagai* and *A. herbicolus* (500 individuals/tree); (T2) release of *C. carnea* larvae (100 larvae/tree); (T3) exclusion of beneficial agents in the trees (insects and mites) with the application of cypermethrin (2 cm^3/l) and (T4) farmer control (abamectin, 1.5 cm^3/l). To evaluate the damage caused by the white mite (*P. latus*) and the impact of the different treatments, in the middle third of each tree were marked three floral branches per tree. In each one of them were released predator mites, *C. carnea* larvae or localized applications according to the treatment. Before the treatment application, a population evaluation of *P. latus* on the plant structures was done. In total, there were done three releases of Phytoseiidae and *C. carnea* and an equal number of product applications, according to the treatments. First application was done after the evaluation of the initial population, second when the fruits on the floral branches had 2 months (1-3 cm diameter) and the third one when the fruits were 4 months old (3-5 cm diameter)

For the follow up and evaluation of the damage caused by the roast mite *P. oleivora* and the impact of the different treatments three 3-4 months old fruits were labelled (3-5 cm diameter), in the middle third of each tree. In each labelled fruits were released predator mites and *C. carnea* larvae or the localized applications according to the treatment. Before applying the treatments the *P. oliveira* population in the fruits was evaluated. Two Phytoseiidae and *C. carnea* releases were done together with the same number of product applications according to the treatment. First application of the release or application treatments was done after evaluating the initial population, the second when the fruits had 6-8 months (6-7 cm diameter), which is 40% of their final size. Experiments were done in two crop cycles starting with the labelling till fruit harvesting. Damage caused by each mite species were evaluated in the labelled structures by comparison between the total area of the fruit with the damaged area caused by mites. Phenological state of the fruit was determined according to the flower and fruit stages of Valencia orange established by Rodríguez (2012). Fruits that reached maturity were harvested to register the following quality parameters: percentage of stains in the fruits, fruit color according to the Table proposed by the Technical Norm 4086 of ICONTEC (1997).

Results analysis

Data were transformed by arcsine and subjected to analysis of variance (Anova) using the statistical package SAS v. 9.2 (SAS, 2008). A mean test using the Multiple Interval of Duncan at 5% was done. Also, Pearson correlations ($P < 0.05$) with information about roast mite damage and quality parameters were performed in order to establish the relation between mite damage and internal fruit damage.

Results and discussion

Impact of the natural enemies on *P. latus* and *P. oleivora*

In both, the treatments and crop cycles evaluated there were differences ($P < 0.05$). In the first cycle, the abamectin treatment showed the best control of *P. lactus* with less damage on the surface of the fruit (18.6%), followed by the releases of *C. carnea* (23.8%) and Phytoseiidae mites (29.8%); contrarily, the greatest damage (69.5%) was registered with the treatment that included the beneficial exclusion. In the second cycle, the release of *C. carnea* showed the lower damage (26.81%); followed by Phytoseiidae releases (26.86%) and abamectin (31.55%); on a similar way to what happened in the first cycle, the greatest damage (60.33%) happened in the beneficial exclusion treatment. These results indicate that the use of Phytoseiidae and *C. carnea* can be a biologic alternative that should be considered for white mite control in citrus (Table 1).

Similarly, for *P. oleivora* there were significant differences within crop cycles and within treatments ($P < 0.05$). In the first cycle, in the abamectin treatment there were no damage caused by this mite on the fruit surface and it was found that the treatment eliminated the

Table 1. Damage percentages in Valencia orange fruits caused by phytofagous mites in two crop cycles. Southwestern region of Colombia.

Mite	First crop season				Second crop season			
	T1	T2	T3	T4	T1	T2	T3	T4
P. latus	29.8b*	23.8c	69.5a	18.6c	26.9c	26.8c	60.3a	31.6b
P. oleivora	29.2a	10.0c	20.0a	0d	23.6a	15.0b	26.3a	22.9a

T1 = Phytoseiidae mite releases, T2 = *Chrysoperla carnea* larvae releases

T3 = Exclusion of beneficial fauna; T4 = Abamectin applications

*Values for each treatment and in the same row with different letters significantly differ ($P < 0.05$) according to Duncan´s population of this phytopaghous. In the treatment with *C. carnea* larvae release there was 10.0% damage whereas for the beneficial exclusion treatment the damage was 20%. With Phytoseiidae release the highest damage on the fruit surface was caused by *P. oleivora* (29.17%). In the treatment of Phytoseiidae release it was observed that the predators, once released on the fruits, disperse quickly (Table 1) due, possibly, to the fact that they did not find a suitable place to settle, opposite of what happens in the leaves. This explains, in part, why this treatment had the greatest damage.

In the second crop cycle, the lower damage (15.0%) was presented by the *C. carnea* larvae release, followed by abamectin (2.85%) and Phytoseiidae release (23.57%); whereas the greatest damage (26.25%) was registered with the beneficial exclusion treatment, however the differences within them were not significant (P < 0.05). It was possible to observe that *C. carnea*, once released, stays on the fruits.

The largest damage caused by *P. lotus* were observed in the treatment with natural enemies exclusion, which demonstrated the importance of the beneficial agents evaluates (Phytoseiidae mites and *C. carnea*) which, although do not have a total control on the pest mite populations, they do contribute to reduce them. It is important to mention that the release treatments of *C. carnea*, Phytoseiidae releases and abamectin applications did not presented significant differences in damage reduction.

Similar results to the ones of this study were found by Smith and Papacek (1985) with *Euseius victoriensis* (Womersley) which showed an effective biological control on *P. latus* mite in citrus grown in Queensland, Australia. Brown and Jones (1983) introduced E. stipulates to control *P. latus* in lemon crops grown in California and they have favorable results, especially in spring. Peña (1990) found that *N. californicus* kept the levels of P. lotus lower than the threshold for economic damage in lime fruits. Besides all the damage caused by *P. latus*, there are other factors that generate fruit falling in the Caicedonia region, like anthracnose which is favored by the high relative humidity levels in the environment. This disease can cause 5% of fallen fruits. There is also a high percentage of natural fall that can be 74% of the fruits, meaning that only 5% achieves the harvesting age.

Fruit quality

The damage caused by *P. oleivora* on the fruits of this orange variety only affected the cosmetic quality of the fruits. These results are contrasting with the ones of Rogers *et al.* (2009) who state that besides the cosmetic damage, they also reduced quality, size, weight, water content, juice volume, soluble solids and ascorbic acid content in the fruit. According to the quality parameters (Technical Norm 4086 of ICONTEC 1997) the values corresponded to caliber E oranges.

When establishing the correlation coefficients of Pearson there were no significant relations between damage caused by *P. oliveira* and quality parameters. The correlations were very low and not significant with exterior damage (Table 2).

Table 2. Quality parameters of harvested fruits of Valencia orange that were attacked by *P. oleivora* and Pearson´s correlation coefficients between damage by *P. oleivora* and quality parameters.

Parameter	Average	Coefficient of correlation of Pearson (P < 0.05)
Weight (g)	199.0	-0.23 (0.31)
Diameter (mm)	71.1	-0.G7 /0.1‡9
Color[a]	3.2	-0.10 (0.57)
°brix	9.7	-0.29 (0.22)

[a] According to the Munshell´s table, in this case the scale value 3 corresponds to a yellow fruits with light green tones.

Conclusions

- There is diversity of species of Phytoseiidae and other natural enemies in the orange Valencia crops in Caicedonia, Colombia, which can be breed in lab conditions for their future release in the field in order to evaluate the impact on mite population that affects fruit quality.
- The treatments of Phytoseiidae and *C. carnea* larvae release resulted as efficient in the control of *P. latus* as the abamectine used by the farmers.
- The treatment of natural enemies exclusion, allowed the valuation of the importance of natural regulators in this agroecosystem.
- The abamectin treatment controlled the *P. oleivora*, while *C. carnea* had a reduced impact on the roast mite, and the released Phytoseeidae dispersed and did not practice control.
- It was established that the white mite *P. latus* causes important losses on Valencia orange production in the town of Caicedonia. Attack and damage caused by this mite in the first stages of the fruit formation causes mummification and fruit abscission. In fruits with longer development attack produced deformations and scars in the peel. In contrast *P. oliveira* causes cosmetic damage because it stains the fruit, nonetheless these fruits can be harvested.

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