UNIVERSIDAD DEL ZULIA
Serbiluz
Sistema de Servicios Bibliotecarios y de Información
Biblioteca Digital
Repositorio Académico
REVISTA de la FACULTAD de AGRONOMIA

Effect of a synthetic insecticide and a botanical on pests, natural enemies and melon productivity

Efecto de un insecticida sintético y un botánico sobre plagas, enemigos naturales y productividad del melón

Efeito de um inseticida sintético e um botânico sobre pragas, inimigos naturais e produtividade do melão

Carlos J. García-Vélez[1]
Dorys T. Chirinos[2*]
Jesús A. Centeno-Parrales[1]
Luis A. Cedeño[2]
Darlinton Pin[2]

[1]Universidad Técnica de Manabí, Instituto de Posgrado, Portoviejo, Código Postal 130150, Manabí, Ecuador.
[2]Universidad Técnica de Manabí, Facultad de Ingeniería Agronómica, Portoviejo, Código Postal 130150, Manabí, Ecuador.

Rev. Fac. Agron. (LUZ). 2023, 40(1): e234010
ISSN 2477-9407
DOI: https://doi.org/10.47280/RevFacAgron(LUZ).v40.n1.10

Crop Production
Associate editor: Professor Juan Vergara-Lopez
University of Zulia, Faculty of Agronomy
Bolivarian Republic of Venezuela

Received: 16-11-2022
Accepted: 21-02-2023
Published: 08-03-2023

Keywords:
Azadirachtin
Ecuador
Lambda-cyhalothrin
Thiamethoxam

Abstract

Melon is attacked by pests such as the whitefly, *Bemisia tabaci* (Gennadius), the cotton aphid, *Aphis gossypii* Glover, the flower thrips, *Frankliniella occidentalis* (Pergande) as well as *Diaphania* worms that can affect yield and crop productivity. To control it, frequent spraying of organo-synthetic insecticides is carried out, which can generate ecological imbalances. During two productive cycles, experimental plots were established to test the effect of an organo-synthetic insecticide and a botanical one on some pests, a natural enemy and on melon productivity. The treatments tested were, 1. Organo-synthetic insecticide: lambda-cyhalothrin + thiamethoxam. 2. Botanical insecticide: azadirachtin. 3. Untreated plot. The populations of *A. gossypii*, *B. tabaci*, *F. occidentalis*, percentage of fruits damaged by *Diaphania* spp. (% FDD), and the effect on parasitism in *B. tabaci* (% PBT), as well as on yield (t.ha^{-1}) and crop productivity. The % FDD, the populations of *A. gossypii* and *F. occidentalis* did not show differences between treatments. The yields were higher in plots treated with azadirachtin, where there were lower populations of *B. tabaci* and higher % PBT. Productivity presented a negative correlation with the populations of *B. tabaci*. Despite the control exerted by azadirachtin on *B. tabaci*, there was a decrease in productivity, which added to the damage of *Diaphania* spp. suggest the importance of these pests and for their management other alternatives should be tested that reduce populations to levels that do not affect yield and at the same time guarantee sustainable production.

*Corresponding author: dorys.chirinos@utm.edu.ec

© The Authors, 2023, Published by the Universidad del Zulia

Resumen

El melón es atacado por plagas, como, la mosca blanca, *Bemisia tabaci* (Gennadius), el pulgón del algodón, *Aphis gossypii* Glover, el trips de las flores, *Frankliniella occidentalis* (Pergande) así como gusanos del género *Diaphania* que pueden afectar el rendimiento y productividad del cultivo. Para su control se realizan frecuentes aspersiones de insecticidas órgano-sintéticos, que pueden generar desequilibrios ecológicos. Durante dos ciclos productivos, se establecieron lotes experimentales para testar el efecto de un insecticida órgano-sintético y un botánico sobre plagas, un enemigo natural y sobre la productividad del melón. Los tratamientos fueron: 1. Insecticida órgano-sintético: lambda-cihalotrina + tiametoxam. 2. Insecticida botánico: azadiractina. 3. Parcela no tratada. Se evaluaron las poblaciones de *A. gossypii*, *B. tabaci*, *F. occidentalis*, frutos dañados por *Diaphania* spp. (% FDD), y el efecto sobre el parasitismo en *B. tabaci* (% PBT), así como sobre el rendimiento y la productividad del cultivo. Las poblaciones de *A. gossypii*, de *F. occidentalis* y el % FDD no mostraron diferencias entre tratamientos. Los rendimientos fueron superiores en parcelas tratadas con azadiractina, donde ocurrieron las menores poblaciones de *B. tabaci* y los mayores % PBT. La productividad presentó una correlación negativa con las poblacionales de *B. tabaci*. A pesar del control ejercido por azadiractina sobre *B. tabaci*, hubo disminución de la productividad, lo que aunado a los daños de *Diaphania* spp. sugieren la importancia de estas plagas y para su manejo deben probarse otras alternativas que disminuyan las poblaciones a niveles que no afecten el rendimiento y a la vez garantizar una producción sostenible.

Palabras clave: azadiractina, Ecuador, lambda-cialotrina, tiametoxam.

Resumo

O melão é atacado por pragas como a mosca branca, *Bemisia tabaci* (Gennadius), pulgão do algodão, *Aphis gossypii* Glover, tripes das flores, *Frankliniella occidentalis* (Pergande), bem como vermes *Diaphania* que podem afetar o rendimento e a produtividade das culturas. Para controlá-la, são realizadas pulverizações frequentes de inseticidas organossintéticos, o que pode gerar desequilíbrios ecológicos. Durante dois ciclos produtivos, foram estabelecidos lotes experimentais em blocos ao acaso para testar o efeito de um inseticida organossintético e um botânico sobre algumas pragas, o rendimento e a produtividade do melão. Os tratamentos testados foram: 1. Inseticida organo-sintético: lambda-cialotrina + tiametoxam. 2. Inseticida botânico: azadiractina. 3. Parcela não tratada. As densidades populacionais de *A. gossypii*, *B. tabaci*, *F. occidentalis*, porcentagem de parasitismo em *B. tabaci* (% PBT), porcentagem de frutos danificados por *Diaphania* spp. (% FDD), rendimento ($t.ha^{-1}$) e produtividade da cultura. As populações de *A. gossypii*, de *F. occidentalis* e o % FDD não apresentaram diferenças entre os tratamentos. As ninfas de *B. tabaci* foram significativamente menores nas parcelas tratadas com azadiractina. A % PBT exercida por *Encarsia nigricephala* (Dozier) (Hymenoptera: Aphelinidae) foi afetada pelas pulverizações L+T. Os rendimentos foram menores nas parcelas tratadas com L+T, tratamento em que as ninfas de *B. tabaci* atingiram os maiores níveis. A produtividade apresentou correlação negativa com as densidades populacionais de *B. tabaci*, podendo diminuir para menos de 90% a partir de quatro ninfas. $folha^{-1}$. *Bemisia tabaci* e *Diaphania* spp. Eram pragas importantes e outras alternativas devem ser testadas para seu manejo, garantindo uma produção sustentável.

Palavras-chave: azadiractina, Equador, lambda-cialotrina, thiamethoxam.

Introduction

Melon, *Cucumis melo* L., belongs to the family Cucurbitaceae which includes herbaceous, annual and perennial plants with creeping and climbing stems (Wan *et al*., 2020). Its origin is attributed to tropical Africa and it is currently planted worldwide, mainly in tropical and subtropical regions, but also in temperate climates as protected crops (Abraham-Juarez *et al*., 2018; Kesh and Kaushik, 2021). Cantaloupe melon is one of the most demanded melons due to its sweet taste, juicy consistency, as well as for its nutritional value and probable health benefits (Bianchi *et al*., 2016; Rolnik and Olas, 2020).

FAO (2022) indicated that in 2020, 1,068,238 ha of melon were harvested worldwide, with a production of 28,467,920 t, while 17,928 t were obtained in Ecuador from 1,669 ha. Gabriel-Ortega *et al*. (2021) mentioned that, in that country, melon planting has increased considerably, becoming the second most produced cucurbit. On the Ecuadorian coast, 924 ha are planted (55.4 % of the national total), reaching a production of 7,549 t, mainly for domestic consumption and approximately 1 % is exported to the European market (Gabriel-Ortega *et al*., 2021). Melon production can be limited by nutrition problems, as well as diseases and pests (Abraham-Juarez *et al*., 2018). According to melon producers in some Ecuadorian provinces, the main insect pests are, whitefly (*Bemisia tabaci* Gennadius) (Hemiptera: Aleyrodidae), cotton aphid (*Aphis gossypii* Glover) (Hemiptera: Aphididae), as well as bollworms of the genus *Diaphania* (Lepidoptera: Crambidae) (Chirinos *et al*., 2020).

These pests are controlled by frequent spraying of organo-synthetic pesticides (Valarezo *et al*., 2008; Chirinos *et al*., 2020) because their use is considered the most accepted and effective control for agricultural pest damage reduction (Perez-Olvera *et al*., 2011). In some Ecuadorian provinces growing cucurbits, two to three weekly organo-synthetic insecticide sprays have been carried out (Chirinos *et al*., 2020). However, the indiscriminate use of synthetic pesticides has caused devastating attacks by some pests, which is attributed to both the emergence of resistance mechanisms in pests and ecological imbalances (Karuppuchamy and Venugopal, 2016).

To reduce the frequent use of organo-synthetic pesticides, other strategies have been considered, including the selective use of organo-synthetic pesticides according to crop phenology, as well as the use of aqueous extracts and oils derived from the neem tree (*Azadirachta indica* Juss.) (Valarezo *et al*., 2008). Since the main pests of melon are sucking pests (whiteflies, aphids, thrips), as well as Lepidoptera larvae (*Diaphania* spp.), one of the insecticides used in this crop consists of a mixture of lambda-cyhalothrin + thiamethoxam, since lambda-cyhalothrin is effective for the control of boreworms (Mohapatra *et al*., 2021), and thiamethoxam is a neonicotinoid effective against sucking insects (Kurwadkar *et al*., 2013). On the other hand, azadirachtin as a botanical insecticide has a broad spectrum of action being able to control both types of pests, but with less environmental impact compared to chemical pesticides of synthetic origin (Fernandes *et al*., 2019).

Then, evaluating the effect of a smaller number of sprays of these insecticides, organo-synthetic and botanical against sucking pests and perforating worms, if effective could be used as alternatives to the high use of pesticides. Based on the above, the objective of this research was to evaluate the effect of applications of an organo-synthetic insecticide and a botanical insecticide on some pests, a natural enemy and on melon crop productivity.

Materials and methods

The study was carried out during two production cycles, September - November, in the years 2020 and 2021 at the campus "La Teodomira", Lodana, Manabí (coordinates 01° 09' 51" S and 80° 23' 24" W, 60 m above sea level), whose life zone corresponds to a tropical dry forest. To initiate the research, a 1000 m^2 (50 x 20 m) plot of Cantaloupe melon variety Maximo® F1 hybrid was planted in each cycle, designed in randomized complete blocks with four replications and three treatments. Among the agronomic tasks, three fertilizations were made, 11, 22 and 40 days after transplanting at a dose of 60 $kg.ha^{-1}$. The first fertilization was carried out with nitrogen (40 %) and phosphorus (90 %), while in the second one potassium (60 %) was applied and in the last one nitrogen (60 %) and phosphorus (10 %) were applied again. Irrigation was carried out twice a week for 30 minutes through a drip system with 0.02 mm drippers placed at 40 cm (according to the distance between plants) with a capacity of 3 $L.h^{-1}$.

In the plot, each treatment and replicate were 3 m apart. The experimental plot measured approximately 30 m^2 and consisted of six rows of approximately 3 m long, separated by 2 m distance. The treatments included were: 1. organo-synthetic insecticide: lambda-cyhalothrin + thiamethoxam (L+T) mixture [141 $g.L^{-1}$ + 106 $g.L^{-1}$ of active ingredient (a.i.)] (dose: 300 $mL.ha^{-1}$). 2. Botanical insecticide: azadirachtin (4 $g.L^{-1}$ a.i.), (dose: 400 $mL.ha^{-1}$). 3. Untreated plot. A total of six sprays were made, which began one week after germination and were applied at weekly intervals for six weeks. Insecticide applications were made in the morning using a 20 L hand-held sprayer.

Leaf sampling for sucking pests began one week after germination and was carried out prior to each spray in the four central rows of the experimental plot to avoid edge effects between treatments, totaling ten samplings in each cycle. Five leaves were randomly selected (two young and three of the middle layer) per plot (20 for each treatment) on which the number of live and parasitized nymphs of *B. tabaci*, nymphs and adults of *A. gossypii* and the flower thrips, *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae), were counted once a week. A Carl Zeiss® stereoscope with a magnification range of 18-40 X was used for this purpose. The number of parasitized nymphs and the number of live nymphs of *B. tabaci* were used to calculate the percentage of parasitism:

$$\%\ \text{Parasitism} = \frac{\text{Parasitized nymphs}}{\text{Parasitized nymphs+live nymphs}} \times 100$$

The parasitoid of *B. tabaci* was identified using the characteristics indicated by Polaszek *et al*. (1992). Damage by *Diaphania hyalinata* L. and *Diaphania nitidalis* Stoll. on fruit was also estimated. For this purpose, during the last three weeks of the trial, five fruits were randomly selected from the two central rows per experimental plot to determine the number of perforated fruits and estimate the percentage of damage:

$$\%\ \text{of damage} = \frac{\text{Damaged fruit}}{\text{Total damaged fruit}} \times 100$$

The number of individuals of each *Diaphania* species was counted in the damaged fruits and the percentage of damaged fruits per species was calculated:

$$\begin{array}{c}\%\ \text{damaged fruit by} \\ \textit{Diaphania}\ \text{species}\end{array} = \frac{\text{Number of damaged fruit by species}}{\text{Total damaged fruit}} \times 100$$

In addition, during those three weeks, all the fruits of each experimental plot were counted and weighed with a balance, thus obtaining the yield for the four experimental plots (120 m^2) per treatment. Yields were then estimated in tons per ha for each treatment. To relate the population densities of insect pests to yield, the productivity percentage (% Productivity) of the melon crop was calculated with the formula descrited for Moura *et al*. (2018):

$$\%\ \text{Productivity} = \frac{\text{Crop yield in the field } t.h^{-1}}{\text{Potencial crop yield}} \times 100$$

The potential yield of the Cantaloupe hybrid Maximo variety, according to its technical data sheet, is 50 $t.ha^{-1}$.

Data analysis

The population densities of pests, parasitism and damage were subjected to normality tests, and some transformations were used, among these, √x+1, log(x), and did not follow a normal distribution. Because of this, they were analyzed and compared with the Kruskal-Wallis nonparametric H-test ($P<0.05$). Yield was analyzed by ANOVA and mean comparisons were performed with Tukey's test ($P<0.05$). A Spearman correlation analysis ($P<0.05$) was performed between productivity and population densities of *A. gossypii*, *B. tabaci* and *F. occidentallis*. With the pest that was detected the highest and significant negative correlation ($P<0.05$), an exponential regression analysis was run between pest population densities (X axis) and Productivity (Y axis), following what was done in other research (Moura *et al*., 2018, Costa *et al*., 2019). The analyses were performed with the statistical program Infostat (Di Rienzo *et al*., 2019).

Results and discussion

Aphis gossypii and *Frankliniella occidentalis*

The Kruskal-Wallis H-test detected no differences when comparing the number of *A. gossypii* individuals, whose densities varied from 1.8 to 3.8 $aphids.leaf^{-1}$ (table 1). Experiments carried out to establish the effectiveness in the control of *A. gossypii* showed differences in the levels of control according to the insecticides sprayed. The number of *A. gossypii* individuals ranged from 3.17 and 47.38 $aphids.leaf^{-1}$ in untreated plots of yellow melon in a field trial (Bomfim *et al*. 2015). In that experiment, populations declined to zero individuals, seven days post-application of a commercial formulation of thiamethoxam at all doses evaluated (Bomfim *et al*., 2015). Populations of *A. gossypii* decreased from 81.3 to 10.6 $individuals.leaf^{-1}$ at 336 hours post-application in plots sprayed with azadirachtin on a hydroponic cucumber (Saleem *et al*., 2019). In a field experiment conducted on cotton, *A. gossypii* populations failed to be controlled with L+T observing maximum levels of 63 $individuals.leaf^{-1}$ (Zambrano *et al*., 2021).

Table 1. Overall average number of individuals of *Frankliniella occidentalis* and *Aphis gossypii* on melon leaves under the treatments in the evaluated cycles.

Treatments	Cicle	*F. occidentalis*	*A. gossypii*
Thiamethoxam + Lambda cyhalothrin	1	13.9 ± 2.2	2.1 ± 0.8
	2	24.6 ± 4.6	1.8 ± 0.4
Azaridachtin	1	10.3 ± 3.6	2.2 ± 1.2
	2	22.5 ± 5.4	3.8 ± 0.5
Control	1	12.7 ± 5.1	3.8 ± 1.4
	2	22.7 ± 5.3	3.2 ± 1.2

Means ± standard error. Comparisons of means performed with the Kruskal-Wallis H-test ($P<0.05$). No significant differences between treatments.

In the case of *F. occidentalis*, the number of thrips ranged from 10.3 to 24.6 individuals.leaf^{-1} with no significant differences between treatments (table 1). These populations could be considered high if compared with damage thresholds of 0.36 thrips.leaf^{-1} estimated for *Frankliniella schultzei* Trybom (Thysanoptera: Thripidae) in commercial melon fields in the region of Formoso do Araguaia, Tocantins state, Brazil (Diamantino *et al*., 2021).

These results differ from what was found in a field trial conducted on cotton in Anand, India that evaluated the effectiveness of L+T on the yellow thrips, *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae); in which populations were reduced to 2.29 individuals.leaf^{-1} in treated plots, compared to the control that reached 10.99 individuals.leaf^{-1} (Padaliya *et al*., 2018). Golmohammadi and Mohammadipour (2015) detected *F. occidentalis* populations of approximately 19 thrips.flower^{-1} in plots sprayed with azadirachtin in an investigation conducted on strawberries grown under greenhouse conditions. The researchers concluded that the botanical insecticide was acceptably effective.

Bemisia tabaci

The number of *B. tabaci* nymphs followed a similar trend in the two cycles. During the first two weeks, populations remained close to zero in the experimental plots (figure 1). After the third week, populations began to increase depending on the treatment applied. In plots treated with the L+T mixture, *B. tabaci* reached peaks of 198 and 229 nymphs.leaf^{-1} for the first and second cycle, respectively. In untreated plots, maximum population levels ranged from 156 nymphs.leaf^{-1} to 81 nymphs.leaf^{-1} between the first and second cycle, while plots sprayed with azadirachtin exhibited the lowest populations (peaks of 65 and 52 nymphs.leaf^{-1}, for the first and second cycle, respectively) (figure 1), differing statistically from the L+T-based treatment (figure 1, $P<0.05$).

The observed *B. tabaci* populations show similarities and differences with those found in research on this and other crops. Bleicher *et al*. (2007) evaluated several doses of *A. indica* leaf and seed extracts and detected *B. tabaci* populations that ranged from 0.16 to 2.46 nymphs per 2.8 cm^2 leaf disk, attributing to these botanical formulations a high efficiency in the control of this phytophagous. Carvalho *et al*. (2015) observed low populations of *B. tabaci* due to the high mortality caused (<90%) by azadirachtin-based nanoformulations on greenhouse-grown tomato plants. In a field experiment on melon conducted in Lodana, Ecuador, *B. tabaci* populations ranging from 200 to 370 nymphs.cm^{-1} were detected in plots treated with azadirachtin-based aqueous extracts demonstrating the ineffectiveness of the extract (Navarrete *et al*. 2017).

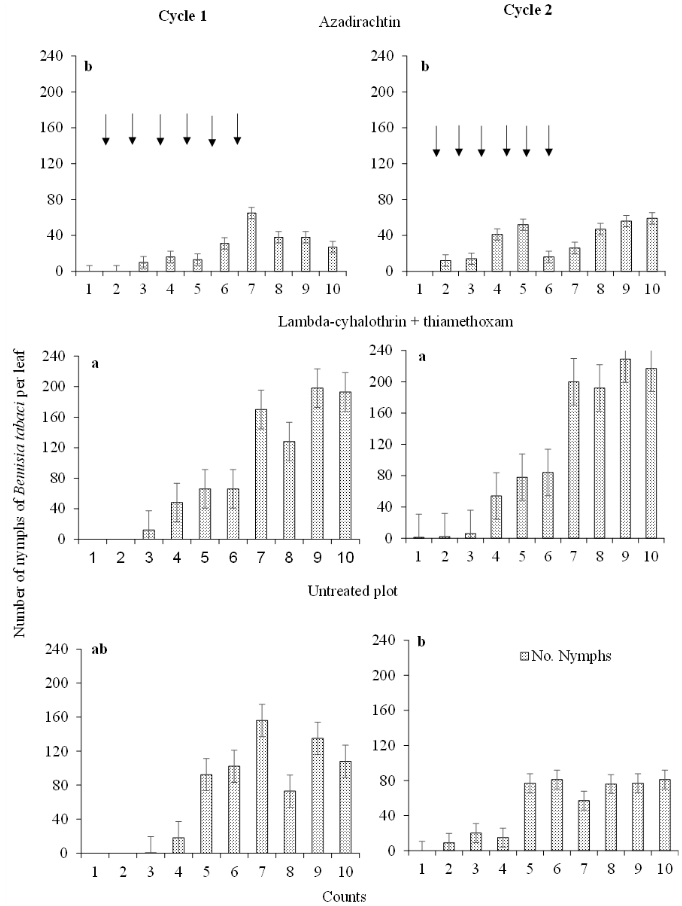

Figure 1. Number of *Bemisia tabaci* nymphs. Comparisons of means using the Kruskal-Wallis H-test ($P<0.05$). Means with equal letters in each cycle do not differ significantly. Arrows indicate dates of spraying.

Flores-Alaña *et al*. (2015) in research conducted with tomato grown in cage-umbraculum, observed that applications of azadirachtin did not reduce *B. tabaci* populations that reached up to 57 nymphs in a leaf area of 1.67 cm^2. A field trial conducted by Lasheen *et al*. (2020) on pumpkin, for the control of *B. tabaci*, showed that in plots treated with thiamethoxam and lambda-cyhalothrin there was the greatest reduction in population densities of the pest, for the 2017-2018 production cycles. Firmino *et al*. (2021) observed up to 234 nymphs.leaf^{-1} in experimental soybean plots treated with L+T showing its ineffectiveness in control.

Parasitism was lower in plots treated with L+T (table 2, $P<0.05$), suggesting that pesticide sprays affected the biological control exerted by parasitoids. Although organo-synthetic insecticides such as pyrethroids and neonicotinoids represent widely used alternatives for the control of *B. tabaci*, their frequent use could generate resistance, as well as suppression of natural enemies (Oliviera 2001, Abubakar *et al*., 2022). On the other hand, the low negative effect of azadirachtin on *B. tabaci* parasitoids has been reported (Gigo *et al*., 2021).

Encarsia nigricephala (Dozier) (Hymenoptera: Aphelinidae) was the parasitoid species detected in this study. It is an endoparasitoid that oviposits on second instar nymphs of aleyrodids (Cardona *et al*., 2005), whose diagnostic characters coincided

Table 2. Percentage of parasitism by *Encarsia nigricephala* in the evaluated cycles.

Treatments	%Parasitism Cycle 1	%Parasitism Cycle 2
Thiamethoxam + Lambda cyhalothrin	10.8[b]	7.9[b]
Azaridachtin	55.1[a]	41.6[a]
Control	56.7[a]	45.5[a]

Comparisons of means were performed with the Kruskal-Wallis H-test (P<0.05). Means with equal letters in each cycle do not differ significantly.

with those referred by Polaszek *et al*. (1992) for this species. This parasitoid was reported for Ecuador in the 1990s parasitizing nymphs of *B. tabaci* on asthma weed plants, *Euphorbia hirta* L. in Quevedo, Los Ríos province (Evans and Polaszek, 1998). It was later mentioned parasitizing whitefly species collected on cucurbits, fabaceae and solanaceae in an inventory carried out in several provinces of the Ecuadorian highlands and coast (Valarezo *et al*., 2008).

Yield, productivity and population densities

In the plots treated with azadirachtin, higher yields were obtained, as well as higher weights and numbers of fruits in both cycles, differing from those obtained in the plots treated with L+T (table 3), which coincides with the lower populations of *B. tabaci* (Figure 1). In addition, in the second cycle, no significant differences were observed between plots treated with azadirachtin and those untreated (table 3).

Table 3. Estimated yield ($t.ha^{-1}$) for the different treatments in the evaluated cycles.

Variable	Cycle	Thiamethoxam + Lambda cyhalothrin	Azaridachtin	Untreated plot
Fruit weight (g)	1	948	960	950
	2	920	969	954
Fruits.120 m^{-2}	1	340	385	366
	2	325	457	397
$t.ha^{-1}$	1	26.86[b]	31.09[a]	28.98[ab]
	2	24.92[b]	36.56[a]	31.56[a]

Means with the same letter in the line did not differ significantly. Comparisons of means performed with Tukey's test (P<0.05).

Spearman's correlation analysis showed a negative and highly significant association between productivity and *B. tabaci* nymph densities, but did not detect a correlation between productivity and population densities of *A. gossypii* and *F. occidentallis* (table 4). This would indicate that, in part, crop productivity could be a function of *B. tabaci* population densities.

Table 4. Spearman correlation analysis (P<0.05) between productivity and populations of three melon sucking insect pests.

	Aphis gossypii	*Bemisia tabaci*	*Frankliniella occidentallis*
% Productivity	r: -0.67	r: -0.89	r: 0.14
	P-value: 0.14	P-value: 0.05	P-value: 0.85

Regression analysis between *B. tabaci* (X-axis) and productivity (Y-axis) suggests that productivity decreases as *B. tabaci* nymph densities increase, which is corroborated by the high and significant R^2 value of the calculated exponential equation. Figure 2 shows that at 20 nymphs.leaf^{-1}, productivity drops to 80 % of crop potential. Furthermore, with four nymphs.leaf^{-1}, productivity reaches 88 % of its potential. Espinel *et al*. (2008) established a threshold of three nymphs.leaf^{-1}, due to the severe damage caused by this stage of development. Based on *B. tabaci* adults collected in commercial melon fields, Costa *et al*. (2019) estimated that 11 adults feeding on leaves at the reproductive stage could drastically decrease crop productivity, decreasing to 45 % of its potential. In the present investigation, average yields were decreased in a range from 49.8 % (L+T-treated plots) to 73.1 % (azadirachtin-treated plots), which coincided with those plots where higher and lower densities of *B. tabaci* nymphs were observed, respectively.

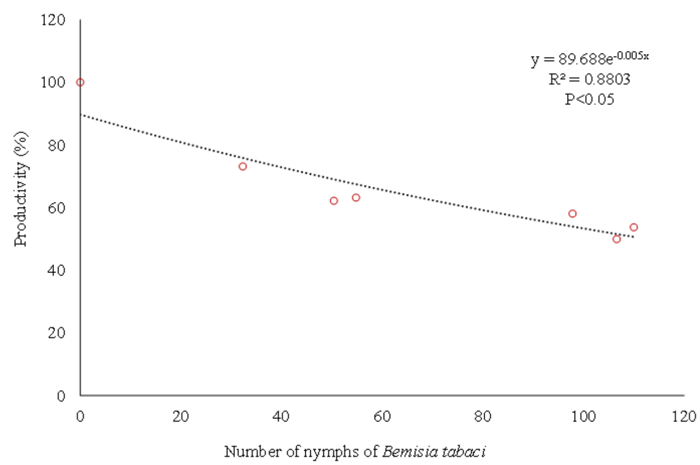

Figure 2. Average population densities of *Bemisia tabaci* nymphs (X axis) and productivity (Y axis).

Fruits damaged by *Diaphania* spp.

D. nitidalis was found in 88.8 % of the drilled fruits, and in the rest *D. hyalinata* (11.2 %), differences are due to feeding habits; while *D. hyalinata* feeds on the foliage and occasionally attacks the fruit, *D. nitidalis* is a fruit boring worm exclusively in the cucurbit family (Everatt *et al*., 2015). The percentage of damaged fruit showed no differences among treatments (table 5). In plots sprayed with L+T, damage ranged from 3.5 to 4.8 % while in plots treated with azadirachtin it reached percentages ranging from 7.7 to 8.8 % (table 5).

Table 5. Damaged fruit (%) by *Diaphania* spp. in the different treatments.

	%Fruits Damaged	
Treatments	Cycle 1	Cycle 2
Thiamethoxam + Lambda cyhalothrin	3.5	4.8
Azaridachtin	7.7	8.8
Untreated plot	13.9	8.2

Azadirachtin applications failed to reduce the damage caused by *Diaphania indica* (Saunders) on bitter gourd (*Momordica charantia* L.) reaching up to 16.57 % of damaged fruits (Nagaraju *et al*., 2018) which is like what was obtained in this research. Field trials evaluating various insecticide treatments conducted during the 2009 and 2010 production cycles of gherkin (*Cucumis anguria* L.) showed 16.8 and 17.7 % damaged fruits, respectively, when lambda-cyhalothrin was applied which was lower than approximately 36 % fruit damage in untreated plots (Balikai and Mallapur, 2017).

Conclusions

During the evaluated production cycles, the lowest populations of *B. tabaci* were observed in plots treated with azadirachtin. *Encarsia nigricephala* was the parasitoid species detected attacking *B. tabaci* nymphs whose parasitism percentages were decreased with the use of lambda-cyhalothrin + thiamethoxan.

The treatments applied showed no differences in the reduction of *Diaphania* spp. damage, as well as aphid and thrips populations in the melon crop. Yields were significantly higher in plots treated with azaridactin, associated with lower populations of *B. tabaci*. Despite the control exerted by azadirachtin on *B. tabaci*, there was a decrease in productivity, which together with the damage caused by *Diaphania* spp. suggests the importance of these pests, and other alternatives for their management should be tested to reduce populations to levels that do not affect yields and at the same time guarantee sustainable production.

Literature cited

Abubakar, M., Koul, B., Chandrashekar, K., Raut, A., & Yadav, D. (2022). Whitefly (*Bemisia tabaci*) Management (WFM) Strategies for Sustainable Agriculture: A Review. *Agriculture*, *12*(9), 1317. https://doi.org/10.3390/agriculture12091317

Abraham-Juárez, M. R., Espitia-Vázquez, I., Guzmán-Mendoza, R., Olalde-Portugal, V., Ruiz-Aguilar, G. M. L., García-Hernández, J. L., Herrera-Isidrón, L., & Núñez-Palenius, H. G. (2018). Development, yield, and quality of melon fruit (*Cucumis melo* L.) inoculated with mexican native strains of *Bacillus subtilis* (Ehrenberg). *Agrociencia*, *52*(1), 92–102. https://www.scielo.org.mx/scielo.php?pid=S1405-31952018000100091&script=sci_arttext&tlng=en

Balikai, R. A., & Mallapur, C. P. (2017). Bio-efficacy of flubendiamide 480 SC (Fame 480 SC) against fruit borer in Gherkin. *International Journal of Horticulture*, *7*(28), 250–261. https://doi.org/10.5376/ijh.2017.07.0028

Bianchi, T., Guerrero, L., Gratacós-Cubarsí, M., Claret, A., Argyris, J., Garcia-Mas, J., & Hortós, M. (2016). Textural properties of different melon (*Cucumis melo* L.) fruit types: Sensory and physical-chemical evaluation. *Scientia Horticulturae*, *201*, 46–56. https://doi.org/10.1016/j.scienta.2016.01.028

Bleicher, E., Gonçalves, M. E. de C., & Silva, L. D. da. (2007). Efeito de derivados de nim aplicados por pulverização sobre a mosca-branca em meloeiro. *Horticultura Brasileira*, *25*(1), 110–113. https://doi.org/10.1590/s0102-05362007000100022

Bomfim, G. V. do, Azevedo, B. M. de, Viana, T. V. de A., Manzano, J., & Vasconcelos, D. V. (2015). Methods of application and dosages of insecticides for *Aphis gossypii* (Glover) (Hemiptera: Aphididae) in the yellow melon. *Revista Ciência Agronômica*, *46*(3), 488–496. https://doi.org/10.5935/1806-6690.20150030

Cardona, C., Rodriguez, I. V., Bueno, J. M., & Tapia, X. (2005). *Biología y manejo de la mosca blanca Trialeurodes vaporariorum en habichuela y frijol césar*. CIAT.

Carvalho, S. S., Vendramim, J. D., De Sá, I. C. G., Da Silva, M. F. D. G. F., Ribeiro, L. D. P., & Forim, M. R. (2015). Efeito inseticida sistêmico de nanoformulações à base de nim sobre *Bemisia tabaci* (Hemiptera: Aleyrodidae) biótipo B em tomateiro. *Bragantia*, *74*(3), 298–306. https://doi.org/10.1590/1678-4499.0404

Chirinos, D. T., Castro, R., Cun, J., Castro, J., Peñarrieta Bravo, S., Solis, L., & Geraud-Pouey, F. (2020). Los insecticidas y el control de plagas agrícolas: la magnitud de su uso en cultivos de algunas provincias de Ecuador. *Revista Ciencia & Tecnología Agropecuaria*, *21*(1), 1–16. https://doi.org/10.21930/rcta.vol21_num1_art:1276

Costa, T. L., Sarmento, R. A., Araújo, T. A. d., Pereira, P. S., Silva, R. S., Lopes, M. C., & Picanço, M. C. (2019). Economic injury levels and sequential sampling plans for *Bemisia tabaci* (Hemiptera: Aleyrodidae) biotype B on open-field melon crops. *Crop Protection*, *125*, 104887. https://doi.org/10.1016/j.cropro.2019.104887

De Moura, M. F., Lopes, M. C., Pereira, R. R., Parish, J. B., Chediak, M., Arcanjo, P. L., Carmo, D. G., & Picanço, M. C. (2018). Sequential sampling plans and economic injury levels for *Empoasca kraemeri* on common bean crops at different technological level. *Pest Management Science*, *74*(2), 398–405. https://doi.org/10.1002/ps.4720

Diamantino, M. L., Ramos, R. S., de Almeida Sarmento, R., Pereira, P. S., & Picanço, M. C. (2021). Decision-making system for the management of *Frankliniella schultzei* thrips in commercial melon fields. *Crop Protection*, 105346. doi:10.1016/j.cropro.2020.105346

Di Rienzo, J. A., Casanoves, F., Balzarini, M. G., Gonzalez, L., Tablada, M., & Robledo, C. W. (2019). *InfoStat versión 2019. Centro de Transferencia InfoStat, FCA*. http://www.infostat.com.ar

Espinel, C., Lozano, M. D., Villamizar, L., Grijalba, E., & Cotes, A. M. (2008). Estrategia MIP para el control de *Bemisia tabaci* (Hemiptera: Aleyrodidae) en melón y tomate. *Revista Colombiana de Entomologia*, *34*(2), 163–168. https://doi.org/10.25100/socolen.v34i2.9281

Evans, G.A. & Polaszek, A. 1998. The *Encarsia cubensis* species-group (Hymenoptera: Aphelinidae). *Proceedings of the Entomological Society of Washington*, *100*(2), 222-233.

Everatt, M., Korycinska, A., & Malumphy, C. (2015). Cucurbit moths *Diaphania* species. https://planthealthportal.defra.gov.uk/assets/factsheets/diaphania-indica-nitidalis-hyalinata.pdf 23.06.2022

FAO. (2022). *Food and agriculture data*. Datos Sobre Alimentación y Agricultura. http://www.fao.org/faostat/en/#data/QC

Fernandes, S. R., Barreiros, L., Oliveira, R. F., Cruz, A., Prudêncio, C., Oliveira, A. I., Pinhoa, C., Santos, N. & Morgado, J. (2019). Chemistry, bioactivities, extraction and analysis of azadirachtin: State-of-the-art. *Fitoterapia*, *134*, 141-150. https://recipp.ipp.pt/bitstream/10400.22/13849/1/ART_SaraFernandes_2019.pdf

Firmino, J. L., Martins, G. L. M., & Tomquelski, G. V. (2021). Eficiência de inseticidas no controle de *Bemisia tabaci* Biótipo B na cultura da soja na região dos Chapadões. *Ciências Multidisciplinares*, *1*(1), 46–58. https://www.researchgate.net/publication/352767267_Eficiencia_de_inseticidas_no_controle_de_Bemisia_tabaci_Biotipo_B_na_cultura_da_soja_na_regiao_dos_Chapadoes

Flores-Alaña, L., Geraud-Pouey, F., Chirinos, D. T., & Meléndez-Ramírez, L. (2015). Efectividad de algunos insecticidas para el control de *Bemisia tabaci* (Gennadius) en tomate, *Solanum lycopersicum* L. *Interciencia*, *40*(2), 121–126. https://www.redalyc.org/pdf/339/33934014005.pdf

Gabriel-Ortega, J., Burgos-López, G., Barahona-Cajape, N., Castro-Piguave, C., Vera-Tumbaco, M., & Morán-Morán, J. (2021). Obtención de semilla híbrida de melón (*Cucumis melo* L.) en invernadero. *Journal of the Selva Andina Research Society*, *12*(1), 38–51. https://doi.org/10.36610/j.jsars.2021.120100038

Gogi, M. D., Syed, A. H., Atta, B., Sufyan, M., Arif, M. J., Arshad, M., Khan, M. A., Mukhtar, A. & Liburd, O. E. (2021). Efficacy of biorational insecticides against *Bemisia tabaci* (Genn.) and their selectivity for its parasitoid *Encarsia formosa* Gahan on Bt cotton. *Scientific Reports*, *11*(1), 1-12. https://www.nature.com/articles/s41598-021-81585-x

Golmohammadi, G., & Mohammadipour, A. (2015). Efficacy of herbal extracts and synthetic compounds against strawberry thrips, *Frankliniella occidentalis* (Pergande) under greenhouse conditions. *Journal of Entomology and Zoology Studies*, *3*(4), 42–44. https://www.entomoljournal.com/vol3Issue4/pdf/3-3-113.1.pdf

Karuppuchamy, P., & Venugopal, S. (2016). Integrated Pest Management. In Omkar (Ed.), *Ecofriendly Pest Management for Food Security* (pp. 651–684). Elsevier B.V. https://doi.org/10.1016/B978-0-12-803265-7.00021-X

Kesh, H., & Kaushik, P. (2021). Advances in melon (*Cucumis melo* L.) breeding: An update. *Scientia Horticulturae*, *282*(February), 110045. https://doi.org/10.1016/j.scienta.2021.110045

Kurwadkar, S. T., Dewinne, D., Wheat, R., McGahan, D. G., & Mitchell, F. L. (2013). Time dependent sorption behavior of dinotefuran, imidacloprid and thiamethoxam. *Journal of Environmental Science and Health*, Part B, *48*(4), 237-242. https://doi.org/10.1080/03601234.2013.742412

Lasheen, S. G., Sherif, R. M., Youssif, M. A. I., & Sallem, H. M. (2020). Effectiveness of some insecticides against *Bemisia tabaci* (Genn) infesting squash plants. *Zagazig Journal of Agricultural Research*, *47*(1), 79–86. https://doi.org/10.21608/zjar.2020.70122

Moura, M. F., Lopes, M. C., Pereira, R.R., Parish, J.B., Chediak, M., Arcanjo, P.L., Carmo, D.G., & Picanço, M.C. (2018). Sequential sampling plans and economic injury levels for *Empoasca kraemeri* on common bean crops at different technological level. *Pest Management Science*, *74*(2), 398–405. https://doi.org/10.1002/ps.4720

Mohapatra, S., Siddamallaiah, L., & Matadha, N. Y. (2021). Behavior of acetamiprid, azoxystrobin, pyraclostrobin, and lambda-cyhalothrin in/on pomegranate tissues. *Environmental Science and Pollution Research*, *28*(2), 27481–27492. https://doi.org/10.1007/s11356-021-12490-z

Nagaraju, M., Nadagouda, S., Hosamani, A., & Hurali, S. (2018). Field evaluation of insecticides for the management of cucumber moth , *Diaphania indica* (Saunders) (Lepidoptera: Crambidae) on bitter gourd. *Journal of Entomology and Zoology Studies Materials*, *6*(2), 79–82. https://www.entomoljournal.com/archives/2018/vol6issue2/PartB/6-1-158-672.pdf

Navarrete, B., Valarezo, O., Cañarte, E., & Solórzano, R. (2017). Efecto del nim (*Azadirachta indica* Juss.) sobre *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae) y controladores biológicos en el cultivo del melón *Cucumis melo* L. *La Granja: Revista de Ciencias de La Vida*, *25*(1), 33–44. https://doi.org/10.17163/lgr.n25.2017.03

Oliveira, M. R. V., Henneberry, T. E., & Anderson, P. (2001). History, current status, and collaborative research projects for Bemisia tabaci. *Crop protection*, *20*(9), 709-723. https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1357&context=usdaarsfacpub

Padaliya, S. R., Thumar, R. K., Borad, M. G., & Patel, N. K. (2018). Bio-efficacy of different ready-mix insecticides against thrips, *Scirtothrips dorsalis* Hood infesting Bt Cotton. *International Journal of Current Microbiology and Applied Sciences*, *7*(7), 2904–2915. https://doi.org/10.20546/ijcmas.2018.707.340

Perez-Olvera, M. A., Navarro-Garza, H., & Miranda-Cruz, E. (2011). Use of pesticides for vegetable crops in Mexico. In M. Stoytcheva (Ed.), *Pesticides in the Modern World - Pesticides Use and Management* (pp. 97–118). Open Intech. https://doi.org/10.5772/18510

Polaszek, A., Evans, G. A., & Bennett, F. D. (1992). *Encarsia* parasitoids of *Bemisia tabaci* (Hymenoptera: Aphelinidae, Homoptera: Aleyrodidae): A preliminary guide to identification. *Bulletin of Entomological Research*, *82*(3), 375–392. https://doi.org/10.1017/S0007485300041171

Rolnik, A., & Olas, B. (2020). Vegetables from the Cucurbitaceae family and their products: Positive effect on human health. *Nutrition*, *78*, 110788. https://doi.org/10.1016/j.nut.2020.110788

Saleem, M. S., Batool, T. S., Akbar, M. F., Raza, S., & Shahzad, S. (2019). Efficiency of botanical pesticides against some pests infesting hydroponic cucumber, cultivated under greenhouse conditions. *Egyptian Journal of Biological Pest Control*, *29*(37), 1–7. https://doi.org/10.1186/s41938-019-0138-4

Valarezo, O., Cañarte, E., Navarrete, B., Guerrero, J., & Arias, B. (2008). Diagnóstico de la “mosca blanca” en Ecuador. *La Granja: Revista de Ciencias de La Vida*, *7*(1), 13–20. https://doi.org/10.17163/lgr.n7.2008.03

Wan, W. N. S. S., Ablah, N. L., Nur, H. N., Alam, A., Ma’Arup, R., Jahan, M., Mustafa, K. A., & Alias, N. (2020). Breeding strategies for enhancing nutrient content and quality in Cucurbitaceae: a review. *International Journal of Vegetable Science*, . https://doi.org/10.1080/19315260.2020.1833125

Zambrano, N. D., Arteaga, W., Velasquez, J., & Chirinos, D. T. (2021). Side effects of Lambda Cyhalothrin and Thiamethoxam on insect pests and atural enemies associated with cotton. *Sarhad Journal of Agriculture*, *37*(4), 1098–1106. https://doi.org/10.17582/journal.sja/2021/37.4.1098.1106