Article

Residual effectiveness of insecticides in *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) in tomato cultivation

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Abstract

Bemisia tabaci (Genn.) is one of the main pests in the cultivation of tomato (*Solanum lycopersicum* L.), which transmits phytopathogenic viruses responsible for severe physiological damage and loss of profitability of the crop. The protection of the plant against viral vectors in the first weeks after transplantation is essential to ensure production. The experiment was conducted in a greenhouse and repeated twice; tomato seedlings of the Río Grande cultivar were used to evaluate the residual effectiveness of five synthetic, four botanical insecticides and one mineral oil. The density of *B. tabaci* eggs and the percentage of effectiveness at 0, 5 and 10 days after the application (DAA) with insecticides were evaluated. The organo-synthetic treatment with the best effectiveness was Sivanto® Prime (Flupyradifurone) in foliar applications and in the soil; within the natural products, the best treatment was PHC® Neem® (Azadirachtin) in foliar applications; both showed effectiveness of 99.96-88.47% and 65.87-43.5%, respectively, at 0, 5 and 10 DAA in the two trials. Information on the residuality and effectiveness of the insecticides evaluated will contribute to complement the optimal management of *B. tabaci*.

Keywords: *Bemisia tabaci*, *Solanum lycopersicum*, insecticides synthetic, organic.

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Introduction

The whitefly *Bemisia tabaci* (Gennadius, 1889) Hemiptera: Aleyrodidae represents a complex of species recognized as extremely invasive, it is one of the most devastating horticultural pests worldwide. *Bemisia tabaci* exhibits high genetic diversity within the complex of polyphagous species. They are known as vectors of many plant viruses, with begomoviruses being the main group of viruses associated with the whitefly (Navas *et al*., 2011). Only species of the *B. tabaco* complex are capable to transmit them persistently (Ghanim, 2014). Most of the information on transmission is based on the interaction of the begomovirus called tomato yellow leaf curl virus (TYLCV) and *B. tabaci* Middle East-Asia Minor 1 (MEAM1, formerly known as biotype B). It is believed that, in general, the interactions of different begomoviruses and different species of *B. tobacco* follow a similar pattern (Rosen *et al*., 2015).

In Mexico, tomato (*Solanum lycopersicum* L.) is the vegetable with the highest production volume, 1 180 586 t, and is the second most cultivated in the world, due to the great importance in human food and for having the highest levels of profitability in the agricultural field (Bautista *et al*., 2010; SIAP, 2016). This crop is attacked by pests, such as whitefly (*Bemisia tabaci* Genn.), which causes physiological problems when feeding on the sap of plants and for being a vector of viruses, which cause the damages of greatest economic impact (Fang *et al*., 2013), specifically of the begomoviruses (Family Geminiviridae) detected in this nightshade in Mexico (Lugo *et al*., 2011).

Currently, *B. tabaci* is widely distributed in world agriculture, with more than 600 hosts. Some hosts with important crops that are exposed to the intensive use of insecticides against this pest, which has the ability to rapidly develop resistance to organophosphate, carbamate, growth regulators, chlorinated hydrocarbon and pyrethroid insecticides (Caballero *et al*., 2013; Xie *et al*., 2014). The problem increases when contact and high toxicity insecticides are used, which cause the decrease of natural enemies; in addition, they only reduce adult populations of *B. tabaci*, but do not affect immature intars found on the underside of the leaves.

Rotation with products of different modes of action mitigates the evolution of insecticide resistance (Sparks *et al*., 2020). The application of plant extracts and mineral oils have an insecticidal, insectistatic effect repellent of insect pests, resulting in a lower impact on the beneficial fauna and can be elaborated by the producer (Molina, 2001).

A relevant diagnosis and protection of the crop against viral vectors in the first weeks after transplantation is of vital importance. The study was conducted with the aim of evaluating the residual effectiveness of five synthetic, four botanical insecticides and one mineral oil in tomato seedlings infested with whiteflies at different days after treatment.

Materials and methods

The research was carried out in a greenhouse of the Chapingo Autonomous University (UACH, for its acronym in Spanish). Two factors were evaluated: 1) insecticide treatments; and 2) period of whitefly infestation in seedlings at 0, 5 and 10 days after application (DAA). Eleven treatments and a control were used (Table 1), which were distributed in a randomized complete block design with three repetitions, generating 36 experimental units in each infestation period, the experimental unit was an entomological cage of 30×30×50 cm (length-width-height), with three tomato seedlings of the Río Grande cultivar (35 days old) in a 0.5 L expanded polystyrene container. The experiment was repeated twice, on February 16, 2017, and June 10, 2017.

The nymphs and adults of *B. tabaci* that were used in the trials were collected by systematic sampling in transect W in a tomato culture in the experimental field of the Superior Agricultural College of the State of Guerrero. The nymphs of *B. tabaci* of the fourth instar (‘pupa’, eyes visible through the integument) were obtained from five infested leaves. The adults of the insect were captured with an entomological sucker. The two intars were transferred to a cage-shadehouse of 1.8×1.5×2 m (length-width-height), where they were reared and reproduced for 60 days in a glass greenhouse at the UACH.

Seeds of the Río Grande tomato cultivar were sown in substrate with bokashi in speedling trays and kept inside the laboratory to avoid contamination with pests and diseases. The tomato seedlings used for the two study phases were transplanted into expanded polystyrene containers with a capacity of 0.5 kg of clay soil 30 days after emergence.

The 11 insecticide treatments and one control (Table 1) were applied when the tomato seedlings had four true leaves (35 days old). A non-ionic coadjuvant was used, which has surfactant, wetting, dispersant and penetrating action, is a reducer of the surface tension of water, based on the technology of organosiloxane compounds modified to be used in mixtures of pesticide products and foliar fertilizers that are applied with water (Break Thru®) in the mixtures of each treatment, at doses of 0.3 ml L^{-1}.

Low doses recommended by manufacturers for insecticide application were used. An untreated control treatment was included per infestation period. The application of the products was carried out with a Truper manual sprinkler considering an expense of 250 L ha^{-1}, up to dripping point and for injection applications in the neck of the plant, the expense was 1 000 L ha^{-1}. The three pots of each experimental unit were placed inside an organza-covered entomological cage with a 400-micron mesh opening, with access at the top and supported by a 20×20×40 cm (length-width-high) metal frame. The infestation was carried out with adults, of unknown age and without sexing. In each cage and for each period (0, 5 and 10 DAA), 20 *B. tabaci* adults were introduced. A total of 4 320 specimens of *B. tabaci* were used for the two trials. Irrigation was carried out according to the need of the plants and they were kept in a greenhouse at an average of 29 °C, 70% relative humidity, with natural photoperiod (light/dark).

The variables under study were the number of eggs per seedling and the percentage of effectiveness of the treatment, which were evaluated 10 days after the introduction of whitefly adults (0, 5 and 10 DAA). Of each experimental unit, the underside of the leaves was examined with a stereoscopic microscope and the number of whitefly eggs per seedling was recorded, obtaining its average value. Data on the variable average number of eggs per seedling at 0, 5 and 10 DAA and the interaction between the two factors were statistically analyzed.

A goodness-of-fit test was first performed and then an individual analysis of variance at 0, 5 and 10 DAA and a combined analysis across DAA, in both trials. In addition, a multiple comparison of means test was performed using Fisher's least significant difference method (p= 0.01) with the Statistical Analysis System (SAS) Institute (2018) software. From the average number of individuals in each evaluated plant, the percentage of effectiveness of each treatment was estimated with the formula of Abbott (1925): TE= ((SC-st) / SC) ×100. Where: TE= treatment efficiency; SC= percentage of incidence in the control; st= percentage of incidence in each treatment.

Table 1. Insecticides and doses used in the control of whitefly (*B. tabaci*) in Río Grande tomato seedlings.

Treat	Insecticide	Active ingredient	Dose* (L ha^{-1})
1	Confidor® 350 SC SA	Imidacloprid	0.75
2	Movento® 150 OD FA	Spirotetramat	0.4
3	Muralla Max® 300 OD FA	Imidacloprid + Betacyfluthrin	0.2
4	Sivanto® Prime 200 SL FA	Flupyradifurone	0.75
5	Sivanto® Prime 200 SL SA	Flupyradifurone	1.75
6	Oberon® 240 SC + Sivanto® Prime 200 SL FA	Spiromesifen + Flupyradifurone	0.15 + 0.75
7	Saf-T- Side FA	Paraffinic petroleum oil	1
8	PHC® Neem® FA	Azadirachtin	1
9	Asphix® 90 FA	Soybean vegetable oil	1
10	Allium líquido® FA	*Allium sativum*	1
11	Biodi®e FA	Argemonine + Berberine + Ricinine + a-terthienyl	1.5
12	Control		-

*= low dose of formulated or commercial product; +: it indicates that the products were combined; **SA= soil application; FA = foliar application.

Results and discussion

Insecticide treatments, DAA and the interaction between the two showed significant effects in the two trials (Table 2).

Table 2. Individual analysis by trial of the effect of insecticide treatment, infestation on different days after treatment (0, 5 and 10) and interaction between both factors on the average number of whitefly (*B. tabaci*) eggs per Río Grande tomato seedling.

Effect	Trial 1			Trial 2		
	DF	F	P	DF	F	P
Days after treatment	2	69.05	<0.0001	2	64.59	<0.0001
Treatments	10	370.89	<0.0001	10	329.75	<0.0001
DAA × Treatments	20	6.14	<0.0001	20	3.46	<0.0001

When data from 0, 5 and 10 DAA were grouped and analyzed as a single set in each trial, it was found that the average number of eggs per tomato seedling, overall, ranged from 22 to 861.89. While the percentage of effectiveness of the insecticides fluctuated from 14.61 to 97.48% in the trials. The multiple comparison of means showed significant evidence (*p*= 0.01) that all insecticide treatments were better than the control in the density of whitefly eggs. Overall, natural insecticide treatments, Saf-T-Side and ASPHIX® 90, had the highest egg densities in the first and second trials (Table 3).

Table 3. Individual analysis by trial across the three DAA dates, of the percentage of effectiveness and multiple comparison of means test using Fisher's least significant difference method (*p*= 0.01) of the treatments on the average of whitefly (*B. tabaci*) eggs per Río Grande tomato seedling, in each trial.

Treatments	Trial 1		Trial 2	
	Eggs	% EF**	Eggs	% EF
Control	724.56 a*		861.89 a	
Confidor® SA****	50 fg	92.52	56.33 fg	93.48
Movento® FA	93 f	87.1	108.11 f	87.53
Muralla Max® FA	220.22 e	69.51	235.33 e	72.72
Sivanto® Prime SA	25 g	96.62	22 g	97.48
Sivanto® Prime FA	32.78 g	95.31	41 e	95.31
Saf-T- Side FA	616 b	14.61	660.56 b	23.53
Sivanto® Prime + Oberon® FA	26.67 g	96.13	28.33 g	96.76
PHC® Neem® FA	360.78 d	49.77	382.89 d	55.68
Asphix® FA	634.22 b	18.94	644.78 b	25.27
Allium líquido® FA	440.33 c	38.44	508.22 c	41.24
Biodi®e FA	447.22 c	37.66	449 c	48.04
LSD***	51.529		60.46	

*= mean values with the same letter by columns are not statistically different (*p*= 0.01); **EF= percentage of effectiveness; ***LSD= Fisher's least significant difference; ****SA= soil application, FA= foliar application.

The multiple comparison of means (*p*= 0.01) indicated that the control represented the group with the highest density of eggs at 0, 5 and 10 DAA in the first and second trials (Tables 4 and 5). In the evaluation carried out 10 days after having infested the plants, an average of 874 eggs plant^{-1} was recorded in the control treatment, this value is considered high, but it has been documented that the populations of *B. tabaci* can reach more than a thousand adults per plant (Argerich and Troilo, 2011).

In the treatment with Confidor® 350 SC (Imidacloprid) applied to the soil, it was found that the number of eggs per plant was always in the statistically lowest group, at 0, 5 and 10 DAA (*p*= 0.01; LSD) in the first trial and at 0 and 5 DAA in the second trial (Tables 4 and 5), it was also determined that this treatment was in the second group with the lowest density of eggs at 10 DAA of the second trial (Tables 4 and 5).

Table 4. Percentage effectiveness and multiple comparison test of means, Fisher's method (LSD; *p*= 0.01), of the treatments in the average number of *B. tabaci* eggs per Río Grande tomato seedling at 0, 5 and 10 DAA, first trial.

Insecticide treatments	0 DAA		5 DAA		10 DAA	
	Eggs	%EF**	Eggs	%EF	Eggs	%EF
Control	736.33 a*		752 a		685.33 a	
Confidor® SA****	34 e	95.38	44 e	94.15	72 e	88.03
Movento® FA	59.67 e	91.9	109 e	85.51	110.33 e	83.89
Muralla Max® FA	204 d	72.3	216 d	71.28	240.67 d	64.96
Sivanto® Prime SA	3.5 e	99.05	29 f	96.51	39 e	94.31
Sivanto® Prime FA	1 e	99.86	18 f	97.61	72 e	88.47
Saf-T- Side FA	566 b	23.13	604.33 b	19.64	677.67 ab	1.07
Sivanto® Prime + Oberon® FA	0 e	100	5.33 f	99.29	74.67 e	89.1
PHC® Neem® FA	251.33 cd	65.87	366 c	51.33	465 c	32.12
Asphix® FA	538 b	42.09	641.33 b	14.72	723.33 a	0
Allium líquido® FA	292.67 cd	60.25	392.67 c	47.87	635.67 ab	7.2
Biodi®e FA	338.67 c	54.01	414.33 c	44.9	588.67 b	14.06
LSD***	108.43		77.524		91.744	

*= mean values with the same letter by columns are not statistically different (*p*= 0.01); **EF= percentage of effectiveness, ***LSD= Fisher's least significant difference, ****SA= soil application, FA= foliar application.

Table 5. Percentage of effectiveness and multiple comparison test of means, Fisher's method (LSD; *p*= 0.01), of the treatments in the average number of whitefly (*B. tabaci*) eggs per Río Grande tomato seedling at 0, 5 and 10 DAA, second trial.

Insecticide treatments	0 DAA		5 DAA		10 DAA	
	Eggs	%EF**	Eggs	%EF	Eggs	%EF
Control	840.67 a*		870.67 a		874.33 a	
Confidor® SA****	41.67 e	95.04	59.33 f	93.19	68 fg	92.22
Movento® FA	54.67 e	93.5	107.33 f	87.67	162.33 ef	81.43
Muralla Max® FA	214.67 d	74.46	230.33 e	73.55	261 e	70.15
Sivanto® Prime SA	0.33 e	99.96	23 f	97.36	42.67	95.12
Sivanto® Prime FA	0.67 e	99.92	21.67 f	97.51	100.67 fg	88.49
Saf-T- Side FA	534.67 b	36.4	657.67b	24.46	789.33 ab	9.72
Sivanto® Prime + Oberon® FA	1 e	99.88	4.67 f	99.46	79.33 fg	90.93
PHC® Neem® FA	308.67 cd	63.28	346 de	60.26	494 d	43.5
Asphix® FA	573 b	31.84	663.67 b	23.77	697.67 bc	20.21
Allium líquido® FA	357.67 c	57.45	525 c	39.7	642 c	26.57
Biodi®e FA	354.67	57.81	378.67 d	56.51	613.67 c	29.81
LSD***	100.13		122.55		111.05	

*= mean values with the same letter by columns are not statistically different (*p*= 0.01); **EF= percentage of effectiveness: ***LSD= Fisher's least significant difference, ****SA= soil application, FA= foliar application.

The active ingredient imidacloprid, of the group of neonicotinoids, has been used for more than two decades against a wide range of sucking insects, for being a systemic insecticide. This insecticide acts on the central nervous system of insects, causing irreversible blockage of acetylcholine receptors (Kagabu, 2011). However, there is abundant scientific evidence that the indiscriminate use of this agrochemical has caused adult whitefly populations to develop resistance to neonicotinoids, such as imidacloprid (Caballero *et al*., 2013). Nevertheless, in this research, Confidor® 350 SC showed a percentage of effectiveness that ranged from 95.38 to 88.03% in the different periods of infestation in the two trials. Probably, because the populations of *B. tabaci* from the valley of Iguala and Cocula, Guerrero, have not been in constant contact with Imidacloprid.

This is because the host crops of the insect are developed on a limited area and are constantly rotated with corn (*Zea mays* L.) and sorghum (*Sorghum bicolor* (L.) Moench) year after year, delaying the hereditary change in whitefly sensitivity to this insecticide as suggested by Sparks *et al*. (2020). In this regard, Caballero *et al*. (2013) documented that they isolated whiteflies from fields that were exposed to imidacloprid until 2007. These populations were evaluated in trials in 2008 and 2009. They showed decreased sensitivity to imidacloprid at the level of LD_{50} and LD_{95}. On the other hand, the population that was evaluated until 2010 showed susceptibility again and the biological efficacy of the product at the two doses mentioned was recovered. Gastélum *et al*. (2014) evaluated insecticides for the management of *B. tabaci* and confirmed that treatments with Imidacloprid, alone and combined, were more efficient in reducing the incidence of adult insects.

The treatment with Movento® 150 OD (Spirotetramat) was in the group with the statistically lowest egg densities, at 0, 5 and 10 DAA in the first trial, and at 0 and 5 DAA in the second trial. While at 10 DAA of the second trial, it was in the third statistically lowest group (p= 0.01). The percentage of effectiveness in the periods of 0, 5 and 10 DAA ranged from 93.50 to 81.43% in the first and second trials (Tables 4 and 5).

Although Spirotetramat is presented as a more effective product against *B. tabaci* eggs, there is evidence that it is effective against adults, as it is a systemic and translaminar insecticide (Nauen *et al*., 2008). In field tests in Spain and Brazil, effectiveness percentages ranging from 84-96 and 78-96% have been found, when used alone or in mixture with imidacloprid (Brück *et al*., 2009). On the other hand, Xie *et al*. (2011) documented that Movento® has persistence and good control of *B. tabaci*, but the efficacy can improve when alternated with products of different mode of action.

The insecticide Muralla Max® 300 OD (Betacyfluthrin + Imidacloprid), except for the values taken at 5 DAA in the first trial and at 10 DAA in the second trial, was classified in the second statistical group with the lowest number of eggs (p= 0.01), always preceded by the rest of the treatments with synthetic insecticides. The efficacy of the treatment ranged from 74.46 to 64.96% in the two trials when infested with whiteflies at 0, 5 and 10 DAA. In this regard, Silva *et al*. (2012) reported that, with the active ingredients betacyfluthrin + imidacloprid applied to *B. tabaci* eggs in soybean cultivation, they obtained 86.99% control of the insect, which is a higher value than those obtained with the Muralla Max® treatment in this research (Tables 4 and 5).

Sivanto® Prime 200 SL (Flupyradifurone; soil application) was the only treatment whose egg density remained statistically in the lowest group or not statistically different from the lowest group (*p*= 0.01) at 0, 5 and 10 DAA in both trials. The percentage of effectiveness of this insecticide with application to the soil fluctuated from 99.96 to 94.31% in the three periods of infestation (0, 5 and 10 DAA) of the two trials. Compared to imidacloprid applied to the soil, flupyradifurone had a higher percentage of effectiveness and decreased the number of eggs (Tables 4 and 5). The values of egg density in the treatment with Sivanto® Prime 200 SL (Flupyradifurone) when applied in a foliar manner, except for the result obtained at 10 DAA in the second trial, placed this insecticide in the lowest statistical group during the different periods of infestation with whiteflies (*p*= 0.01; LSD).

The effectiveness of this insecticide in foliar application ranged from 99.92 to 88.47% in the periods of infestation in the two trials (Tables 4 and 5). Several studies have confirmed that the lowest densities of *B. tabaci* occur in treatments with Flupyradifurone compared to neonicotinoid insecticides (Smith and Giurcanu, 2014). Sivanto® Prime (Flupyradifurone) is an insecticide that controls sucking insects, which consists of acting as an antagonist of the nicotinic acetylcholine receptor of the insect, thus imitating the acetylcholine neurotransmitter.

Which causes that this cannot be activated by the respective enzyme, in its natural form, and causes excitation of the nerve of the cell, the persistence of that effect causes an alteration in the nerve of the insect and, subsequently, its collapse and despite being of the same group of neonicotinoids, it has not been shown to present cross-resistance with imidacloprid, acting on resistant pests, including the whitefly (Nauen *et al*., 2002; Nauen *et al*., 2015).

In several investigations, it has been found that treatments with Flupyradifurone cause prolonged inhibition of feeding and reduction of the incidence of whiteflies, so it has great potential to suppress the transmission of virus diseases (Dempsey *et al*., 2017; Roditakis *et al*., 2017). In addition, it has no adverse effects for bees, mammals, humans and most beneficial insects. It adapts well to integrated agricultural pest management systems (Jeschke *et al*., 2015).

In the combination of Sivanto® Prime 200 SL (Flupyradifurone) + Oberon® 240 SC (Spiromesifen), except for the result obtained at 10 DAA in the second trial, they placed this combined treatment in the group (*p*= 0.01). The percentage of effectiveness ranged from 100 to 89.10% in the three infestation periods (0, 5 and 10 DAA) of both trials (Tables 4 and 5). MahaLakshmi *et al*. (2015) estimated the efficacy of ten insecticides against whiteflies, they reported that the treatment with Spiromesifen (Oberon® 240 SC) was the most effective of ten insecticides evaluated, which reduced the population of nymphs of the insect by 80%. In addition, Smith and Giurcanu (2014) evaluated the combination of modes of action against *B. tabaci* and found the lowest densities of adults in the treatment with Flupyradifurone (Sivanto® Prime).

The paraffinic petroleum oil Saf-T-Side, in both trials, showed significant evidence (*p*= 0.01; LSD) that the average egg densities with this treatment were consistently in the second and third highest groups at 0, 10 and 15 DAA.

The efficacy of the treatment for both trials ranged from 36.4% to 1.07% in the three infestation periods (Tables 4 and 5). This paraffined agricultural oil prevents the respiratory process of eggs, larvae and adults, and causes hypoxia (Varela *et al*., 2013). De Almeida *et al*. (2014), when evaluating mineral oils with the same mode of action as Saf-T-Side, obtained less than 10% mortality of *B. tabaci* eggs. Other studies have determined that *B. tabaci* is susceptible to petroleum oil when it is in immature instars, such as egg, to control the nymphs of the first stage (Larew and Locke, 1990).

The statistical group (*p*= 0.01) of PHC® Neem® (Azadirachtin) varied at 0, 5 and 10 DAA in the two trials. It was the natural insecticide that showed the lowest density of eggs, always preceded by the synthetic treatments. The efficacy ranged from 65.87% to 43.50% in the two trials, across the different periods of infestation (Tables 4 and 5). Neem seed extracts are known to cause mortality of *B. tabaci* (Carvalho *et al*., 2012), make it difficult for the insect to find the food source; they cause repellency and excitation of the nervous system that makes it difficult for them to fly and ovulate; the irritating effect induces insects to leave their shelters, which facilitates control (Navarrete *et al*., 2017). De Almeida *et al*. (2014) documented that neem seed oil has great potential for use in integrated whitefly management programs. MahaLakshmi *et al*. (2015) found a reduction of 35.23% of the nymph population in the treatment with 3% Azadirachtin, at doses of 5 ml L^{-1}.

The natural insecticide Asphix® 90 (Soybean vegetable oil) did not show significant differences with the control treatment at 10 DAA in the first trial; with the exception of this result, egg densities at 0 and 5 DAA in the first trial and at 0, 5 and 10 DAA in the second trial were statistically not different from the Saf-T-Side treatment, they were in the second and third groups with the highest egg density (*p*= 0.01; LSD). Soybean extract had an effectiveness percentage of 42.09 to 0% at 0, 5 and 10 DAA (Table 4 and 5).

The insecticidal action of Asphix® 90 probably has greater activity when the insect is present at the time of application, because the product has a desiccant effect, is highly lipophilic, alters the waxy cover of nymphs and adults; it blocks spiracles, causes suffocation; it limits the exchange of gases through the aeropile in eggs, which harden and hatching becomes difficult (Altiara, 2022). In treatment with *Allium* líquido® (*Allium sativum*), egg densities at 0, 5 and 10 DAA were intermediate in the two trials, always with a higher average than treatment with PHC® Neem®.

It has effectiveness of 60.25 to 26.57% during the periods of infestation (0, 5 and 10 DAA) in both trials (Tables 4 and 5). In an experiment conducted by Liu *et al*. (2014), who evaluated 16 botanical oils, they found that *A. sativum* exhibited the highest effectiveness against *B. tabaci* adults. On the contrary, Gómez *et al*. (1997) reported that the garlic extract applied in the product Garlic Barrier® had no effect against adults of *B. tabaci*.

Egg densities in the Biodi®e treatment (Argemonine + Berberine + Ricinine + a-terthienyl) showed significant evidence (*p*= 0.01; LSD) similar to the treatment with Allium líquido®. It was almost always in the same intermediate statistical group, with a percentage of effectiveness that fluctuated from 57.81 to 14.06% across the different periods of infestation (Tables 4 and 5). Probably, using high doses of Biodi®e, better percentages of effectiveness than those obtained in the present research could be achieved. As it is not a systemic product, it is recommended to make good coverages to achieve maximum efficiencies of the product in the field.

Conclusions

The results of this research show that the populations of *B. tabaci* from the northern region of Guerrero exhibit variable response to all synthetic insecticides evaluated. Natural products have repellent or deterrent effect against *B. tabaci*. The treatment with Sivanto® Prime (Flupyradifurone) in foliar and soil applications had the highest percentage of effectiveness of all synthetic products, at 0, 5 and 10 DAA, in the two trials. Of the treatments with natural products, PHC® NEEM® (Azadirachtin) had the highest percentage of effectiveness at 0, 5 and 10 DAA in the two trials. The information from this study on the residual effectiveness of the products used will contribute to the design of an integrated management program for *B. tabaci*, together with other control methods such as cultural and of genetic resistance of the host plant, to dispense with the excessive use of insecticides in the management of *B. tabaci* in tomato and other host crops.

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