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Integrated management of tomato fruit borer (*Neoleucinodes elegantalis*)

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The management of *Neoleucinodes elegantalis* (Guenée) (Lepidoptera: Crambidae) with neem-based and registered insecticides most applied on tomato crops in the Agreste region on *N. elegantalis* (eggs, pre-pupae and pupae) were evaluated in this study; methomyl, chlorpyrifos, lambda-cyhalothrin, beta-cypermethrin, deltamethrin, etofenprox, chlorantraniliprole and the neem-based insecticides (azadirachtin A/B and emulsifiable neem oil) were used for studying the repellent effect on oviposition. Lufenuron, deltamethrin and indoxacarb associated with 2.5% sucrose were used as toxic baits on tomato plants. Regarding the ovicidal effect, etofenprox and methomyl had the highest egg mortality, reducing larval survival and fruit damage. Etofenprox had the highest average mortality: 50% in pupae and 38% in pre-pupae. As for repellency, all insecticides tested reduced significantly the number of eggs when compared to the control, except for azadirachtin and chlorantraniliprole. Lufenuron and deltamethrin decreased the number of eggs, showing great potential for use in toxic baits, while indoxacarb stimulated oviposition, thus not being recommended for this purpose. The appropriate use of synthetic insecticides can maximize their potential of control, as long as their use is directed to the stage of the pest that causes higher damage to the crop, or exploring their potential as oviposition deterrent, as well as their use in toxic baits.

Key words: Toxic bait, ovicidal effect, repellence, integrated management.

INTRODUCTION

The tomato crop has a great economic and social importance to Brazil. In 2011, the Brazilian production was 3,653,017 t in 57,355 ha with a productivity of 63,729 kg/ha (IBGE, 2015). This culture, however, provides a favorable habitat for several species of insects, which can achieve high rates of reproduction and survival, compromising the production (Picanço and Guedes, 1999; Picanço and Marquini, 1999). Among the insects, the tomato fruit borer (TFB) *Neoleucinodes elegantalis* (Guenée) (Lepidoptera: Crambidae) is a major pest in most tomato-growing regions. It severely infests the fruit, making them unsuitable for consumption and industrial processing (Gravena and Benvenga, 2003), which can lead to 22% production loss (Picanço et al., 2007), and even damage other solanaceous fruits, such as eggplant, scarlet eggplant, jua, jurubeba and pepper (Toledo, 1948;

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Zucchi et al., 1993).

Furthermore, control this pest is difficult due to its behavior. The female lays the eggs, preferably under the sepals of small green fruit (23 mm) and after five days, the larvae hatch, penetrating the fruit between the first and second hour of scotophase, where they remain for about 16 days (Fernández and Salas, 1985; Blackmer et al., 2001). Therefore, *N. elegantalis* control has been done almost exclusively with the use of synthetic insecticides, applied according to pre-established timetables (Lima et al., 2001).

Management practices aiming at the proper use of insecticides are necessary, thus reducing their application and maximizing effects. Among these practices, the use of repellent insecticide can be considered an important tool for deterring oviposition. Host-plant location is not only related to feeding, but also to oviposition site selection. In Lepidoptera, finding the oviposition site is mediated by the presence of one or more substances that form the specific volatiles or blends of volatiles of the host (França et al., 2009a). The alteration of the plant natural aroma by applying non-specific volatiles can promote rejection. In this sense, some synthetic chemical and botanical insecticides have shown an oviposition deterrent effect on *N. elegantalis* (Cook et al., 2007), becoming strong allies in the management of this pest.

Also, the development of tactics for pest management based on behavior manipulation has been shown as a promising alternative (Witzgall et al., 2008). Chemicals involved in behavioral management, such as feeding stimulants and semiochemicals, can become excellent tools in pest control (Foster and Harris, 1997). Likewise, attractive toxic baits containing feeding stimulants make pest management by behavioral manipulation an effective tool, helping to reduce quantity and increase efficiency of insecticides used in agricultural production systems (Potts, 1999). According to Arruda-Gatti and Ventura (2003), these baits are widely used for the integrated management of insects of agricultural importance, assisting in the decision making of whether or not to control a particular pest. However, the mortality factor is added to the toxic bait, which usually uses a synthetic insecticide. One of the advantages of toxic baits is the benefit to the environment, since they have less influence on some natural enemies, because they are not applied in the total area cultivated (Galli et al., 2004).

The objective of this study was to improve strategies that assist in the integrated management of *N. elegantalis*, directing insecticide applications at different development stages, in order to increase efficiency. Therefore, the direct effects of insecticides on eggs, pupae and pre-pupae were evaluated, as well as insecticide effects on adults (with toxic baits) and repellency/deterrence of *N. elegantalis* oviposition.

MATERIALS AND METHODS

The experiments were conducted in the Agronomy Department vegetable garden and at the Laboratory of Agricultural Entomology, Federal Rural University of Pernambuco (UFRPE).

Insect

The insects used in the experiments were obtained from a population kept under 25 ± 2°C, 65 ± 10% relative humidity and 12 h photophase, at the Laboratory of Agricultural Entomology. Breeding was adapted from the methodology developed by Prof. Marcelo Coutinho Picanço at the Laboratory of Integrated Pest Management, Federal University of Viçosa. Branches with green fruit (about 3 cm in diameter) and leaves of the tomato cultivar Yoshimatsu L-1 were put in plastic bottles with water and placed inside cages, as a site for *N. elegantalis* oviposition. The fruit were daily changed, and the eggs transferred to green fruit of organic scarlet eggplant. Each fruit was infested with about four to six eggs, according to size. The scarlet eggplant fruit were put in plastic trays lined with paper towel and kept for about 15 days, until the larvae reached the last instar, when they abandoned the fruit, spending the pupal stage on the paper towel. Pupae were transferred to wooden cages (60 × 60 × 60 cm) covered with organza until adult emergence. Adults were fed with a 10% sucrose solution.

Survey of insecticides used to control N. elegantalis

The questionnaires about insecticide use for *N. elegantalis* control in tomato crops were given to farmers from the Agreste municipalities of Camocim de São Félix and Bezerros, which are major tomato producers in the state of Pernambuco (IBGE, 2012). The survey was conducted in six properties, three for each municipality, from September 2011 to February 2012.

Ovicidal effect of synthetic and botanical insecticides

Tomato plants of the cultivar Yoshimatsu L-1, with fruit and leaves, were placed in breeding cages for *N. elegantalis* oviposition. After 48 h, 15 eggs were selected per fruit, the remaining removed and discarded with the help of a brush. Oviposition sites for the selected eggs were marked with a marker pen. The fruit were sprayed with a 5.0 ml solution of each product, with the aid of a Paasche electric micro-atomizer coupled to a compressor, calibrated with nine pounds of pressure (9 mmHg). The insecticides were applied at 10 cm from the spray table, and the control was sprayed with distilled water. The following insecticides were tested: azadirachtin A/B (Azamax®), emulsifiable neem oil (Natuneem®) (1 ml L^{-1}), chlorpyrifos (Lorsban® 480 BR) (1.5 ml L^{-1}), methomyl (Lannate® BR) (1 ml L^{-1}), beta-cypermethrin (Akito®) (0.4 ml L^{-1}), fenpropathrin (Danimen® 300 EC) (1.5 ml L^{-1}) and etofenprox (Safety®) (0.5 ml L^{-1}). The number of hatched larvae and the average number of entrance holes in the fruit were counted six days after spraying; the effect of insecticides on newly-hatched larvae (Shock Effect) was also observed, because the pest has direct contact with the dry residues. The assessment of average number of holes per fruit was carried out 21 days after application. To calculate the efficiency of the treatments on egg mortality (Ovicidal Efficiency), on preventing fruit damage by newly-hatched larvae (Larvicidal Efficiency: Shock Action) and on the full development of the pest inside the fruit (Larvicidal Efficiency: Physiological Action), the formula proposed by Abbott and adapted by Benvenga was used for comparing the treatments to the control (Abbott, 1925; Benvenga, 2009). A completely randomized design with eight treatments and five replicates, each consisting of 15 eggs was carried out; results were

Table 1. Formulas used to calculate the efficiency of chemical treatments to control *N. elegantalis* in tomato fruit, in the laboratory (Benvenga, 2009).

Ovicidal efficiency	**Formulae**
Reduction in larvae hatching compared to the control (%)	$R (\%) = [(NLTS - NLTR) / (NLTS)] \times 100$
Larvicidal Efficiency (Shock action)	
Reduction in entrance holes compared to the control (%)	$R (\%) = [(NOeTS - NOeTR) / (NOeTS)] \times 100$
Larvicidal Efficiency (Physiological action)	
Reduction in exit holes compared to the control (%)	$R (\%) = [(NOsTS - NOsTR) / (NOsTS)] \times 100$
Biological Efficiency (Ovicidal Action + Larvicidal Action)	
Reduction in hatching and exit holes compared to the control (%)	$R (\%) = [(NOsTS/NOTS) - (NOsTR/NOTR) / (NOsTS/NOTS)] \times 100$

Control	**Treatment**
NLTS = Average number of hatched larvae	NLTR = Average number of hatched larvae
NOTS = Average number of eggs	NOTR = Average number of eggs
NOeTS = Average number of entrance holes	NOeTR = Average number of entrance holes
NOsTS = Average number of exit holes	NOsTR = Average number of exit holes

submitted to analysis of variance and means were compared by the Tukey's test ($P \leq 0.05$).

In the formula of biological efficiency, indices were established for the control and treatment, with an initial reference on number of eggs in relation to the number of exit holes in fruit at the end of the study (Table 1).

Effect of synthetic and botanical insecticides on pre-pupae and pupae

Pre-pupae and pupae were taken from the *N. elegantalis* breeding collection and packed in plastic pots containing tomato leaves; they were then sprayed with the same insecticides, following application techniques used in the previous experiment. Development time, mortality and possible morphological changes were observed.

Mortality values were corrected using the Abbot's formula (Abbott, 1925). A completely randomized design with six treatments and five replications, each consisting of 20 pupae or pre-pupae was carried out; results were submitted to analysis of variance and means were compared by the Tukey's test ($P \leq 0.05$).

Effects of synthetic and botanical insecticides on oviposition

Tomato branches approximately 30 cm long, containing two leaves and two to three fruits (2 to 3 cm diameter), placed in plastic bottles with water, were sprayed with a 5.0 mL solution of each insecticide by a Paasche electric spray gun coupled to a compressor, calibrated with 12 mmHg. After drying, they were placed inside wooden cages covered with organza (1 × 1 × 1 m), in a hexagonal arrangement with six plants treated or untreated. The following insecticides were tested: methomyl (Lannate®) (1 ml L^{-1}), chlorpyrifos (Lorsban®) (1.5 ml L^{-1}), lambda-cyhalothrin (Karate Zeon®) (0.4 ml L^{-1}), beta-cypermethrin (Akito®) (0.4 mL L^{-1}), deltamethrin (Decis®) (0.4 ml L-1) etofenprox (Safety ®) (0.5 ml L^{-1}) chlorantraniliprole (Premio®) (0.02 ml L^{-1}), all registered for the control of *N. elegantalis.* The following neem-based botanical insecticides were used at a concentration of 1%: azadirachtin A/B (Azamax® CE - 12000 mg kg^{-1} of azadirachtin A and B) and emulsifiable neem oil (Natuneem® 1500 mg kg^{-1}). Botanical and synthetic insecticides, as well as the control were tested separately in a randomized complete block design with eight replications. Inside each cage, 30 mated females (three to four days old) were released. A 10% honey solution was used as food source in the cage. The evaluations were made 48 h after infestation by counting the number of eggs per fruit. The mean percentage of egg reduction for each insecticide was calculated, according to a formula:

$$PR = [(NC - NT) / (NC + NT) \times 100]$$

where PR = mean percentage of egg reduction, NC = mean number of eggs in the control and NT = mean number of eggs in the treatment (Obeng-Ofori, 1995).

The results were analyzed by the Student's t-test at 5% probability, after homogeneity and normality tests; for lambda-cyhalothrin, chlorpyrifos and beta-cypermethrin, the data were transformed into arcsine $\sqrt{(x / 100)}$ to meet the assumptions of ANOVA, using the SAS version 8.02 program (SAS Institute, 1999-2001).

Use of toxic baits and oviposition-repellent insecticides

Tomato plants were grown in the Agronomy Department vegetable garden. When fruit reached 2 to 3 cm in diameter, four cages were assembled using PVC pipes (25 mm), with the following dimensions: 1.20 m length × 1.00 m width × 1.30 height m, covered by a voile-type cloth and having side vents with a Velcro closure system. The cages were fixed to the beds with the aid of iron clamps, to provide greater stability. Four plants with about 10 to 15 fruits were placed in each cage. Plants were sprayed with the insecticides lufenuron (Match® EC), deltamethrin (Decis®) and indoxacarb (Rumo®) at commercial concentrations, associated with

Table 2. Main insecticides used to control *N. elegantalis* in tomato crops in the Agreste region of Pernambuco, according to questionnaires data.

Commercial Name	Active ingredient	Chemical Group	Action Mode
Lorsban® 480 BR	Chlorpyrifos	Organophosphate	Acetylcholinesterase inhibitor (A)
Vexter®	Chlorpyrifos	Organophosphate	
Nufos® 480 EC	Chlorpyrifos	Organophosphate	
Malathion®1000 EC Cheminova®	Malathion	Organophosphate	
Cyptrin® 250 CE	Cypermethrin	Pyrethroid	Sodium channel modulator (B)
Decis® 25 CE	Deltamethrin	Pyrethroid	
Sumidan® 150 SC	Esfenvalerate	Pyrethroid	
Talcord® 250	Permethrin	Pyrethroid	
Akito®	Beta-cypermethrin	Pyrethroid	
Danimen® 300 EC	Fenpropathrin	Pyrethroid	
Fastac® 100	Alpha-cypermethrin	Pyrethroid	
Safety®	Etofenprox	Diphenyl ether	Sodium channel modulator
Bac-control WP®	*Bacillus thuringiensis*, kurstaki		Microbial disruptors of the mid-gut membrane
Premio®	Chlorantraniliprole	Anthranilamide	Feeding inhibition and muscular paralysis
Polytrin®	Cypermethrin + profenofos	Pyrethroid + Organophosphate	A + B
Lannate® BR	Methomyl	Oxime Methylcarbamate	Acetylcholinesterase inhibitor

2.5% sucrose (França et al., 2009b). The application was carried out with a manual backpack sprayer with a light-jet cone nozzle. After spraying, 45 female *N. elegantalis* (aged 48 to 72 h) were released per cage. At 48 h of spraying, the insects were collected and the dead females were counted. Then, bunches were removed and taken to the laboratory of Agricultural Entomology for egg quantification. Each insecticide and the control were tested separately in a completely randomized design with eight replications.

Square root data transformation (x + 0.5) was carried out when necessary to meet ANOVA prerequisites. The results were submitted to analysis of variance, and the means were compared by the t-test using the SAS version 8.02 program (SAS Institute, 1999-2001).

RESULTS

Survey of insecticides used to control *N. elegantalis*

After analyzing the questionnaires, it has been found that the main insecticides used by tomato growers in the Agreste region of Pernambuco are pyrethroids and organophosphates (Table 2); they act as sodium channel modulators and acetylcholinesterase inhibitors in nerve synapses, respectively, causing the continuous passage of nerve impulses, leading the insect to fatigue and, consequently, death (IRAC-BR, 2012).

Ovicidal effect of synthetic and botanical insecticides

The etofenprox, methomyl and fenpropathrin were primarily responsible for inviability of *N. elegantalis* eggs, with percentages of 98.6, 91.9 and 45.3%, respectively, differing from the control; etofenprox and methomyl markedly reduced larvae survival and fruit damage. Although fenpropathrin has not been as effective in reducing larval survival, it greatly decreased their entrance into the fruit, thus avoiding possible damage. The other insecticides were not considered effective. Regarding larvicidal efficiency, etofenprox, methomyl, fenpropathrin and azadirachtin produced better results, showing a reduction of larvae holes of 98, 90.63, 85.94 and 64.06%, respectively, when compared to the control. The insecticides tested showed similar performance to the

Table 3. Effect of synthetic insecticides and emulsifiable neem oil on *N. elegantalis* eggs at 27 ± 3 °C, 69 ± 5% relative humidity and 12 h photophase.

Treatment	Egg inviability (%)[a]	Larvae survival (%)[a]	Entrance holes[a,b]	Exit holes[a,c]
Azadirachtin	21.3 ± 7.71^{bc}	78.6 ± 7.71^{ab}	4.6 ±1.66^{bc}	0.3 ± 0.20^{b}
Beta-cypermethrin	27.9 ± 6.79^{bc}	71.9 ± 6.79^{ab}	5.4 ± 2.03^{bc}	2.2 ± 0.58^{a}
Chlorpyrifos	7.9 ± 3.26^{c}	91.9 ± 3.26^{a}	11.0 ± 1.14^{ab}	0.20 ± 0.20^{b}
Etofenprox	98.6 ± 1.33^{a}	1.3 ± 1.33^{c}	0.2 ± 0.20^{c}	0.2 ± 0.20^{b}
Fenpropathrin	45.3 ± 13.88^{b}	54.6 ± 13.88^{b}	1.8 ± 0.40^{c}	1.0 ± 0.44^{ab}
Methomyl	91.9 ± 3.2 6^{a}	7.9 ± 3.26 ^{c}	1.2 ± 0.48^{c}	0.0 ± 0.00^{b}
Emulsifiable neem oil	14.6 ± 5.73^{bc}	85.3 ± 5.73^{ab}	6.0 ± 2.69^{abc}	0.4 ± 0.19^{b}
Control	5.3 ± 2.49^{c}	94.6 ± 2.49^{a}	12.8 ± 1.49^{a}	1.4 ± 0.67^{ab}

[a] Means (± SE) followed by the same letter in the column do not differ by the Tukey's test (P> 0.05). [b] Larvae entrance hole in tomato fruit. [c] Pre-pupae exit hole in tomato fruit.

Table 4. Effect of synthetic and neem-based botanical insecticides on the development period (days), mortality (%) and morphological changes (%) of *N. elegantalis* pre-pupae at 27 ± 3°C, 69 ± 5% relative humidity and 12 h photophase.

Treatment	Development period (%)[a]	Mortality[a] (%)	Morphological chages (%)[a]
Azadirachtin	3.2 ± 0.37^{b}	15.2 ± 0.86^{a}	1.2 ± 0.40^{a}
Beta-cypermethrin	3.4 ± 0.24^{b}	19.0 ± 1.85^{a}	5.0 ± 0.31^{a}
Chlorpyrifos	3.6 ± 0.24^{b}	18.0 ± 0.67^{a}	7.0 ± 0.24^{a}
Etofenprox	3.8 ± 0.20^{b}	38.0 ± 0.40^{a}	8.0 ± 0.40^{a}
Fenpropathrin	3.6 ± 0.24^{b}	29.0 ± 1.46^{a}	2.0 ± 0.40^{a}
Methomyl	5.0 ± 0.31^{a}	19.0 ± 0.73^{a}	5.0 ± 0.00^{a}
Emulsifiable neem oil	3.0 ± 0.31^{b}	14.0 ± 0.37^{a}	0.6 ± 0.73^{a}
Control	3.8 ± 0.20^{b}	17.0 ± 0.97^{a}	3.0 ± 0.40^{a}

[a] Means (± SE) followed by the same letter in the column do not differ by the Tukey's test (P> 0.05).

control, in relation to larvae holes in tomato fruit (Table 3).

Effect of synthetic and botanical insecticides on pre-pupae and pupae

The insecticides did not affect the pre-pupal period in relation to the control, except that methomyl lengthened this period, but with no significant morphological changes (Table 4). The insecticides tested did not affect pupal development, when compared to the control, although, among the insecticides, Fenpropathrin presented a higher pupal development period (Table 5). Etofenprox had an upper percentage of morphological changes in pre-pupae, but none of the insecticides caused significant changes (Table 4). Insecticides caused varied morphological changes in pupae, such as deformed abdomens and two-headed individuals, incomplete biological cycle and adults with atrophied wings (Figure 3). However, none of the insecticides provided a number of significant changes in pupae morphology, compared to the control, with methomyl, azadirachtin and neem emulsifiable oil causing the fewest alterations (Table 5). Etofenprox provided greater corrected mortality in pupae and pre-pupae, 35.89 and 25.30% respectively (Tables 4 and 5).

Effect of synthetic insecticides on oviposition

The following insecticides reduced significantly the number of eggs, when compared to the control: chlorpyrifos (t = -10.39; P < 0.0001; GL = 17.8), lambda-cyhalothrin (t = -10.63; P < 0.0001; GL = 20.4), beta-cypermethrin (t = -7.95; P < 0.0001; GL = 23.8), deltamethrin (t = -10.54; P < 0.0001; GL = 34), azadirachtin (t = -5.54; P < 0.0001; GL = 34), methomyl (t= -3.72; P = 0.0007; GL = 34) and etofenprox (t = -3.91; P = 0.0004; GL = 34); reduction percentages were 89.51, 74.34, 45.79, 45.16, 36.86, 25.27 and 23.37%, respectively. Chlorantraniliprole (t = -1.60; P = 0.11; GL = 34) reduced the number of eggs in just 10.30%, and neem emulsifiable oil (t = -1.94; P = 0.06; GL = 18.9) achieved a 15% reduction, thus not differing from the control (Figure 1).

Table 5. Effect of synthetic insecticides and emulsifiable neem oil on the development period (days), mortality (%) and morphological changes (%) of *N. elegantalis* pupae at 27 ± 3°C, 69 ± 5% relative humidity and 12 h photophase.

Treatment	Development period (days)[a]	Mortality (%)[a]	Morphological changes (%)[a]
Azadirachtin	8.2 ± 0.20[a]	19.0 ± 1.48[b]	1.8 ± 0.37[a]
Beta-cypermethrin	8.2 ± 0.80[a]	26.0 ± 0.66[ab]	9.0 ± 0.37[b]
Chlorpyrifos	8.2 ± 0.20[a]	37.0 ± 0.81[ab]	16.0 ± 0.58[b]
Etofenprox	8.4 ± 0.81[a]	50.0 ± 1.30[a]	6.0 ± 0.20[b]
Fenpropathrin	9.0 ± 0.31[a]	37.0 ± 1.12[ab]	6.0 ± 0.37[b]
Methomyl	8.4 ± 0.50[a]	23.0 ± 1.63[b]	2.0 ± 0.40[a]
Emulsifiable neem oil	6.4 ± 0.87[a]	10.0 ± 2.35[b]	0.8 ± 0.40[a]
Control	8.2 ± 0.48[a]	22.0 ± 1.02[b]	8.00±0.40[b]

[a]Means (± SE) followed by the same letter in the column do not differ by the Tukey's test (P>0.05).

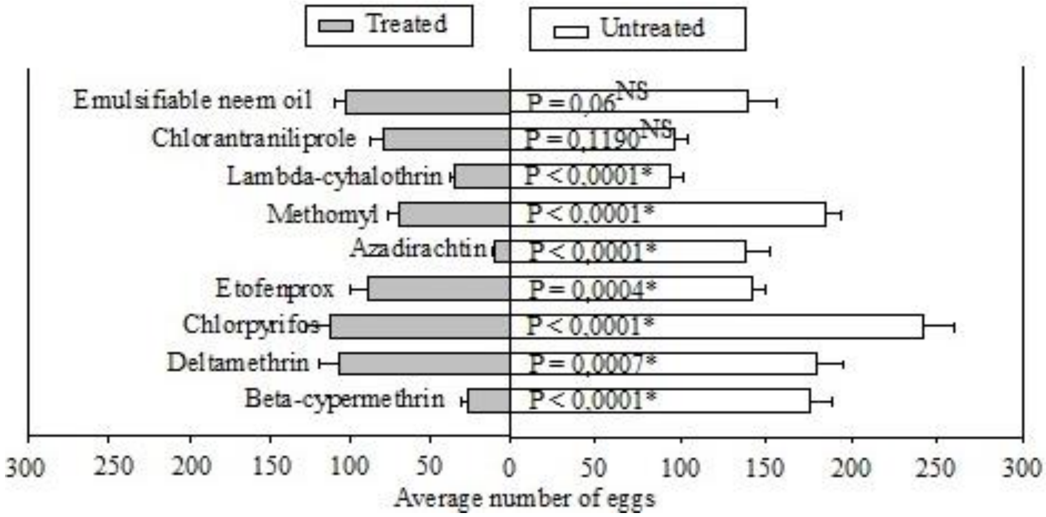

Figure 1. Number of *N. elegantalis* eggs in tomato fruit treated and not treated with synthetic and neem-based botanical insecticides at 25.42 ± 1.66°C, 69.85 ± 6.46% relative humidity and 12 h photophase. NS = non-significant, * significant at 5% probability.

Use of toxic baits and oviposition-repellent insecticides

Deltamethrin (t = -6.41, P < 0.0001; GL = 14) and lufenuron (t = -3.49; P = 0.007; GL = 8.19) reduced significantly the number of eggs when compared to the control, but female mortality was not significant (P> 0.05). Indoxacarb (t = 2.64; P = 0.02; GL = 9.44) caused a significant increase in the number of eggs compared to the control (Figure 2).

DISCUSSION

Pyrethroid insecticides are the most used by tomato growers, due to their low mammalian toxicity, environmental impact and quantity/ha. Organophosphates have a high biological activity, relative instability and a half-life in plants from two to 10 days, but in general, they are very toxic to vertebrates (Santos et al., 2007a; Santos et al., 2007b). However, despite the growth in insecticide use over the years, according to reports from producers, the damage caused by pests has also increased, probably due to selection of resistant insect populations. Thus, insecticide resistance management is an important tool in integrated pest management programs and requires the controlled use of chemicals by varying the concentration and frequency of applications, using insecticides in a rotation system or in a mixture, or applying sequence of chemicals that have different modes of action, for example (Gullan and Cranston, 2007).

The effects of chemical insecticides have been investigated more frequently to optimize their application, directing them to the most susceptible stage of the target-pest. In relation to ovicidal effect, etofenprox, fenpropathrin

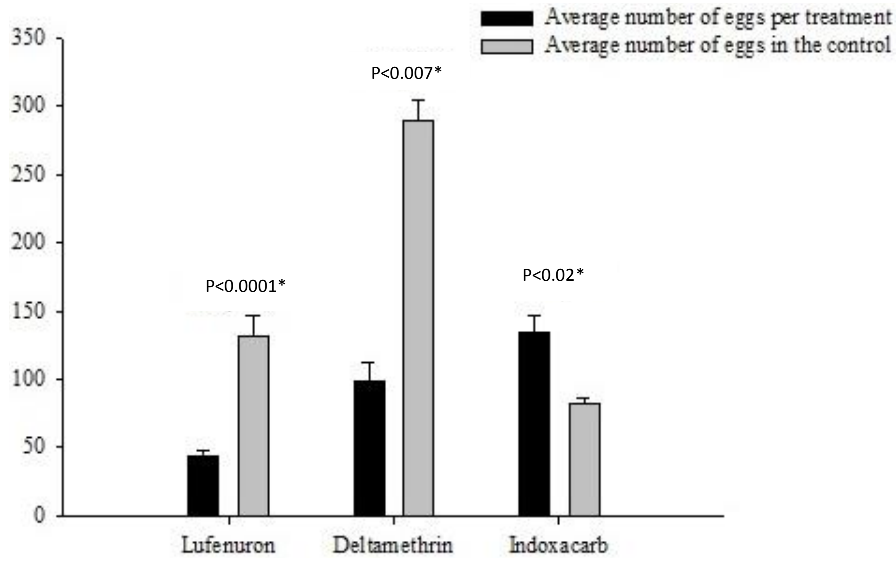

Figure 2. Number of *N. elegantalis* eggs in tomato fruit treated and not treated with synthetic insecticides, such as toxic baits associated with 2.5% sucrose.
* Significant at 5% probability.

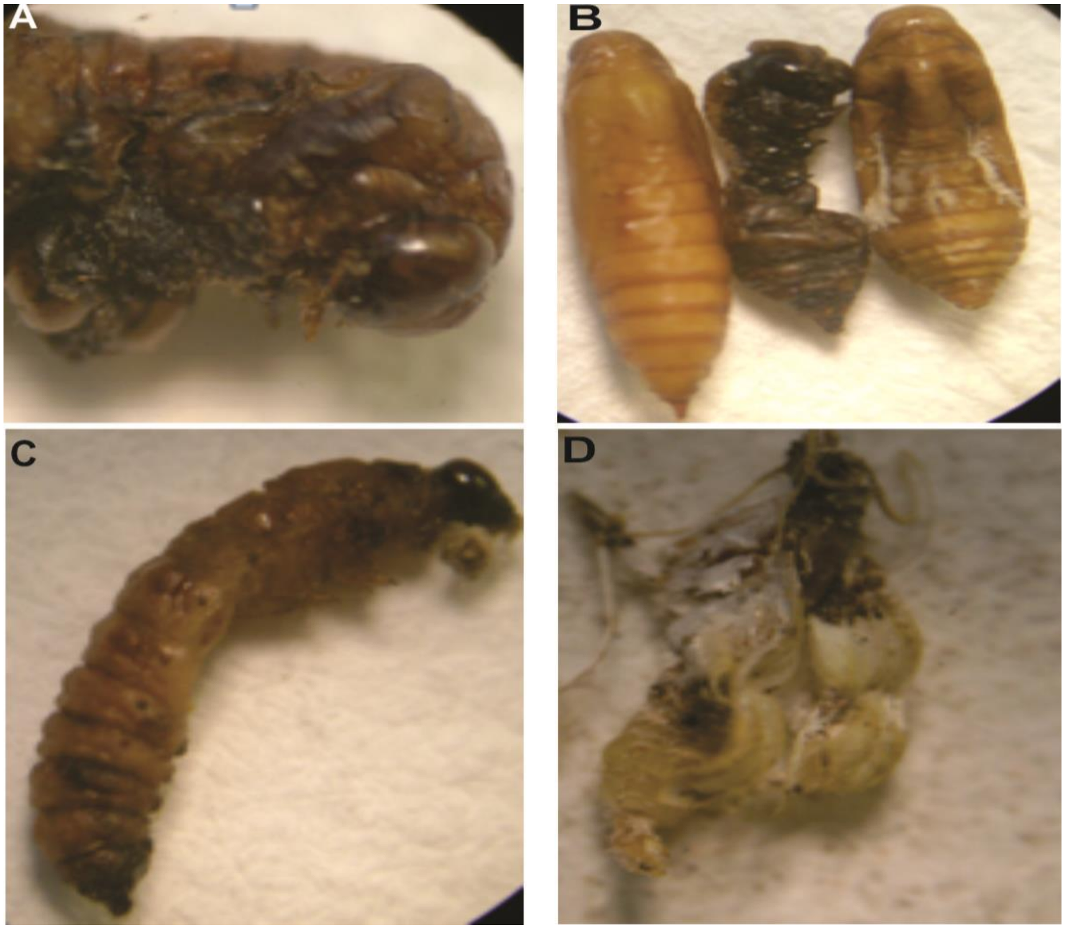

Figure 3. Pupae with two heads (A). Healthy pupae next to pupae with morphological changes (B). Deformed pre-pupae (C). Moth with deformed and stunted wings (D).

and methomyl proved to be a promising alternative for controlling *N. elegantalis* larvae before they could penetrate the fruit. Azadirachtin (NeemPro) had the highest slope of a curve dosage-mortality of *N. elegantalis* eggs compared to other insecticides, meaning that a small increase in the concentration causes significant increases in mortality; however, deltamethrin (Decis® 250 CE) was 144.58 times more toxic than the neem-based insecticides tested (França et al., 2009a).

The insect development stage in which insecticides are applied can influence their effectiveness, hence the importance of applying them at the right time (Neto e Silva et al., 2011). The insecticide lufenuron (Match® EC) was more effective on *Lobesia botrana* Den & Schiff eggs at 0 to 24 h from oviposition (Sáenz-De-Cabezón et al., 2006). However, considering insect development stages, eggs are more tolerant to chemical insecticides. The development of *Phthorimaea operculella* Zeller eggs became unaffected when exposed to various concentrations of thiacloprid (Calypso 480 SC), because larvae hatching was not affected; however, larval survival and adult emergence were reduced (Saour, 2008). 12 insecticides at different concentrations on eggs and larvae of *Grapholita lobarzewskii* Nowicki, had a larvicidal effect greater than the ovicidal (Charmillot et al., 2007).

The effects of botanical and synthetic insecticides on oviposition of some Lepidoptera species have been tested. The emulsifiable neem oil (Natuneem), azadirachtin (NeemPro), deltamethrin (Decis®) and lambda-cyhalothrin (Karate Zeon®) reduced the number of *N. elegantalis* eggs, when compared to the control, in tests of oviposition preference.[15] Aqueous extracts of cinnamon leaves and branches (*Melia azedarach* L.), powdered tobacco (*Nicotiana tabacum* L.) and the commercial product Dalneem® (3000 ppm azadirachtin) in the form of emulsifiable oil at 10% concentration caused a reduction in oviposition of *Plutella xylostela* L. (Dequech et al., 2008). Methanol extracts from neem seeds and cinnamon at 2, 4, 6, 8 and 10%, reduced oviposition of *Earias vittella* Fabricius (Gajmer et al., 2002). Aqueous solutions of emulsifiable neem oil reduced the number of eggs laid by *Leucoptera coffeella* on coffee leaves (Martinez and Martinez, 2003). However, further studies should be conducted in order to explore the deterrent or repellent effects of insecticides on *N. elegantalis* oviposition.

In this study, high natural mortality of pre-pupae and pupae was found in the control treatment. However, the soil is the preferred site for *N. elegantalis* pupation, which may have influenced their development, because during the breeding of the pest in the laboratory, this problem is commonly observed (Salas et al., 1991).

The use of toxic baits has been studied for the control of several urban pests and insect vectors of pathogens (Sackmann and Corley, 2007; Müller and Schlein, 2008); however, studies with lepidopteran pests are incipient. Research conducted with adult *N. elegantalis* found that mortality caused by lufenuron and deltamethrin associated with a 10% honey solution increased directly with the evaluation periods (0, 0.5, 1, 2, 12 and 24 h after exposure) for males, females and adults (male and females), reaching 100% mortality at 2 h of observation (França et al., 2009b).

The deterrent effect of insecticides on oviposition can be an important tool to prevent the establishment of pest insect infestations, as well as the use of toxic baits can increase the efficiency of *N. elegantalis* control.

Chemical control is the most used in *N. elegantalis* management, but its effectiveness is limited, particularly due to the pest behavior. The neonate larvae penetrate the fruit quickly, thus protecting themselves from insecticides (Eiras and Blackmer, 2003). Hence, the results obtained in this study will bring new perspectives to the management of *N. elegantalis* in tomato crops in the Agreste region of Pernambuco, by using etofenprox, fenpropathrin and methomyl as ovicidal agents, chlorpyrifos and lambda-cyhalothrin as oviposition deterrents, and lufenuron and deltamethrin in toxic baits. A significant reduction in tomato production losses is expected, and consequently, economic and social benefits for the producers, as well as a better quality product for the consumers.

Conflict of Interests

The authors have not declared any conflict of interests.

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REFERENCES

Abbott WS (1925). A method for computing the effectiveness of insecticides. J. Econ. Entomol. 18:265-267

Arruda-Gatti IC, Ventura UM (2003). Iscas contendo cucurbitacinas para o manejo de *Diabrotica* spp. Semina Ciênc Agrár 24:331-336.

Benvenga SR (2009). *Neoleucinodes elegantalis* (Guenée) (Lep.: Crambidae) em tomateiro estaqueado: dinâmica populacional, nível de controle com feromônio sexual e eficiência de agrotóxicos. Faculdade de Ciências Agrárias e Veterinárias - UNESP. http://base.repositorio.unesp.br/handle/unesp/102319

Blackmer JL, Eiras AE, Souza CLM (2001). Oviposition preference of *Neoleucinodes elegantalis* (Guenée) (Lepidoptera: Crambidae) and rates of parasitism by *Trichogramma pretiosum* Riley (Hymenoptera: Trichogrammatidae) on *Lycopersicon esculentum* in São José de Ubá, RJ, Brazil. Neotrop. Entomol. 30:89-95.

Charmillot PJ, Pasquier D, Salamin C, Ter-Hovannesyan A (2007). Ovicidal and larvicidal effectiveness of insecticides applied by dipping apples on the small fruit tortrix *Grapholita lobarzewskii.* Pest Manag. Sci. 63:677-681.

Cook SM, Khan ZR, Pickett JA (2007). The use of push-pull strategies in integrated pest management. Annu. Rev. Entomol. 52:75-400.

Dequech STB, Egewarth R, Sausen CD, Sturza VS, Ribeiro LP (2008). Ação de extratos de plantas na oviposição e na mortalidade da traça-das-crucíferas. Ciên. Rural 39:551-554.

Eiras AE, Blackmer JL (2003). Eclosion time and larval behaviour of the tomato fruit borer, *Neoleucinodes elegantalis* (Guenée) (Lepidoptera: Crambidae). Sci. Agric. 60:195-197.

Fernández S, Salas J (1985). Estúdios sobre la biologia del perfurador del tomate *Neoleucinode elegantalis* Guenee (Lepidoptera: Pyraustidae). Agron. Trop. 35:77-82.

Foster SP, Harris MO (1997). Behavioral manipulation methods for insect pest-management. Annu. Rev. Entomol. 42:123-46. 10.1146/annurev.ento.42.1.123

França SM, Oliveira JV, Oliveira CM, Picanço MC, Lôbo AP (2009a). Efeitos ovicida e repelente de inseticidas botânicos e sintéticos em *Neoleucinodes elegantalis* (Guenée) (Lepidoptera: Crambidae). Bol San Veg Plagas 35:649-655.

França SM, Oliveira JV, Picanço MC, Lôbo AP, Silva EM, Gontijo PC (2009b). Seleção de atrativos alimentares e toxicidade de inseticidas para o manejo da broca-pequena-do-tomateiro. Pesqu Agropecu Bras. 44:561-568.

Gajmer T, Singh R, Saini RK, Kalidhar SB (2002). Effect of methanolic extracts of neem (*Azadiractha indica* A. Juss) and bakain (*Melia azedarach* L.) seeds on oviposition and egg hatching of *Eiras vitella* (Fab.) (Lep., Noctuidae). J. Appl. Entomol. 126:238-243.

Galli JC, Senô KCA, Cividanes FJ (2004). Dinâmica populacional de crisopídeos (Neuroptera: Chrysopidae) associados a pomares de goiaba *Psidium guajava* L. com dois sistemas de pulverizações de fenthion. Bol San Veg Plagas. 30:197-202.

Gravena S, Benvenga SR (2003). Manual prático para manejo ecológico de pragas do tomate. Gravena-Man Ecol. LTDA: Jaboticabal.

Gullan PJ, Cranston PS (2007). The insects: an outline of entomology. Willey-Blackwell: London.

IBGE- Instituto Brasileiro de Geografia e Estatística (2012). Levantamento sistemático da produção agrícola, tomate: produção e área 2011. Available from: http:www.sidra.ibge.gov.br. [Accessed 04 December 2012].

IBGE- Instituto Brasileiro de Geografia e Estatística (2015). [internet] Levantamento sistemático da produção agrícola, tomate: produção e área. Available from: http:www.sidra.ibge.gov.br. [Accessed 08 Agosty 2015].

IRAC-BR (2012). Comitê Brasileiro de Ação à resistência a inseticidas. Available from: http://www.irac-br.org.br/ [accessed 20 December 2012].

Lima MF, Boiça Jr. AL, Souza RS (2001). Efeito de inseticidas no controle da broca pequena *Neoleucinodes elegantalis* na cultura do tomateiro. Rev. Ecossist. 26:54-57.

Martinez SS, Martinez AA (2003). Redução da oviposição e da sobrevivência de ovos de *Leucoptera coffella* causadas pelo óleo emulsionável de nim. Man Int Plagas Agroecol. 67:58-62.

Müller GC, Schlein Y (2008). Efficacy of toxic sugar baits againt adult cistern-dwelling *Anopheles claviger.* Trans. R. Soc. Trop. Med. Hyg. 102:480-484.

Neto e Silva OAB, Botton M, Garcia MS, Silva A (2011). Efeito de inseticidas reguladores de crescimento sobre ovos, lagartas e adultos de *Grapholita molesta* (Busk) (Lep.: Tortricidae). Rev. Bras. Frutic. 33:420-428.

Obeng-Ofori D (1995). Plant oils as grain protectants against infestations of *Cryptolestes pusillus* and *Rhyzopertha dominica* in stored grain. Entomol. Exp. Appl. 77:133-139.

Picanço MC, Guedes RNC (1999). Manejo Integrado de Pragas no Brasil: situação atual, problemas e perspectivas. Ação Ambiental 2:23-26.

Picanço MC, Marquini F (1999). Manejo integrado de pragas de hortaliças em ambiente protegido. Inf Agropec. 20:126-133.

Picanço MC, Bacci L, Crespo ALB, Miranda MMM, Martins JC (2007). Effect of integrated pest management practices on tomato production and conservation of natural enemies. Agric. For. Entomol. 9:327-335.

Potts L (1999) Feeding stimulants and semiochemicals as pest management tools. [accessed 27 December 2012]. Available from: http://www.colostate.edu/Depts/Entomology/courses/en507/papers_1999/potts.htm.

Sackmann P, Corley JC (2007). Control of *Vespula germanica* (Hym. Vespidae) populations using toxic baits: bait attractiveness and pesticide efficacy. J. Appl. Entomol. 13:630-636.

Sáenz-De-Cabezón FJ, Pérez-Moreno L, Zalom FG, Marco V (2006). Effects of Lufenuron on *Lobesia botrana* (Lepidoptera: Tortricidae) egg, larval, and adult stages. J. Econ. Entomol. 99:427-43.

Salas J, Alvarez C, Parra A (1991). Contribuicion al conocimiento de la ecologia del perforador del fruto del tomate *Neoleucinodes elegantalis* Guenée (Lepidoptera: Pyraustidae). Agron. Trop. 41:275-284.

Santos MAT, Areas MA, Reyes FGR (2007a). Piretróides – uma visão geral. Alim. Nut. 18:339-349. 0103-4235

Santos VMR, Donnici CL, Dacosta JBN, Caixeiro JMR (2007b). Compostos organofosforados pentavalentes: histórico, métodos sintéticos de preparação e aplicações como inseticidas e agentes antitumorais. Quim. Nova 30:159-170.

Saour G (2008). Effect of triacloprid against the popato tuber moth *Phthorimaea operculetta* Zeller (Lepidoptera: Gelechiidae). J. Pest Sci. 81:3-8.

SAS Institute (1999-2001). SAS/STAT User’s guide, version 8.02, TS level 2MO. SAS Institute Inc., Cary, NC.

Toledo AA (1948). Contribuição para o estudo da *Leucinodes elegantalis* Guen., praga do tomate. Biológico 14:103-108.

Witzgall P, Stelinski L, Gut L, Thomson D (2008). Codling moth management and chemical ecology. Annu. Rev. Entomol. 53:503-522.

Zucchi RA, Silveira NS, Nakano O (1993). Guia de identificação de pragas agrícolas, FEALQ: Piracicaba.