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Management of *Neoleucinodes elegantalis* (Lepidoptera: Crambidae) in Tomatoes Using Mating Disruption and Attract and Kill

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ABSTRACT

The mating disruption technique has been widely used for the control of several lepidopteran pests. In the present study, we assessed the efficiency of two formulations of SPLAT Neo, a wax emulsion containing E-11-hexadecenol, with and without the insecticide cypermethrin, in affecting mating disruption of *Neoleucinodes elegantalis* (Guenée). We also determined the best phenological age or stage of the crop for the application of the pheromone formulation, based on its effectiveness in reducing injuries on tomato fruits. We performed two field trials. The first field trial had three treatments: (1) Areas treated once (30 days after transplanting seedlings) with SPLAT Neo (mating disruption, formulation without cypermethrin); (2) Areas treated once with SPLAT Cida Neo (attract and kill, formulation with cypermethrin), and (3) Control plots, i.e. areas treated with the growers' pest management procedures, based on pre-scheduled calendar applications of conventional insecticides. The use of SPLAT Neo with and without cypermethrin resulted in a significant season-long reduction of the average number of *N. elegantalis* eggs throughout the tomato cycle, compared to the control. Areas that received two SPLAT Neo applications had a lower number of males captured by monitoring pheromone traps, a lower number of eggs laid in the field, and significantly lower levels of fruit injury at pre, first, and second tomato harvests. The crop subjected to a single SPLAT Neo application, however, experienced reduction in fruit injury only at the second harvest. Our data suggest that two SPLAT Neo applications promote efficient control of *N. elegantalis*, resulting in significant reduction of fruit damage in tomato.

Keywords: Behavioral control, Pheromone release technology, Sexual pheromone, SPLAT, Tomato phenology.

INTRODUCTION

The small tomato borer, *Neoleucinodes elegantalis* (Guenée) (Lepidoptera: Cambridae), is considered a key pest of tomato, severely infesting the fruit, rendering them unsuitable for consumption and industrial processing (Gravena and Benvenga, 2003). It occurs in virtually all staked and crawling tomato producing regions in Brazil, having as host plants all the solanaceous fruits such as brinjal, jilo, joa, jurubeba and pepper (Zucchi *et al*., 1993). Its control has been carried out almost exclusively with the use of synthetic insecticides (Reis and Souza, 1996), which are most often applied in an indiscriminate way, without any regard to the principles of ecological pest management. Furthermore, chemical control has limited effectiveness, mainly due to the habit of the pest, whose neonate larvae promptly penetrate into the fruit, protecting themselves from insecticides and natural enemies (Eiras and Blackmer, 2003). Thus, the use of other

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control tactics that optimize the management of this pest has been broadly required.

The mating disruption technique has been widely used for the control of lepidopteran pests in recent decades. Its success was observed in the control of the oriental fruit moth, *Grapholita molesta* Busck, in apples and peaches (Stelinski *et al*., 2007; Pastori *et al*., 2008; Härter *et al*., 2010), of the codling moth, *Cydia pomonella* (L.) (Stelinski *et al*., 2007; Stelinski *et al*., 2009; Knight *et al*., 2012) and of the citrus leafminer, *Phylllocnistis citrella* Stainton (Stelinski *et al*., 2010). This method consists of distributing a large amount of synthetic sex pheromone in the field, aiming to prevent the male from finding a female, disrupting mating and, consequently, preventing the emergence of new generations of the pest in the treated area (Cardé and Minks, 1995; Witzgall *et al*., 2008).

The use of sex pheromones in pest control has several advantages over conventional chemical control, including the absence of toxicity to humans and other vertebrates, and high specificity to the target pest species. Furthermore, sex pheromones lead to behavioral responses in target insect pests within a few minutes. Another advantage, in contrast to the use of insecticides, is that the effectiveness of mating disruption increases over sequential use over the years, resulting in increased reduction of pest density (Witzgall *et al*., 2008; Stelinski *et al*., 2009). This technique, when used with long-lasting flowable formulations like SPLAT, also presents the possibility of mechanical application through adapted spray equipment, which may perform the application in two rows of grape vines simultaneously, optimizing its use (Teixeira *et al*., 2010).

Thus, the objectives of this study were to evaluate the efficiency of a component of *N. elegantalis* sex pheromone formulated in SPLAT in promoting mating disruption, the best suitable phenological age in tomatoes for the application of the disruption formulation, and the level of *N. elegantalis* mating disruption efficiency and related prevention of fruit injuries.

MATERIALS AND METHODS

Formulation Used

The SPLAT® formulation (Specialized Pheromone Technology and Lure Aplication) was developed and patented by ISCA Technologies (Riverside, California, USA), consisting of an amorphous and pasty emulsion composed of wax, oil, and water, which controls the release of semiochemicals and insecticides. The formulations contain an identified component of the *N. elegantalis* sex pheromone, with or without insecticide.

SPLAT Treatment

SPLAT treatment was carried out in commercial crawling tomato crops, variety TY, spaced 0.6×3 m, in the town of Bezerros (2011) (08° 09'14, 1" S; 35° 43'29, 2" W and 462.9 m asl). An area of 3 ha was used, divided into three sub-areas containing the following treatments: (a) SPLAT Cida Neo- (SPLAT Neo with Cypermethrin+grower's treatments); (b) SPLAT Neo+ grower's treatments, and (c) Control (growers' treatment), which was based on insecticide applications at pre-established schedules. Treatment plots were spaced 50 m from the control plot, isolated by a barrier of native vegetation (Savanna hyperxerophilic), believed to aid in the prevention of the invasion of gravid *N. elegantalis* females. There was a distance of 40 m between treatments. SPLAT Neo formulations were applied manually with the aid of a manual SPLAT applicator 30 days after transplanting, i.e. during first tomato bunches. The application was performed at 3,000 point sources ha^{-1} of SPLAT Cida Neo or SPLAT Neo, which resulted in one in every three plants receiving a point source. At the edges of the treatments (approximately 10 m) were applied 10% more point sources, aiming to reduce possible edge effects, common in this type of experiment (Mafra-Neto, 2005). Each point source applied to the plants contained ~1 g of the product applied at the pointer of the branches near the inflorescence. Egg counts were carried out weekly on tomato bunches, with fruit size of approximately 2 cm in diameter. According to Blackmer *et al*. (2001), under field conditions, *N. elegantalis* lays 89% of the eggs on small tomato fruits of about 2.3 cm diameter. For the egg count, eight sites per treatment (four sites at the edge and four at the center of the plot) were evaluated. Each point of evaluation was composed of five sequential plants, which were duly marked with ribbons and cards. In each plant, a bunch with five fruits was evaluated, totaling 25 fruits examined per plot. The eggs were collected with the aid of a fine-tipped brush dipped in water, and transferred to a Petri dish containing moist filter paper. The Petri dishes were sealed with plastic film and packed in plastic boxes, which were taken to the Laboratory of Agricultural Entomology, UFRPE, where the eggs were quantified with the aid of a stereoscopic microscope. To verify the injuries caused by *N. elegantalis*, the harvest of damaged and undamaged fruits was performed in six rows of 50 m of length per treatment, which were distributed three rows at the center and three at the edges, totaling 300 linear meters per treatment.

Monitoring N. elegantalis

The monitoring of *N. elegantalis* population dynamics was conducted in a commercial crop with 3 ha of crawling tomato, variety TY, in the town of Camocim de São Félix, PE, during the crop cycle, in 2011. Four delta traps baited with a septa containing the sex pheromone BIO NEO® (Biocontrol, Pest Control Methods Ltda., São Paulo) were installed per hectare. Traps were properly identified and distributed two at the center and two at the edges, fixed on wooden stakes 1.5 m in height, always 15-30 cm above the plant canopy and with the trap's openings facing the direction from which the wind was coming.

Double SPLAT Treatment

This was carried out in a commercial field with 3 ha of crawling tomato, variety TY, in the town of Camocim de São Félix, PE, from November 2011 to February 2012. Each treatment occupied an area of 1 ha spaced 50 m from each other. The treatments including tomato cultivar, product application, density of point sources and the methodology used were similar to those of experiment 1; however, SPLAT formulations were applied twice, the first application at 20 days after transplanting (early flowering) and the second at 30 days (with the first bunches of fruit). To evaluate the level of disruption of male orientation to pheromone sources, we used four plastic delta traps (28×20×15 cm) (ISCA Tecnologias, Ltda, Ijui, RS) lured with rubber septa impregnated with the synthetic sex pheromone of the pest per treatment, 25 m apart from each other. The septa were replaced every 45 days and the floor containing adhesive glue was replaced as needed. Trap catches were tabulated weekly. Methodology of egg count and quantification of fruit injury was as described in Field Trial 1.

Statistical Analysis

We used a completely randomized design consisting of three treatments, each divided into eight sampling units. The number of eggs collected was analyzed by multivariate repeated measures over time ($P< 0.05$) (PROC ANOVA specifying PROFILE) (SAS Institute, 2001). The sampling dates (7, 14, 21, 28, 35, 42, and 49 days after treatment) were considered repeated measures in this analysis, as eggs were sampled several times and on the same plants in the same area (Green, 1993; Paine, 1996), thus, avoiding the problem of "pseudo-replication" over time (Stewart-Oaten *et al*., 1986; Green, 1993). The number of eggs and adults collected weekly and of fruits with injuries was subjected to analysis of variance. For number of eggs and males collected, analysis of variance was done after a square-root (x+0.5) transformation of the data. Means were compared by Tukey test, 5% probability, using SAS version 8.02 (PROC GLM SAS Institute, 2001).

RESULTS

SPLAT Treatment

The number of *N. elegantalis* eggs was high in all the treatments during the first evaluation, seven days after treatment. SPLAT Cida Neo caused significant reduction in oviposition (F= 6.09, P= 0.008) compared to the control (Figure 1) (HSD Tukey at 5% significance). This effect was not observed for SPLAT Neo in the first evaluation. From the following evaluation onwards, both SPLAT treatments showed significant reductions in oviposition, compared to the control (F= 15:46, P< 0.0001) (Figure 2). There was, however, a directly proportional relationship between the number of eggs and the days after SPLAT application, from 14 days after product application (Figure 1).

Repeated measure analysis over time allowed the time effect and its interactions in treatments to be interpreted. All interactions between treatments (SPLAT Cida Neo and SPLAT Neo) and time (days after SPLAT treatment) were significant (F= 2.37, P= 0.02) in reducing the number of *N. elegantalis* eggs. Also, there was a significant effect of time (days after SPLAT treatment) (F= 37.25, P<0.0001) and treatment (F= 14.45, P= 0.0004).

Fruit crop injury caused by *N. elegantalis* in field trial 1 did not differ among treatments in the first harvest. At the second harvest, there was no significant difference between SPLAT treatments, but both SPLAT treatments significantly reduced fruit injuries when compared with the control (Table 1).

Monitoring N. elegantalis

The presence of *N. elegantalis* in pheromone baited traps was observed since

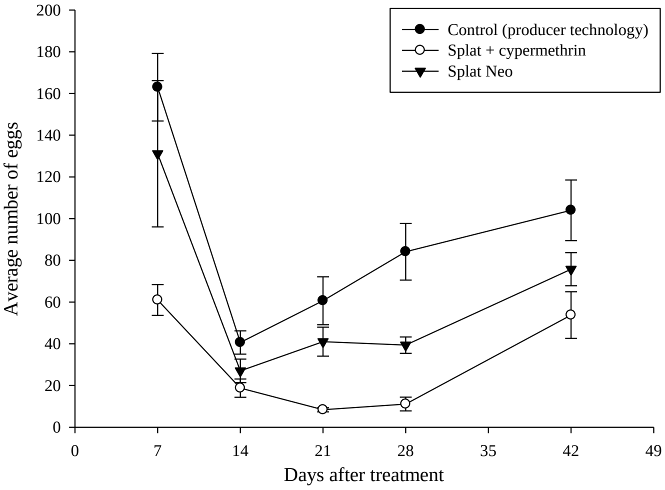

Figure 1. Number of *Neoleucinodes elegantalis* eggs during the development of crawling tomato, variety TY, submitted to emulsified wax (SPLAT Cida Neo and SPLAT Neo), carried out 30 days after transplanting or conventional control (Bezerros, PE, 2011).

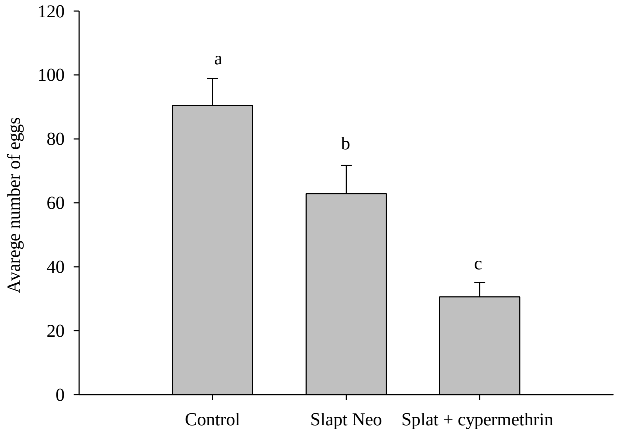

Figure 2. Average number of *Neoleucinodes elegantalis* eggs during the tomato crop cycle variety TY, treated a single application of either SPLAT Cida Neo or SPLAT Neo 30 days after transplanting and treated with conventional control (grower's pest management program). Columns with the same letter do not differ significantly by Tukey test (P< 0.05) (Bezerros, PE, 2011).

the onset of fruiting. There was an increase in the number of males caught in monitoring traps, starting when the plants started growing the third tomato bunches, 46 days after transplantation. The number of captured males gradually increased until it reached a peak at 78 and 86 days (Figure 3).

Double SPLAT Treatment

Both SPLAT treatments caused complete pheromone trap shutdown in the first evaluation at 7 days after treatment, whereas the control monitoring traps captured 4.75 males per trap (Figure 4). At the first evaluation, 7 days after treatment, no eggs were observed in any of the treatments (Figure 5).

A significantly lower number of *N. elegantalis* males were captured in areas treated with SPLAT Cida Neo and SPLAT Neo than in the conventional control areas throughout the evaluation period (49 days) (F= 38.05, P< 0.0001). Trap captures in the SPLAT Cida Neo treatment showed a population peak in the third and last evaluations, carried out at 41 and 69 days after transplanting (21 and 49 days after the first treatment) (Figure 4). In general, the average number of collected males was 8.17 insects per trap per day in the control, 1.32 in SPLAT Cida Neo, and 0.79 in SPLAT Neo, confirming that the pheromone was effective in disrupting *N. elegantalis* male orientation, as the capture was reduced by 83.84% in SPLAT Cida Neo and 90.45% in SPLAT Neo.

Repeated measure analysis over time allowed the time effect and its interactions in treatments to be interpreted. All interactions between treatments (SPLAT) and time (days after SPLAT treatments) were significant (F= 12.67, P< 0.0001) in reducing the number of *N. elegantalis* eggs. Also, there was a significant effect of time (F= 11.18, P< 0.0001) and treatment (F= 53.71, P< 0.0001) (Table 1).

The use of SPLAT significantly reduced the egg collection when compared to the control, except at the first evaluation (7 days after the first treatment), in which the SPLAT Cida Neo caused no significant reduction in the number of eggs (F = 2.79, P = 0.08).

It was also observed that the number of eggs in the SPLAT Cida Neo treatment was higher than that of the SPLAT Neo throughout all the evaluations (Figure 5) (Tukey's test, P< 0.05), although the mean

Table 1. Percentage of damaged and undamaged fruits (means±SE) by *Neoleucinodes elegantalis* in the 1st and 2nd harvests in tomato crops treated either with SPLAT Cida Neo, SPLAT Neo, or conventional control.[a]

Single application (27 days after transplanting)			
	Treatments	Undamaged fruits± *SE* (%)	Damaged fruits±*SE* (%)
1st Harvest	Control	34.34 ± 1.01a	65.66 ± 1.01a
	SPLAT Cida Neo	32.64 ± 0.69a	67.36 ± 0.69a
	SPLAT Neo	40.21 ± 3.47a	59.79 ± 3.47a
2st Harvest	Control	59.44 ± 0.56b	40.55 ± 0.56a
	SPLAT Cida Neo	81.13 ± 4.18a	18.67 ± 4.28b
	SPLAT Neo	81.31 ± 1.38a	19.39 ± 1.04b
Causes of variation	*DF*	*F*	*P*
Among treatments	2	14.45	0.0004
Time	4	37.25	< 0.0001
Time×Treatment	8	2.37	0.02
Wilks' Lambda value= 0.029			
Double application (20 and 30 after transplanting)			
	Treatments	Undamaged fruits± *SE* (%)	Damaged fruits±*SE* (%)
1st Harvest	Control	40.28 ± 6.53b	59.75 ± 6.52a
	SPLAT Cida Neo	67.94 ± 6.62a	32.06 ± 6.62b
	SPLAT Neo	67.68 ± 2.67a	32.32 ± 2.67b
2st Harvest	Control	73.17 ± 3.17b	26.82 ± 3.17a
	SPLAT Cida Neo	86.74 ± 3.27a	13.26 ± 3.27b
	SPLAT Neo	91.90 ± 1.77a	8.10 ± 1.89b
Causes of variation	*DF*	*F*	*P*
Among treatments	2	53.71	< 0.0001
Time	5	11.18	< 0.0001
Time×Treatment	10	12.67	< 0.0001
Wilks' Lambda value= 0.14			

[a] The same letters in the same column, for the harvests, do not differ significantly by Tukey test at 5% probability.

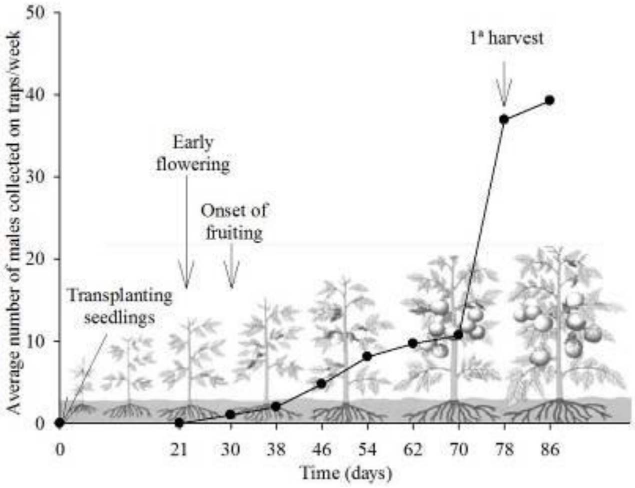

Figure 3. Population fluctuation of *Neoleucinodes elegantalis*. Number of males captured per week in delta traps baited with the pheromone BioNeo® in crawling tomato crops, variety TY (Camocim de São Félix, PE, 2011).

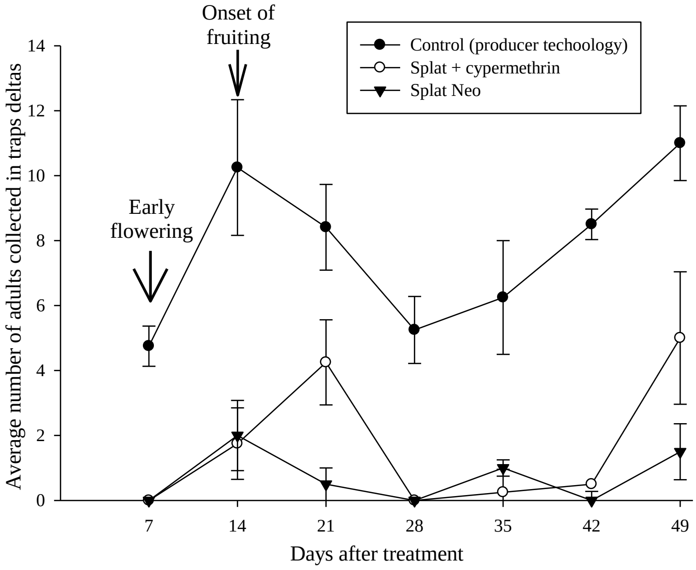

Figure 4. Average number of *Neoleucinodes elegantalis* males collected in delta traps on tomato, variety TY, submitted to emulsified wax (SPLAT Cida Neo and SPLAT Neo), 20 and 30 days after transplanting and treated with conventional control (grower's pest management program) (Camocim de São Félix, PE, 2011 - 2012).

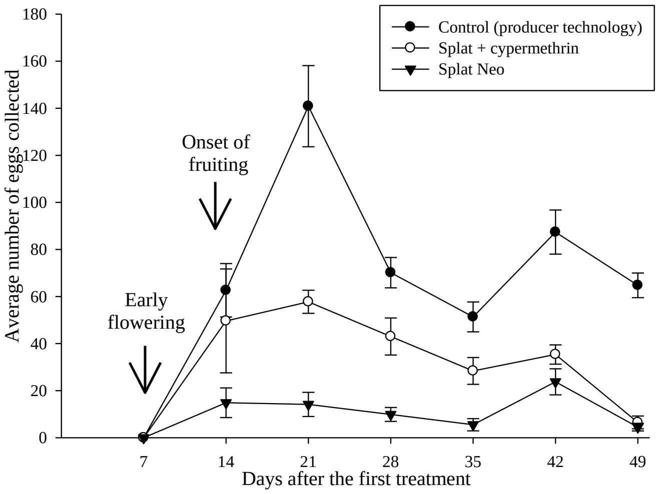

Figure 5. Average number of *Neoleucinodes elegantalis* eggs during the development of crawling tomato, variety TY, exposed to emulsified wax (SPLAT Cida Neo and SPLAT Neo), 20 and 30 days after transplanting (Camocim de São Félix, PE, 2011 - 2012).

number of eggs had been significantly reduced in both treatments (Figure 6).

At the first harvest, a significant reduction in injuries on the fruits was observed, which reached 32.06% (±6.62) and 32.32% (±2.67) in the treatments submitted to SPLAT Cida Neo and SPLAT Neo, respectively, compared to the control. In the second harvest, the reductions in injuries were 65.66% (±1.01) and 67.36% (±0.69), in the treatments submitted to SPLAT Cida Neo and SPLAT Neo, respectively, corresponding to three times less damaged fruit than the control (Table 1).

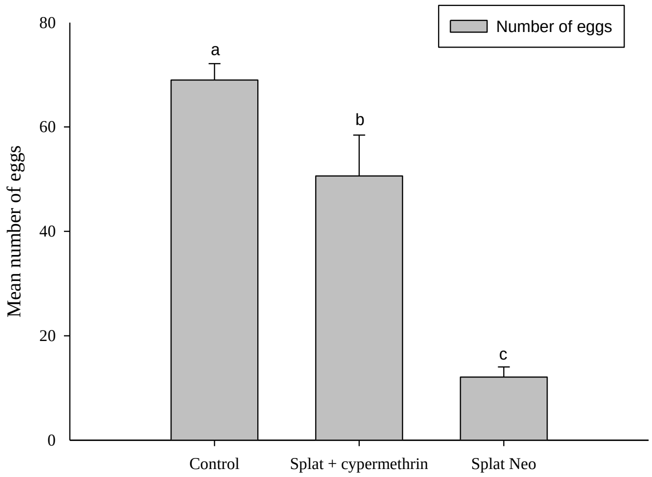

Figure 6. Average number of *Neoleucinodes elegantalis* eggs during the development of crawling tomato, variety TY, exposed to emulsified wax (SPLAT Cida Neo and SPLAT Neo), and control (producer's technology), 20 and 30 days after transplanting (Camocim de São Félix, PE, 2011-2012). Columns with different letters present significant difference by Tukey test ($P< 0.05$).

DISCUSSION

The density of pheromone point sources per area is an important factor for the efficiency of male mating disruption, as it will influence the mechanisms involved in this process. Thus, in the present work, the high population density and the behavioral peculiarities of *N. elegantalis* led to the decision to apply a high dispenser density (3000 sites /ha). Several mechanisms can explain communicational disruption, including false-plume-following, camouflage, nervous system desensitization including adaptation and habituation, sensory imbalance, and combinations thereof (Miller *et al*., 2006). However, our field data did not elucidate which mechanism might be responsible for mating disruption in *N. elegantalis*.

In general, it was found that the higher the number of dispensers, the lower the number of males captured in traps and, therefore, the greater the efficiency of the mating disruption program (Bohnenblust *et al*., 2011). Härter *et al*. (2010) achieved an efficient control of *G. molesta* in peach, using 1,000 pheromone point sources ha^{-1} (SPLAT® emitters), reducing the males captured in traps and the damage caused by this pest. Pastori *et al*. (2008) tested 1000 release sites (SPLAT® emitters) of the *Bonagota salubricola* Meyrick pheromone, associated with the *G. molesta* pheromone in apple orchards. This treatment reduced the male captures of both species only in the first season, as the reduction in the following cycle was only observed for *G. molesta*. Still, this reduction in male capture, in this case, was not reflected in a reduction in the damage caused by the pest. The same happened with the millet stem borer, *Coniesta ignefusalis* Hampson, according to Youm *et al*. (2012). They achieved a 99% suppression in capture of male millet stem borer in pheromone monitoring traps with the application of 400 polyethylene vials loaded with 0.5 mg pheromone/ha replaced every 21 days in 0.5 ha plots. However, the sampling of the central portions of these plots before and after harvest showed no significant differences in infestation, damage, or yield loss between plots treated with pheromone and untreated plots. This was possibly due to a large border effect in these small plots, fostering the oviposition by gravid females in most of the plot area.

The data seem to support the hypothesis that suppressing mating early on, at first flowering stage, might be important to effectively suppress *N. elegantalis* in tomato fields. But the density of release points, the pheromone dosage, or both, may also play an important role in pest suppression. Thus, further bioassays should be conducted to study the effect of the timing of SPLAT Neo application, point source density, pheromone dose and their interaction in order to achieve a highly effective suppression of *N. elegantalis* in commercial tomato fields. In Michigan, it was shown that a single mechanical application of SPLAT-OFM very early in the season not only achieved nearly complete trap shutdown all the way to harvest, but it also completely disrupted mating, measured with tethered *G. molesta* virgin females in treated apple orchards (Stelinski *et al*., 2007).

Another aspect to be considered is the fact that the pheromone release rate by some prototype SPLAT formulations falls exponentially over time (Stelinski *et al*., 2007, Stelinski *et al*., 2009, Knight *et al*., 2012). A reduction in the emission rate of *N. elegantalis* sex pheromone by the SPLAT Neo formulations as they aged in the field could explain the observed increase in the number of eggs throughout the evaluations over time in our trials. Fernández and Salas (1985) reported that the *N. elegantalis* development period from egg to adult was ~30 days and the pre-oviposition period was 3.84 days, in a study conducted in tomato fruits. The observed increase in *N. elegantalis* infestation at 78 days after transplanting could be a consequence of the development and egg-laying of the untreated first *N. elegantalis* generation to invade the crop.

Another possibility that can be considered is the occurrence of mated female immigration from outside the treated area. According to Cardé and Minks (1995), the immigration ability, aiming at the entry capacity of mated females coming from outside the treated area, can be a big problem for this technique that only prevents mating. Although the high levels of mating disruption in the area under the sex-pheromone influence result in extremely low levels of mating in the local pest population, they do not protect the area from the immigration of gravid females from outside populations. The effect of the immigration of gravid females is higher along the edges of the field, and the size of the edge correlated with the ability of the species to disperse. When gravid females are abundant and highly mobile, the edge effect is high, and edges where oviposition and larval damage is observed can be extensive. In cases of large edge effect, mating disruption will likely fail when there is no strong geographic isolation (geographic barriers) between populations; for example, if used in small plots by a producer in an area that is not isolated from other commercial tomato fields. Witzgall *et al*. (2008) observed that programs in larger areas of 100 or more hectares of treated orchards seemed to lead to effective mating disruption programs due to the reduced effect of gravid female migration. Still, besides the small treated areas, our results in this study indicate that mating disruption of *N. elegantalis* was successfully achieved with SPLAT Neo, because the levels of fruit injury were generally lower in mating disruption and attract and kill treatments, compared with the tomato plots treated only with conventional synthetic insecticides. This indicates that mating disruption using SPLAT Neo, with or without the addition of insecticide in the formulation, was effective in the management of *N. elegantalis*. This type of dispenser reduced by half the damage caused by *G. molesta* in apple orchards (Stelinski *et al*., 2007) and the use of the mating disruption method in this culture has led to a reduction in damage caused by *C. pomonella* and *G. molesta* (Bohnenblust *et al*., 2011; Knight *et al*., 2012).

In this work, we also tested SPLAT Cida Neo, i.e. SPLAT formulations containing pheromone and small doses of the insecticide cypermethrin. In our trials, we did not observe a consistent effect of SPLAT Cida Neo: the formulation applied only during the cycle reduced all the evaluated pest population parameters; however, this reduction was not observed when SPLAT Cida Neo was applied twice during the tomato production cycle. The failure of the double SPLAT Cida Neo application treatment may be explained by the chance positioning, due to randomization of all the treated plots at the edges of the treated fields. These double SPLAT Cida Neo plots probably suffered higher pressure from outside-mated female migration than any other plots, therefore causing this treatment to receive a higher load of viable eggs over time than the other treatments with at least some of the plots protected from strong edge effects.

It is clear that the edge effect is higher when neighbor pest populations are high, and that mating disruption performs better at low pest densities (e.g., see Cardé and Minks 1995). Teixeira *et al*. (2010) observed that the larval infestation of grape bunches by *Paralobesia viteana* Clemens was larger at the edges than inside the vineyards, in crops treated with different densities of SPLAT-GBM applied mechanically.

But despite these unfavorable settings, the results of this study indicate that both SPLAT Neo and SPLAT Cida Neo treatments effectively disrupt mating of *N. elegantalis* in the field. This is the first record of the successful use of a commercial sex pheromone mating disruption formulation for the management and control of small tomato borer in open tomato fields. Moreover, the use of these two formulations, namely, SPLAT Neo and SPLAT Cida Neo, have several advantages over the exclusive use of conventional pesticides for pest control, including low cost, biodegradability, water and sunlight resistance, lack of drift, field longevity, and the possibility of mechanical application (Stelinski *et al*., 2007, 2010). We conclude, therefore, that the application of SPLAT Neo or SPLAT Cida Neo had positive effects in reducing tomato fruit injury in open commercial tomato fields, and that the mating disruption technique using these products will prove to be a promising tool for the management of the small tomato borer in Brazil, more specifically, in the Agreste region of Pernambuco.

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مدیریت آفت بال پولک دار *Neoleucinodes elegantalis* در گوجه فرنگی با اختلال در جفت یابی وروش جلب و نابودی

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چکیده

برای مبارزه با چندین آفت بال پولک دار، روش اختلال در جفت یابی به گونه ای گسترده به کار رفته است. در پژوهش حاضر، کار آیی دو فرمولاسیون SPLAT Neo (یک امولسیون مومی حاوی E-11-hexadecenol با و بدون حشره کش cypermethrin) در ایجاد اختلال در جفت یابی حشره Neoleucinodes elegantalis (Guenée) ارزیابی شد. همچنین، بهترین سن فنولوژیکی یا مرحله رشد گیاه برای مصرف فرمولاسیون فرمون (pheromone) بر مبنای تاثیر بر کاهش صدمات روی میوه های گوجه فرنگی مشخص شد. به این منظور دو آزمون صحرایی اجرا شد. اولین آزمون سه تیمار داشت: (۱) یک نوبت تیمار کردن سطح مورد نظر ۳۰ روز بعد از نشا ء گیاهچه ها با SPLAT Neo (برای ایجاد اختلال در جفت یابی با استفاده از فرمولاسیون بدون cypermethrin)، (۲) یک نوبت تیمار کردن با SPLAT Cida Neo (برای جلب و نابودی حشره با فرمولاسیون حاوی cypermethrin)، و (۳) کرت های شاهد که در آن ها یک نوبت مبارزه با آفت به روش خود کشاورزان بر مبنای برنامه ریزی تقویمی مصرف حشره کش های سنتی انجام شد. نتایج نشان داد که در مقایسه با تیمار شاهد، کار برد SPLAT Neo با و بدون cypermethrin منجر به کاهش معنا دار تعداد میانگین تخم *N. elegantalis* در طول فصل رشد گوجه فرنگی شد. در قسمت هایی که SPLAT Neo در دو نوبت مصرف شده بود تعداد حشره نر محبوس در تله فرمون و تعداد تخم حشره در مزرعه کمتر بود، و صدمات به میوه های گوجه فرنگی در قبل از برداشت، و دربرداشت اول و دوم به طور معنا داری کاهش داشت. با این همه، گیاهانی که یک نوبت تیمار SPLAT Neo دریافت داشتند فقط در برداشت دوم صدمه کمتری در میوه ها نشان دادند. این نتایج حاکی از آن است که مصرف SPLAT Neo در دو نوبت باعث افزایش کارایی مبارزه با *N. elegantalis* و کاهش معنادار صدمات به میوه گوجه فرنگی می شود.