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CHEMICAL CONTROL OF THE POTATO TUBER MOTH *PHTHORIMAEA OPERCULELLA* (ZELLER) ON TOBACCO

T. VANEVA-GANCHEVA[1]* and Y. DIMITROV[2]
[1] *Institute of Tobacco and Tobacco Products, BG - 4108 Markovo, Bulgaria*
[2] *Agricultural University, Faculty of Plant Protection and Agroecology, Department of Entomology, BG - 4000 Plovdiv, Bulgaria*

Abstract

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For the purpose of assessing the potential of chemical compounds belonging to different groups (acetamiprid, deltamethrin, imidacloprid and chlorpyrifosethyl + cypermethrin – registered to be used on tobacco in Bulgaria and also indoxacarb and chlorantraniliprole – not registered) to control the attacks of the potato tuber moth *Phthorimaea operculella* (Zeller) on tobacco, their ovicidal and larvicidal effects have been established under laboratory conditions. Their biological efficiency has also been assessed under field conditions by controlling the extent of the damages caused to the tobacco. Depending on the degree of influence on the eggs, the analyzed substances rank as follows: chlorpyrifosethyl+cypermethrin > deltamethrin > acetamiprid > indoxacarb > imidacloprid > chloranrhaniliprole. Chloranrhaniliprole, chlorpyrifosethyl+cypermethrin and deltamethrin demonstrate the fastest and the strongest effect on the young larvae of the potato tuber moth > 90% mortality. Indoxacarb and acetamiprid also achieve a high mortality rate of > 90% but the effect is slower. Imidacloprid demonstrates the weakest larvicidal effect during the laboratory testing. In accordance with the effectiveness, which is based on the control over the extent of damages under field conditions, the active substances rank as follows: chlorantraniliprole > indoxacarb > deltamethrin > chlorpyrifosethyl+cypermethrin > acetamiprid > imidacloprid. Chlorantraniliprole and indoxacarb provide the most effective and the longest control on the potato tuber moth but, unfortunately, they have not been registered on tobacco. Of all the active compounds registered to be used on tobacco, deltamethrin and chlorpyrifosethyl+cypermethrin can be successfully applied during the attacks of the potato tuber moth and to exercise mutual control over tobacco pests. Acetamiprid and imidacloprid can be applied together to control tobacco pests and also during the attacks of the potato tuber moth in the initial stages after planting, i.e. as the period of protection of the tobacco plants is extended, the extent of damages increases.

Key words: tobacco, chemical control, *Phthorimaea operculella* (Zeller)

Introduction

The potato tuber moth *P. operculella* is one of the most important pests on potatoes and acts as a pest on tobacco (Bennet et al., 1999; Kroshel, 2006, Vuuren et al., 1998). Over the last few years, the potato tuber moth has been annually found in the tobacco agrocenosis (Vaneva and Dimitrov, in preparation). The control over this species is very difficult owing to its high reproductive capacity, its polyvolatility and adaptability towards the seasonal changes of the weather conditions. In literature there has been a debate on the application of an integrated approach for prevention and control over the attacks of the potato tuber moth on its main host – potatoes (Clough et al., 2010; Kroschel, 2006; Schreiber et al., 2010). Chemical control is difficult to be exercised due to the latent feeding of the caterpillars and the ability of the species to develop resistance towards the traditional organophosphorous, carbamate and pyrethroid insecticides (Hafez, 2011; Doğramaci et al., 2008; (Llanderal-Cázares et al., 1996; Collantes et al., 1986; Richardson and Rose, 1967; Champ and Shepherd, 1965) cited by Kroschel (2006). Therefore, we need to make further tests in order to clarify certain issues related to the possibilities for exercising an adequate control over this species on tobacco. In spite of the fact that the application of the agrotechnical and

E-mail: tania_vaneva@abv.bg; dimitrov_ento@abv.bg

biological approaches reduces the mass occurrence of pests, the production of high-quality tobacco is almost impossible without using insecticides. In Bulgaria, there are no registered insecticides to be used in the fight against the potato tuber moth. This species exists in the tobacco agrocenosis throughout the entire vegetation period after planting (Vaneva and Dimitrov, in preparation) when tobacco is also attacked by other pests. This necessitates finding other active compounds that will provide a mutual control over the pests on tobacco and establishing the effectiveness of such compounds on other types of the Gelechiidae family. The purpose of this study is to evaluate the potential of acetamiprid, deltamethrin, imidacloprid and chlorpyrifosethyl+ deltamethrin (registered to be used against other pests on tobacco in Bulgaria) as well as chlorantraniliprole and indoxacarb (not registered on tobacco) to control the attacks of the potato tuber moth on tobacco.

Material and Methods

The following chemical compounds were tested: deltamethrin in a dose of 2.00 g a. i. da^{-1} (Decis 2,5 EK), imidacloprid in a dose of 10.71 g a. i. da^{-1} (Konfidor 70 ВГ), acetamiprid 6.00 g a. i. da^{-1} (Mospilan 20 SP) and chlorpyrifosethyl+cypermethrin in a dose of 35.00+3.50 g a. i. da^{-1} (Nurele D) registered to be used against tobacco trips on tobacco. We also tested the effect of chlorantraniliprole 3.20 g a. i. da^{-1} (Koragen 20 SK) suggested to be used in the fight against *T. absoluta* and also indoxacarb 5.25 g a. i. da^{-1}(Avant 15 SK).

Laboratory testing

The laboratory test was conducted at the laboratory complex of the Institute of Tobacco and Tobacco Products in the town of Plovdiv. The biological material – eggs, caterpillars and pupae of the potato tuber moth, has been provided by growing a population at the laboratory. The caterpillars were fed with potatoes and other caterpillars collected from naturally attacked tobacco plants were added to them.

The ovicidal effect of the tested compounds has been established on eggs 2-3 days after being laid. On a piece of filter paper placed in a Petri dish we put about 50-75 eggs. The eggs were treated with a solution of the respective insecticide made by recalculating the necessary quantity of preparation per 1 liter of water. The treatment was conducted in four repetitions by spraying twice using a sprayer. After the insecticide solution dried, the eggs were placed in a thermostat under a temperature of 25°C. For a period of 7 days after applying the treatment, we daily checked the number of the newly hatched caterpillars and the unhatched eggs. The vitality of the embryo was assessed using a microscope. All the eggs in which the caterpillar was unable to gnaw the chorion were considered to be unhatched. Untreated eggs were used as a control sample. We calculated the mortality rate of the eggs in the variants and the control sample as well.

The larvicidal effect of the tested chemical compounds has been established on caterpillars from the first age group - 1-2 days after being hatched. The tobacco plants of Basmi variety group were treated with a solution of the tested active compounds using a sprayer. The insecticide solution was made by recalculating the necessary quantity of the preparation per 1 liter of water. After the solution dried, we placed 30-40 caterpillars on each leaf in four repetitions. Untreated tobacco leaves were used as a control sample. We registered the number of the living caterpillars gnawing the leaves on the 3rd, 7th and 14th days after applying the treatment. We also established the mortality rate of the caterpillars in the variants and the control sample as well.

Field testing

The experiment was performed under the conditions of the experimental field of the Institute of Tobacco and Tobacco Products in the town of Plovdiv using tobacco plants of Basmi variety group. The tobacco plants were planted at the end of May 2012 and grown in accordance with the agrotechnics considered to be optimal for this kind. Monitoring of the dynamics of the flight of the potato tuber moth was conducted using pheromone traps of the type Pherocon VI Trap delta (Trece, USA). We placed a trap in an area of 5 da in the beginning of March 2012. The dynamics of the flight was observed by registering the number of the captured moths weekly. The adhesive bottoms were changed every week and the pheromone capsule was changed every four weeks. The weekly catch was divided by the number of days and was later used in the graphic representation of the flight of the potato tuber moth on tobacco plants.

We used a block method with randomized positioning of the variants and an experimental field covering an area of 20 m^2 in three repetitions. We conducted two successive insecticide treatments: the first one was applied two weeks after planting and the second one – two weeks after the first treatment. The treatment was applied using a knapsack sprayer and a quantity of the solution equal to 40 l da^{-1} and 50 l da^{-1} respectively for the first and the second treatment. The control lots were not treated. We registered the number of mines on all plants of the respective variant 14 days after treatment. The results are presented as the average number of mines per 100 plants of each variant.

Data analysis

During the laboratory test, the mortality rate of the eggs and the caterpillars in the treated variants was corrected by

the percentage of the natural mortality rate in the control sample based on the formula of Schneider-Orelli`s:

$$\% M = (a-\kappa)/(100-\kappa)*100,$$

where % M = the corrected mortality rate, a= % the mortality rate within the variant, κ = % the mortality rate within the control sample.

During the field test, the effectiveness of the tested compounds was expressed using the extent of damages (the average number of mines per 100 plants).

All the results have been processed for a variation analysis ANOVA using SPSS 9 for Windows XP. The comparative evaluation of the average values has been performed using Duncan's criterion at the 0.05 probability level.

Results

Laboratory testing

Ovicidal effect

The processed data expressed as a mortality rate and grouped in accordance with Duncan's criterion has been presented in Table 1. Depending on the extent of influence on the embryo, the tested chemical compounds are divided into four groups. The highest mortality rate was registered when applying chlorpyrifosethyl+cypermethrin and deltamethrin. Acetamiprid has a weaker ovicidal effect comparable with the effect achieved by the previous compounds. The embryocidal effect of indoxacarb is much weaker than the effect of chlorpyrifosethyl+cypermethrin and deltamethrin and is close to the effect of the acetamiprid. The largest number of eggs hatched after a treatment using imidacloprid and chlorantraniliprole. The ovicidal effect of the aforementioned compounds is inferior to the effect of chlorpyrifosethyl+cypermethrin, deltamethrin and acetamiprid.

Larvicidal effect

The grouping of the tested compounds based on the extent of the larvicidal effect in accordance with Duncan's criterion has been presented in Table 2. The strongest initial larvicidal effect has been registered for chlorantraniliprole,

Table 1
Ovicidal effect of acetamiprid, deltamethrin, imidacloprid, indoxacarb, chlorantraniliprole and chlorpyrifosethyl+cypermethrin on eggs of *P. operculella* Zeller

Active substance, Dose (g a. i. da $^{-1}$)	Number of eggs	Number of hatched caterpillars	Mortality rate, %
Chlorpyrifosethyl+cypermethrin, 35+3.50 g a. i. da^{-1}	58.5 ± 1.85	24.75 ± 2.56	55.20 ± 3.90a
Deltamethrin, 2.0 g a. i. da $^{-1}$	50.00 ± 2.89	26.00 ± 2.48	49.60 ± 4.87a
Acetamiprid, 6.00 g a. i. da^{-1}	55.00 ± 4,60	27.50 ± 2.90	47.01 ± 4.20ab
Indoxacarb, 5.25 g a. i. da^{-1}	56.00 ± 1.68	32.25 ± 1.31	38.72 ± 2.39bc
Imidacloprid, 10.71 g a. i. da^{-1}	56.50 ± 2.60	36.50 ± 1.75	31.30 ± 1.61c
Chlorantraniliprole, 3.20 g a. i. da^{-1}	75.00 ± 0.00	49.75 ± 0.49	29.48 ± 0.87c

The data has been presented as a mean ±SE.

Table 2
Larvicidal effect of acetamiprid, deltamethrin, imidacloprid, indoxacarb, chlorantraniliprole and chlorpyrifosethyl+cypermethrin on caterpillars from the first age group of *P. operculella* Zeller under laboratory conditions

Active substance, Dose (g a. i da^{-1})	Number of caterpillars	Mortality rate, % after treatment		
		3	7	14
Chlorantraniliprole, 3.2 g a. i. da^{-1}	40.50±0.50	92.98±0.82a	100.0±0.00a	100±0.00a
Chlorpyrifosethyl +cypermethrin, 35+3.50 g a. i. da^{-1}	30.67±0.67	91.54±1.91a	100.0±0.00a	100±0.00a
Deltamethrin, 2.00 g a. i. da $^{-1}$	30.00±0.00	91.45±1.84a	100.0±0.00a	100±0.00a
Indoxacarb, 5.25 g a. i. da^{-1}	30.00±0.00	76.62±2.28b	92.12±1.68b	100±0.00a
Acetamiprid, 6.00 g a. i. da^{-1}	33.25±1.60	74.60±5.22b	91.94±0.97b	100±0.00a
Imidacloprid, 10.71 g a. i. da^{-1}	32.50±1.44	40.01± 8.63c	75.01± 2.61c	88.38±1.25b

The data has been presented as a mean ±SE.

chlorpyrifosethyl+cypermethrin and deltamethrin. Acetamiprid and indoxacarb cause death with a smaller number of caterpillars. Imidacloprid has the weakest larvicidal effect. Seven days after treatment, the mortality rate of the caterpillars treated with chlorantraniliprole, chlorpyrifosethyl+cypermethrin and deltamethrin reached 100% (there were no living caterpillars in the initially found mines). When applying acetamiprid and indoxacarb, the mortality rate of the caterpillars increased but still there were proven differences. Imidacloprid demonstrated the weakest larvicidal effect and living caterpillars were found by the 14th day after treatment.

Field testing

The dynamics of the flight of the potato tuber moth has been presented in Figure 1. The beginning of the flight was registered at the end of March – the beginning of April in a very low density. The first moths after planting the tobacco plants were detected during the first week of June. Chemical treatment was applied with a density of 0.5 moths/day. A significant increase in the number of the captured moths was detected after the second treatment. Fourteen days after the first treatment the extent of damages of all tested compounds significantly decreased compared with the control sample but no substantial differences were found in their effects (Table 3). The smallest number of mines was detected when applying chlorantraniliprole and indoxacarb (< 1 item) and the largest number was registered after applying imidacloprid (>5 items < 6 items). During the second registering that took place 14 days after the second treatment, the differences between the effects of the variants became significant. The best control was achieved when applying chlorantraniliprole followed by indoxacarb, where no new mines were found. When using deltamethrin and chlorpyrifosethyl+cypermethrin, the extent of damages slightly increased but the effectiveness of these compounds is comparable with the effectiveness of the first two compounds. Acetamiprid has been proven to have a weaker effect than the compounds chlorantraniliprole, indoxacarb, deltamethrin and chlorpyrifosethyl+cypermethrin. Imidacloprid demonstrated a weaker control over the extent of damages compared to chlorantraniliprole and indoxacarb but its differences compared to deltamethrin, chlorpyrifosethyl+cypermethrin and acetamiprid have not been proven.

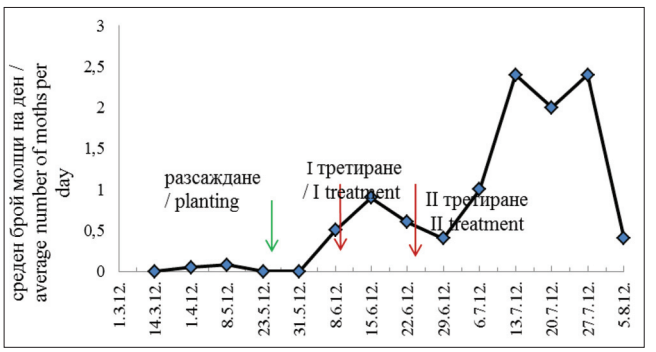

Fig. 1. Dynamics of the flight of the potato tuber moth *P. operculella* Zeller on tobacco of Basmi variety group in the region of the town of Plovdiv in the year 2012

Discussion

In order to exercise effective control over pests, the degree of the effectiveness of insecticides on the various stages of the development of insects shall be thoroughly examined (Smith and Salkeld, 1966 cited by Saour, 2008). The results show that the eggs of the potato tuber moth treated with the tested active substances keep their vitality largely. The embryo finishes its development and a large number of the treated eggs hatch. The strongest ovicidal effect was established when applying chemical compounds with explicit contact effect. Many authors (Stanev and Kaytazov, 1962; Edomwande et al., 2000; Foot, 1975, Saour, 2008, Shelton et al., 1981) talk about the unsatisfactory embryocidal effect of insecti-

Table 3
Biological effectiveness of acetamiprid, deltamethrin, imidacloprid, indoxacarb, chlorantraniliprole and chlorpyrifosethyl+cypermethrin against *P. operculella* Zeller assessed by controlling the extent of damages on tobacco under field conditions

Active substance/ Dose	14 days after the first treatment	14 days after the second treatment
	Average number of mines/100 plants	
chlorantraniliprole, 3.20 g a. i.	0.13±0.13a	0.13 ±0.13a
indoxacarb, 5.25 g a. i.	0.56±0.29a	0.56±0.29ab
deltamethrin, 2.00 g a. i.	1.15±0.92a	2.19±0.97abc
chlorpyrifosethyl+ cypermethrin, 35+3.50 g a. i.	2.71±1.32a	3.01±1.46abc
acetamiprid, 6.00 g a. i.	2.35±1.19a	6.48±0.23bc
imidacloprid, 10.71 g a. i. g	5.67±4.22a	7.05±4.48c
Control	12.55±3.08b	19.36±1.31d

The data has been presented as a mean ±SE.

cides from different chemical groups against the potato tuber moth. The weak ovicidal effect is probably due to the ability of the chorion to affect the penetration of the chemical component to the embryo or the low contact effect (Edomwande et al., 2000; Saour, 2008).

The differences in the larvicidal effects of the tested compounds were first established during the laboratory testing whose results clearly indicate which substances have the potential to control the attacks of the potato tuber moth and which do not. The established differences in the extent of the larvicidal effect under laboratory conditions have been confirmed during the field-testing. The effectiveness under field conditions has been manifested by ensuring a longer period of protection for the tobacco plants. The best control over the potato tuber moth can be exercised by chlorantraniliprole and indoxacarb. Chlorantraniliprole demonstrates a powerful initial larvicidal effect and continuous control over the emergence of new damages throughout the entire period of the experiment (28 days). Chlorantraniliprole is recommended to be used on tobacco in the USA against the pests of the order Lepidoptera including *P. operculella* (Bailey, 2010; Varnedore et al., 2011; Moore et al., 2012). Lawrens (2009) states that chlorantraniliprole effectively controls the attacks of the potato tuber moth on tobacco even when applied shortly after the infection.

The results from the field-testing show that indoxacarb provides efficient and continuous control. During the laboratory testing, we registered a weaker initial effect and the mortality rate of the treated caterpillars increased in the course of time. These results confirm the data presented by Dobie (2010), who talks about a slower but at the same time the most continuous effect of indoxacarb against young caterpillars of the potato tuber moth compared with other tested compounds. The same author also says that the weak initial effect of indoxacarb is because the latter has to be swallowed by the caterpillars and metabolized to a bioactive metabolite (Dobie, 2010).

Chlorpyrifos+ cypermethrin and deltamethrin are widely used to control the pests on a large number of crops including tobacco. The results from this survey clearly indicate that the aforementioned compounds manifest high biological effectiveness against the potato tuber moth under laboratory and field conditions and can successfully be applied for mutual control over the pests on tobacco.

Acetamiprid and imidacloprid show an average to weak larvicidal effect against young caterpillars of the potato tuber moth. During the field experiment after the second treatment, the control over the extent of damages decreased. The obtained results correspond to the data presented by Kau (2006), Lawrens (2009) who talk about the unsatisfactory effect of imidacloprid against the potato tuber moth on tomatoes and tobacco. Foot (1974), says that insecticides with an explicit systemic effect are likely to manifest their insecticidal properties largely when applied to the soil and their effectiveness in case of leaf treatment is insufficient.

Conclusion

The ovicidal effect of the tested chemical compounds varies from average to weak (55.2 % to 29.48 % mortality). The effectiveness of the ovicidal effect is as follows: chlorpyrifos+ cypermethrin > deltamethrin > acetamiprid > indoxacarb > imidacloprid > chlorantraniliprole. The active substances with contact effect show the strongest ovicidal effect. Chlorantraniliprole, chlorpyrifos+ cypermethrin and deltamethrin have manifested the strongest initial larvicidal effect – mortality > 90% during the laboratory testing. The same compounds have also been proven to be the most effective against the young caterpillars of the potato tuber moth. Indoxacarb and acetamiprid also have a high mortality rate > 90% but their effect is slower – seven days after treatment. Imidacloprid shows the weakest larvicidal effect. Chlorantraniliprole and indoxacarb demonstrate the highest effectiveness under field conditions. Deltamethrin and chlorpyrifosethyl+cypermethrin exercise a good control and acetamiprid and imidacloprid have a weaker and shorter effect. Chlorantraniliprole and indoxacarb provide the most effective and the longest control over the potato tuber moth but, unfortunately, these compounds have not been registered on tobacco. Of all the active compounds registered to be used on tobacco, deltamethrin and chlorpyrifosethyl+cypermethrin can be successfully applied during the attacks of the potato tuber moth and to provide mutual control over the tobacco pests. Acetamiprid and imidacloprid can be applied together to control the tobacco pests and during the attacks of the potato tuber moth in the initial stages after planting, i.e. as the period of protection of the tobacco plants is extended, the extent of damages increases.

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