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Chemical control of *Helicoverpa armigera* (Hübner) (Lepidoptera; Noctuidae) in tobacco for seed production

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Abstract

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Helicoverpa armigera (Hübner) (Lepidoptera; Noctuidae) is a pest of paramount important for tobacco seed production due to its feeding preference to seed capsules. For the purpose of assessing the potential of a chemical strategy addressed to *H. armigera* egg and neonate larvae, we test compounds belonging to different groups (chlorantraniliprole, emamectin benzoate, metaflumizon and methoxyfenozide). In this order their ovicidal and neonate larval toxicity have been established under laboratory conditions. Under field conditions their biological efficiency has also been assessed by controlling the extent of the damages caused to the tobacco seed capsules. We conducted two insecticidal treatments based on pheromone monitoring data. We have placed one pheromone trap per 0.5 ha to monitor seasonal pest flight activity. Depending on the extent of influence on the embryo, moderate eggs mortality rate demonstrate emamectin benzoate, chlorantraniliprole, methoxyfenozide and low egg mortality achieves metaflumizone. All tested chemical compounds provoke significantly high neonate larval mortality rates but no substantial differences were found in their effects. In the field all tested compounds si gnificantly decreased extent of damaged compared with the control sample but no significant differences were found in their effects. The lowest number of damaged capsules was detected when applying emamectin benzoate followed by chlorantraniliprol, metaflumizone and methoxifenozide. The tested pest strategy points to *H. armigera* eggs and neonate larva gives opportunity to use combined ovicidal and larvicidal efficacy of the tested chemical components and successfully preserve seed capsules from damages.

Keywords: tobacco; *Helicoverpa armigera*; chemical control

Introduction

Helicoverpa armigera (Hübner) has recently extended its geographical range from Europe, Africa, Asia and Australia to the South and Central America (Carneiro et al., 2014; Kriticos et al., 2015; Pratissoli et al., 2015). The pest is highly polyphagous and has been reported to damage more than 100 host plants, some of them are economically important crops: soybeans, cotton, sorghum, corn, sunflower, peanuts, beans, tobacco, tomatoes and peppers.

H. armigera is considered to be among the most damaging insect pests because of its high reproductive potential, multiple generations, migratory behavior, extremely polyphagous larvae, feeding preference for reproductive stages of plants and its ability to enter facultative diapause and thus adapt to different climates. The pest has been reported to cause serious crop losses throughout its range, in particular to tomatoes, corn, and cotton ranging from 20 to 80% (Čamprag et al., 2004; Hussain and Bilal, 2007; Hanafy and El-Sayed, 2013). *H. armigera* is also a major pest on tobacco during growth and reproductive period. The pest causes significant losses especially on tobacco for seed production by feeding on growing buds and developing capsules. One fully growing larvae can damage 50 mg tobacco leaf per 24 hours or 54 mg seeds (Čamprag et al., 2004). There is a strongly negative correlation between level of damage capsules and seed yield (Vaneva-Gancheva, 2007).

Management of *H. armigera* has a long history of exposure to a broad array of insecticides. As a result it has already evolved resistance problems to conventional chemicals (Duraimurugan and Regupathy, 2005; Joußen et al., 2012; Hussain et al., 2014).

The present survey were conducted with a view to test chemical strategy targeted to egg and neonate larvae of *H. armigera* on tobacco crop for seed production. We reported the comparative laboratory ovicidal and neonate larvae efficacy and two field treatments on tobacco plant.

Material and Methods

The following chemical compounds were tested: chlorantraniliprole in a dose of 4.0 g a. i. da^{-1} (Coragen 20 SC), emamectin benzoate in a dose of 1.425 g a. i. da^{-1}(Affirm 095 SG), metaflumizon in a dose of 24 g a. i. da^{-1} (Alverde 240 SC), methoxyfenozide in a dose of 9.6 g a. i. da^{-1} (Raner 240 SC).

Laboratory testing

The laboratory test was conducted at the laboratory complex of the Institute of Tobacco and Tobacco Products (ITTP) in Plovdiv. The biological material – eggs of the *H. armigera*, were collected from tobacco field. 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 20 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 three 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 number of neonates that hatched from each treatment was recorded too. The vitality of the neonates was followed for three days. We also calculated the mortality rate of the neonates that hatched from treated eggs in the variants and the control sample.

Field testing

The test was performed in the experimental field of ITTP using tobacco plants of Virginia variety group. The tobacco plants were planted at the end of May 2014 and grown with the optimal agronomic practices. 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 placed a trap in an area of 0.5 ha in the end of May 2014. The dynamics of the flight was observed by registering the number of the captured moths weekly. The bottoms were changed weekly 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 *H. armigera* on tobacco crop. We used pheromone monitoring data to set first chemical treatment. It is well known that some days after pick of flight can expect the mass egg laying, so we applied first chemical treatment one week after first mass flight and the second one – two weeks after the first treatment, because of oviposition period. The treatments were applied using a knapsack sprayer and a quantity of the solution equal to 50 l da^{-1}. The control lots were not treated. We registered the number of damaged capsules on 30 plants of the respective variant 30 days after the second treatment. The results are presented as the average number of damaged capsules per 100 capsules.

Data analysis

The mortality rate of the eggs and neonates larvae during the laboratory test 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:

$$\%M = (a-к)/(100-к)*100,$$

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

The effectiveness of the tested compounds during the field test was expressed using the extent of damages (the average number of damaged capsules per 100 capsules).

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

Depending on the extent of influence on the embryo, the tested chemical compounds are divided into two groups (Table 1). The highest mortality rate was obtained when applying emamectin benzoate, chlorantraniliprole and methoxyfenozide. The embryocidal effect of metaflumizon is significantly weaker than the effect of chemical compounds of first group.

Table 1
Ovicidal and neonate larvicidal effect of chlorantraniliprole, emamectin benzoate, methoxyfenozide and metaflumizon on *H. armigera*

Active substance, dose (g a. i. da $^{-1}$)	Number of treated eggs	Number of hatched larvae	Eggs mortality rate, %	Neonate larvae mortality rare, %
emamectin benzoate, 1.425 g a. i. da $^{-1}$	20.0 ± 0.00	7.67 ± 0.88	57.41 ± 4.90a	90.43 ± 5.14a
chlorantraniliprole, 4.0 g a. i. da^{-1}	20.0 ± 0.00	8.33 ± 0.33	54.58 ± 0.97a	92.13 ± 3.96a
methoxyfenozide, 9.6 g a. i. da $^{-1}$	20.0 ± 0.00	10.0 ± 1.15	45.22 ± 7.10a	89.46 ± 1.46a
metaflumizon, 24 g a. i. da $^{-1}$	20.0 ± 0.00	13.0 ± 0.58	29.14 ± 2.14b	87.51 ± 4.48a
control	20.0 ± 0.00	18.0 ± 0.58		

The data has been presented as a mean ±SE

Neonate larval effect

All tested chemical compounds provoked significantly high neonate larval mortality rates compared with the control sample on three days after hatching, but no substantial differences were found in their effects (Table 1). The neonates from treated egg exhibited the highest mortality due to treatment with chlorantraniliprole followed by emamectin benzoate, methoxyfenozide and mataflumizone. In contrast to the weak ovicidal effect, metaflumizon exhibited high neonates' larval mortality rate.

Monitoring data

The first moths after planting the tobacco plants were detected during the second week of June (Fig. 1). A significant increase in the number of the captured moths was registered in July. Flight dynamics of pest clearly shows two picks of flight. The first one is in the second decade of July with 1.3 moths per day and the second pick is one month later with 1.1 captured moths per day.

Field test

Thirty days after the second treatment the extent of damages of all tested compounds significantly decreased compared with the control sample, but no significant differences were found in their effects (Table 2). The lowest number of damaged capsules was achieved when applying emamectin benzoate – under 0.1 capsules per 100 capsules. When applying chlorantraniliprole, metaflumizon and methoxyfenozide, the extent of damages slightly increased between 0.2 to 0.4 capsules per 100 capsules. In control variant the rate of damage achieved 1.13 capsules per 100 capsules.

Table 2
Effectiveness of chlorantraniliprole, emamectin benzoate, methoxyfenozide and metaflumizon against *H. armigera* assessed by controlling the extent of damages on tobacco seed capsules under field conditions

Active substance, dose (g a. i. da $^{-1}$)	Average number damaged capsules per 100 capsules
emamectin benzoate, 1.425 g a. i. da $^{-1}$	0.08 ± 0.05a
chlorantraniliprole, 4.0 g a. i. da^{-1}	0.22 ± 0.12a
metaflumizon, 24 g a. i. da $^{-1}$	0.29 ± 0.12a
methoxyfenozide, 9.6 g a. i. da $^{-1}$	0.38 ± 0.11a
control	1.13 ± 0.25b

The data has been presented as a mean ±SE

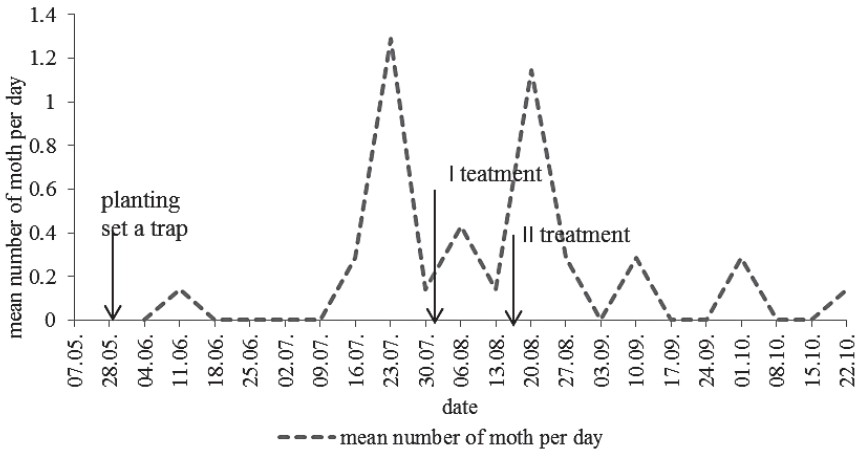

Fig. 1. Seasonal flight dynamics of the *H. armigera* on tobacco crop during 2014 in Plovdiv region

Discussion

Tobacco hybrid seed production is expensive and labor-intensive. There are many handmade manipulations like emasculation and pollination. *H. armigera* is an important pest for tobacco seed production due to its feeding preference to seed capsules. Control of this pest in reproductive stage on tobacco is critical. The most popular pest control strategy is aimed at a larval stage and most common ETL is 10 % of damage plant (Razaq et al., 2005; Shivanna et al., 2012; Said et al., 2015). There are a plenty of research experience about biological efficacy of chemical components against larval stage of *H. armigera* (Babar et al., 2012; Carneiro et al., 2014; Parsaeyan et al., 2013; Sattar et al., 2017), but there is comparatively less information concerning ovicidal toxicity. Our results showed a moderate egg mortality rate when applying emamectin benzoate, chlorantraniliprole, methoxyfenozide and significantly weaker egg mortality in metaflumizone variant. A similar ovicidal effect was reported by Parsaeyan et al. (2013), when use emamectin benzoate. According to Babar et al. (2012) high egg mortality was achieved when applying flubendiamide and thiodicarb followed emamectin benzoate and chlorantraniliprole. In the other survey for effectiveness on emamectin benzoate of Spodoptera exigua, Bengochea et al. (2014) announced for any ovicidal activity, but progressive neonate mortality.

We target chemical control of the *H. armigera* on egg and neonate larvae before larvae make injury on seed capsules. In view of the fact above we base on pheromone monitoring data and make decision for the first chemical treatment one week after the first mass flight and second correcting treatment two week after the first, because of oviposition period. This pest strategy gives opportunity to use combined ovicidal and larvicidal efficacy of the tested chemical components. In contrast to the weak egg mortality the neonate from treated eggs exhibited high mortality due to treatment with all tested components. All tested insecticides significantly decrease the extent of damages compared with the control sample but no significant differences were found. Emamectin benzoate was noticed to show highest protection of seed capsules from *H. armigera* attack – only 0.08 damaged capsules per 100 seed capsules, followed by chlorantraniliprole, metaflumizon and methoxyfenozide.

Emamectin benzoate and chlorantraniliprole are the most popular and efficient insecticides against Lepidoptera pests. Emamectin benzoate is a semisynthetic derivative of abamectin and has been developed for the purpose of controlling lepidopterous pests on a variety crops. Chlorantraniliprole is an anthranilic diamide insecticide, which specifically targets insect ryanodine receptors (RyRs). The excellent ingestion effect of emamectin benzoate and chlorantraniliprole on the second and third install larva of *H. armigera* was reported by many authors (Carneiro et al., 2014; Parsaeyan et al., 2013; Sattar et al., 2017). Liu et al. (2017) also reported for high levels of toxicity of imago when it was treated with chlorantraniliprole and emamectin benzoate. The authors conclude that the chlorantraniliprol can be used as an attracticide for controlling this pest. Parsaeyan et al. (2013) generalized that emamectin benzoate induce significant effects on *H. armigera* population by a negatively affecting larval and pupal stage, adult longevity and oviposition. An excellent field protection from *H. armigera* attack of chlorantraniliprole and emamectin benzoate was reported by many researchers worldwide at different crops (Razaq et al., 2005; Hanafy and El-Saied, 2013; Gadhiya et al., 2014; Sreekanth et al., 2014; Adsure and Mohite, 2015; Ambule et al., 2015; Faqiri and Kumar, 2016).

There is a little information available on the efficacy of metaflumizone and methoxyfenozide against *H. armigera*. Metaflumizone is a sodium channel blocker insecticide and belongs to the class of semicarbazone insecticides. Methoxyfenozide is affecting the larval stage by blocking or inhibiting the synthesis of chitin. Our lab-testing results show that metaflumizone and methoxyfenozide provide high larvicidal efficacy. There is a difference in the embryocidal effect of these chemical compounds – metaflumizon has a significantly weaker effect. In the field test the effectiveness of metaflumizone and methoxyfenozide compounds is comparable with the effectiveness of the chlorantraniliprole and emamectin benzoate. In contrast to our results Gadhiya et al. (2014) reported for a poor effect of metaflumizone when it is a part of comparatively experiment with emamectin benzoate and chlorantraniliprole. Alavo et al. (2011) announced for a good efficacy of topical application of methoxyfenozide against L2 and L5 instar of *H. armigera* and also for a good field control. Saber et al. (2013) concluded that methoxyfenozide induce significant effect on field population dynamics of *H. armigera*. The results of resistance survey conducted in Pakistan reported for a different level of *H. armigera* methoxifenoside resistance (Hussain et al., 2014).

Conclusions

A pest control strategy targets to *H. armigera* egg and neonate larvae gives opportunity to use combined ovicidal and larvicidal efficacy of the tested chemical components. This strategy bases on pheromone date to set first chemical treatment. Emamectin benzoate, chlorantraniliprole, methoxyfenozide and metaflumizon successfully preserved seed capsules from damages when they are applied twice: one week after the first mass flight and two weeks later and pest density was no more than 1.5 moths per day at the pick.

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