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Original scientific paper

THE EFFECT OF INSECTICIDES ON THE TOTAL PERCENTAGE OF *Ostrinia nubilalis* Hbn ATTACK ON MAIZE HYBRIDS

Snežana GOŠIĆ DONDO[1], Dragan GRČAK[2], Milosav GRČAK[2],
Danijela KONDIĆ[3], Djuradj HAJDER[3], Željko POPOVIĆ[4], Desimir KNEŽEVIĆ[2*]

[1]Maize Research Institute "Zemun Polje", Belgrade, Serbia
[2]University of Priština, Faculty of Agriculture, Kosovska Mitrovica–Lešak, Kosovo and Metohia, Serbia
[3]University of Banja Luka, Faculty of Agriculture, Banjaluka, Republika Srpska, Bosnia & Herzegovina
[4]University of Novi Sad, Faculty of Science, Novi Sad, Serbia

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The objective of the paper was to determine the effect of insecticides on the development of the European corn borer (*Ostinia nubilalis* Hbn) and the effect of damage in six maize hybrids of different maturity groups. The research involved the following hybrids: ZP 427, ZP 434, ZP 555, ZP 600, ZP 606 and ZP 666. In the field trial, insecticides were applied in two terms, during the flight of *O. nubilalis* first generation and during the flight of second *O. nubilalis* generation. We used Fobos EC insecticide and a combination of Match 050 EC + Nurelle D insecticides, whose active substances are different. The active substance in Fobos EC insecticide is bifenthrin 100 g l^{-1}, in Match 050 EC lufenuron 50 g l^{-1} and, in Nurelle D insecticide, the active ingredient is a combination of chlorpyrifos 500 g l^{-1} and cypermethrin 50 g l^{-1}. The damage inflicted on plants was assessed in July and September. Fobos insecticide had the best plant protection effect, after its use, the arithmetic mean of the total attack percentage of all hybrids was approximately 81.62% while in the control group, it was approximately 91.72%.

Keywords: *Ostrinia nubilalis*, maize, insecticide, resistance, variability

INTRODUCTION

Maize is now one of the most widely grown crops, and it is cultivated from the equator to the approximately 50° north and south, and altitude from sea level to 3000 m above sea level

Corresponding authors: Desimir Knežević, University of Priština, Faculty of Agriculture, Kosovska Mitrovica, Lešak, Kosovo and Metohia, Serbia, Phone +381 64 614 88 82, e-mail: deskoa@ptt.rs

(MORRIS, 2002). Maize is the most important crop species in Republic of Serbia (MADIĆ *et al*., 2017), and in recent years, it has been the main export product. In 2016, Republic of Serbia took the 18th place in terms of total maize production in the world (GRČAK *et al*., 2018). In the Republic of Serbia, in 2017, maize was harvested from an area of 1,002,319 hectares (Statistical Office of the Republic of Serbia, 2018).

Maize can be attacked by a wide range of pests (nematodes, centipedes, gastropods, birds, mammals, insects, etc.), among which, a special place belongs to arthropods. In the total number of all maize pests, over 70% are insects. According to previous studies (ALAMAŠI *et al.*, 2002) about 875 species of insects can attack maize worldwide, whereas in the Republic of Serbia approximately 90 insect species. The Coleoptera and Lepidoptera represent about 60% of harmful insects that cause significant economic damage to maize cultivation (ALAMAŠI *et al.*, 2002). From the Lepidoptera order, maize (in Serbia and surrounding countries) are attacked by about 30 species, classified into five families. A majority of species belong to the family of moths, and according to the economic importance, the representatives of *Noctuidae* and *Pyralidae* families stand out. The most important are owlet moths and maize earworms (*Agrotis segetum, Agrotis ipsilon, and Helicoverpa armigera*), European corn borers and beet webworms (KEREŠI *et al*., 2014).

One of the most important maize pests is the European corn borer (*Ostrinia nubilalis*). It is estimated that caterpillars of this species may decrease the yield from 10-30%, in the event of a moderate infestation (IVOVIĆ, 2015) or even 70-80%, which happened during a great infestation in the first decade of the previous century in Vojvodina, Serbia (ČAMPRAG *et al*., 2004). The European corn borer is not only a pest of maize, but some other plant species, as well, especially vegetable species (CAPINERA, 2008). The emergence of butterflies in Republic of Serbia is common for the period from June to August. They are the most active during the night and at dawn. In their lifetime, an adult European corn borer generally flies a distance between 1.5 and 12 km, although migrations can reach up to 80 km (SAPPINGTON, 2018). They overwinter in the stage of adult caterpillars, the most often either in the stem or in the soil in the parts of plowed maize stalks (POPOVIĆ *et al*., 2015).

Hybrids that were used in this study are selected because they were of different FAO maturity groups and because they were the most current according to the Institute of Maize - Zemun Polje. The most common treatment against *O. nubilalis* in Republic of Serbia is crop rotation and destruction of maize remains on the fields before the start of the season. For the control of larvae of *Ostrinia nubilalis* in Republic of Serbia is registered insecticide Fobos-EC. The potential contribution of the research in plant protection is justification of insecticide application for reducing populations of *O. nubilalis* buterflies. A treatment of maize with insecticide is efficient for reduction population of thrips up to 14 days after treatment (BEREŚ *et al*., 2017).

The objective of the paper was to determine (i) the effect of insecticides on the development of European corn borer (*Ostrinia nubilalis* Hbn), (ii) effect of time of insecticide application in efficiency of maize plant protection from attack by European corn borer (*Ostrinia nubilalis* Hbn), (iii) the impact of active substances of insecticides in efficiency of suppression of development of European corn borer (*Ostrinia nubilalis* Hbn) and its attack to plants of maize. (iv) variability of different FAO group hybrids of maize resistance to attack of European corn borer (*Ostrinia nubilalis* Hbn), (v) the effect of damage in six maize hybrids of different maturity groups.

MATERIALS AND METHODS

The effect of the European corn borer attack was studied in six maize hybrids of different maturity groups ZP 427, ZP 434, ZP 555, ZP 600, ZP 606 and ZP 666, as well as the effectiveness of preventing damage when using insecticides with different active substances. The surveys were conducted in a field experiment of the Maize Research Institute "Zemun Polje" in Belgrade during 2018. The experiment was set up in three repetitions on a plot of 10.5 m². The sowing of maize hybrids was performed by machines on the 28th of April, in three rows of 5 m length with a distance between rows of 0.7 m and a distance between plants in a row of 0.25 m.

The experiment was set up as a randomized complete block (RCB) design, split plot experimental design, with two treatments and a control group in three replications. The plants were treated with the Fobos EC (bifenthrin, Galenika) in the amount of 200 ml ha^{-1} and a combination of Match 050 EC (lufenuron 50 g l^{-1}) and Nurelle D (chlorpyrifos 500 g l^{-1} and cypermethrin 50 g l^{-1}) in the amount of 0.75 *l* ha^{-1}. Another important factor in the experiment is the timing of plant treatments with insecticides: - I-1 (Fobos EC) and II-1 (Match 050 EC + Nurelle D) - 4th of June (first time), 15 days after the first-generation maximum flight, and I-2 (Fobos EC) and II-2 (Match+Nurelle) - 18th of July (second time), 15 days after the second-generation maximum flight. In all plants, the intensity of damage caused by caterpillars of the European corn borer (*O. nubilalis*) was assessed according to the Hadžistević tolerance scale (HADŽISTEVIĆ, 1966). The treatment 15 days after maximum flight is choose due to wide used methodology (GOŠIĆ-DONDO *et al*., 2016), namely then the larvae is most vulnerable before they drill and insert in the plant.

Mathematical-statistical data processing was carried out using SPSS Statistics 20 (trial version software (PALLANT, 2007). The significant differences among the average values were estimated according to Tukey test.

RESULTS AND DISCUSSION

The intensity of the European corn borer attack in the studies conducted during 2018 varied depending on the maize hybrids, as well as the overall intensity of first and second flying generations. The highest total attack intensity was found in the ZP 666 hybrid (94.27%) in the control variant, and the lowest total attack intensity was found in ZP 434 (77.12%) in the variant where Fobos insecticide (I-1) was applied. The first-generation attack intensity was the lowest in ZP 666 hybrids (13.07%) in the variant where Fobos (I-1) insecticide was applied, while it was the highest in ZP 606 hybrids of the control variant - 69.29%. The lowest intensity of the attack by the second-generation larvae of the European corn borer (*O. nubilalis*) was found in ZP 555 hybrids (23.9%) of the control variant and the highest in ZP 666 hybrids (68.62%) of I-1 variant with Fobos insecticide (Table 1).

The application of Fobos insecticide (I-1) in the first term had a greater effect of protection against the European corn borer caterpillars in ZP 555, ZP 600, ZP 606 and ZP 666 hybrids. Than the application of the combination Match + Nurelle (II-1) had a greater effect on ZP 427 and ZP 434 hybrids than Fobos insecticide (I-1), which was expressed through a smaller number of attacked plants, that is, a lower percentage of the first-generation attack. However, the intensity of the second-generation attack after the application of Fobos (I-1) was lower in ZP 427, ZP 434, and ZP 555 hybrids than in the combination of Match + Nurelle (II-1) in the first term. Whereas the attack intensity of the second-generation caterpillars (*O. nubilalis*) in ZP 600, ZP 606, ZP 666 hybrids was lower after the application of the Match + Nurelle (II-1) combination than after the application of Fobos insecticide (I-1) in the first term (Table 1).

Table 1. The attack intensity and the average number of plants attacked by the European corn borer (O. nubilalis) in different maize hybrids with appropriate treatments

	Number of plants	No. of plants attacked by the 1st generation	% of attack by the 1st generation	No. of plants attacked by the 2nd generation	% of attack by the 2nd generation	Total number of attacked plants	% of total attack
			ZP 427				
Control	165	107	65.02	43	26.13	150	91.15
Fobos (I-1)	152	54	35.54	72	47.36	126	82.9
Match +Nurelle (II-1)	153	44	28.91	87	57.16	131	86.08
Fobos (I-2)	162	78	48.21	57	35.09	135	83.3
Match +Nurelle (II-2)	157	73	46.56	53	33.64	126	80.2
			ZP 434				
Control	169	109	64.36	41	24.39	150	88.76
Fobos (I-1)	162	55	33.88	70	43.24	125	77.12
Match +Nurelle (II-1)	157	42	26.58	85	54.16	127	80.74
Fobos (I-2)	158	70	44.22	57	36.04	127	80.26
Match +Nurelle (II-2)	169	81	47.91	62	36.69	143	84.59
			ZP 555				
Control	159	107	67.29	38	23.9	145	91.2
Fobos (I-1)	156	45	29.12	84	53.88	129	83
Match +Nurelle (II-1)	166	48	29.93	99	58.62	147	88.55
Fobos (I-2)	160	82	50.72	52	33.07	135	83.79
Match +Nurelle (II-2)	159	90	56.55	52	30.2	142	86.75
			ZP 600				
Control	159	110	68.16	42	25.73	152	93.90
Fobos (I-1)	149	34	22.69	90	60.46	124	83.16
Match +Nurelle (II-1)	152	41	27.07	84	54.82	125	81.89
Fobos (I-2)	153	81	52.86	46	30.3	127	83.16
Match +Nurelle (II-2)	149	79	52.88	42	27.99	121	80.86
			ZP 606				
Control	162	110	69.29	42	24.48	152	93.77
Fobos (I-1)	165	40	24.21	95	57.66	135	81.87
Match +Nurelle (II-1)	166	70	42.42	66	39.7	136	82.11
Fobos (I-2)	166	86	51.5	54	32.82	140	84.32
Match +Nurelle (II-2)	162	90	55.3	44	27.32	134	82.62
			ZP 666				
Control	156	102	67.34	45	26.93	147	94.27
Fobos (I-1)	153	20	13.07	105	68.62	125	81.7
Match +Nurelle (II-1)	159	52	32.86	80	50.25	132	83.11
Fobos (I-2)	164	77	46.82	55	33.57	132	80.38
Match +Nurelle (II-2)	158	91	57.7	37	23.28	128	80.98

The differences in effects of treatment to hybrids of maize can be due to hybrid specific genetic nature and differences of physiological phase of development at the time of treatment. This specific nature includes biological and physical barriers for insect attack which can create in breeding by selection hybrids with resistance to *Ostrinia nubilalis* (BOHN *et al*., 2003; CARDINAL *et al*., 2006). They reported that selection for earliness and yield and in the next step selection for European corn borer can be promising for improving resistance and yield (OLOYEDE-KAMIYO *et al*., 2012).

After the application of Fobos (I-2) insecticide in the second term, the attack intensity was lower in ZP 434, ZP 555, ZP 606, ZP 666 hybrids compared to the application of the Match+Nurelle combination (II-1), while the attack intensity in ZP 427 hybrids was lower after the application of the Match+Nurelle (II-2) combination than after the application of Fobos (I-2). In ZP 600 hybrids, the insecticide application efficacy in the second term was similar with the attack intensity of first-generation caterpillars was the same. However, the attack intensity of the second generation in ZP 427, ZP 555, ZP 600, ZP 606 and ZP 666 hybrids was lower in the second term after the application of Match + Nurelle (II-2) insecticides than after the application of Fobos (I-2), while in ZP 434 hybrids, after the application of Fobos insecticide (I-2) and after the application of Match + Nurelle (II-2) in the second term, the attack intensity of the European corn borer was the same (Table 1).

The different values of intensity attack of first or in second generation European corn borer can be due to morphological, biochemical and genetic traits as well as specific mechanisms of hybrids resistance (MITCHELL *et al.*, 2016). The leaf thickness, waxy cuticle and high density of trichomes can be physical barrier for insect oviposition and feeding (BEREŚ, 2013). In investigation of FRANETA *et al.* (2014) was found higher resistance of the hybrid NS 6030 to the first brood of *O. nubilalis* based on stalk and leaf damages. Some organic compounds in cell plants, antioxidative substances, phenolic acids and fiber in cell walls have suppression on larvae of *O. nubilalis* and increase resistance to stalk damage (BUTRŎN *et al.*, 2010).

In ZP 427 hybrids, the lowest percentage of the first-generation attack was in the treatment with Match + Nurelle (II-1) - 28.91%, with 44 plants attacked, and the highest number of plants (107) attacked was in the control group. After the application of Fobos (I-2), the intensity of attack by *O. nubilalis* was 48.21%, and after the application of the Match + Nurelle (II-2) insecticide combination, a similar percentage (46.56%) of the attack intensity was found (Table 1).

ZP 434 hybrids had the lowest first-generation attack intensity (26.58%) after the application of Match + Nurelle (II-1), while the highest intensity was found in the control group (64.36%). The highest total intensity of the attack by the European corn borer was in the control group (88.76%) with 150 plants attacked, while the lowest attack was 77.12% after the application of Fobos (I-1) (Table 1).

The attack intensity of the first-generation of *O. nubilalis,* after a treatment with Fobos (I-1) in ZP 555 hybrids was 29.12%, where a total of 45 plants were found to have symptoms of the European corn borer attack. Approximately the same attack intensity (29.93%) was found after a treatment with the insecticide combination of Match + Nurelle (II-1) in 48 plants, while the highest attack intensity was found in the control variant - 67.29% with 107 plants attacked. Treatments with Fobos (I-2) and Match + Nurelle (II-2), performed after the maximum of the second-generation of flying, had approximately the same effect on the attack of *O. nubilalis*, where the attack intensity after the application of Fobos (I-2) was 50.72%, and after the application of Match + Nurelle (II-2), it was 56.55% (Table 1).

In ZP 600 hybrids, the highest intensity of the first-generation attack was found in the control group (68.16%), while a treatment with Fobos insecticide (I-1) resulted in a low attack intensity of 22.69%, and a similar attack intensity of 27.07%. was found after the application of Match + Nurelle (II-1) insecticide combination. The total attack intensity was the highest in the control variant (93.90%) with 152 plants attacked, while the lowest total attack intensity was found after Match + Nurelle treatment (II-2) and it was 80.86% (121 plants attacked), and similar results were found after the application of Match + Nurelle (II-1) - 81.89% (Table 1).

ZP 606 hybrids had the highest intensity of *O. nubilalis* first-generation attack in the control variant (67.43%), while the lowest intensity of the first-generation attack was after a treatment with Fobos (I-1) and it was 13.07%. The highest total attack intensity was found in the control variant (93.77%) with a total of 147 plants attacked. The lowest total attack intensity was approximately the same after the application of Fobos (I-2) - 80.38%, Match + Nurelle (II-2) - 80.98%, and Fobos (I-1) - 81.7% (Table 1).

In the ZP 666 control variant, the highest attack intensity and the highest total damage were found in the control variant 94.27% in 147 of 156 maize plants. The lowest intensity of attack by the first-generation larvae was found after the application of Fobos (I-1) insecticide - 13.07% with only 201 plants attacked. The intensity of the attack varied and had an increasing trend, depending on the term of application and the insecticide type - Match + Nurelle (II-1) - 32.68%, Fobos (I-2) - 46.82%, and Match + Nurelle (II-2) - 57.7% (Table 1). This indicates that European corn borer larvae found the plants to be attractive for laying eggs and feeding, and the treatments I-2 and II-2 were performed after the completion of the first-generation life cycle. The effectiveness of insecticides for controlling the European corn borer largely depended not only on the active substance and the amount of insecticides, but also on the method and timing of application (FRANETA *et al.,* 2018). In our analysis the efficiency of two the insecticides tested on the ZP hybrids, it was found that the variations between the application times were small.

Table 2. Univariate analysis of variance -Tests of Between-Subjects Effects Dependent Variable: percentage of overal attack

Source	df	Type III Sum of Squares	Mean Square	F	Sig.
Corrected Model	29	1651.910[a]	56.962	1.702	.039
Intercept	1	639938.209	639938.209	19324.053	.000
Hybrid	5	153.663	30.733	.928	.469
Treatment	4	1251.138	312.784	9.445	.000
Hybrid x treatment	20	247.109	12.355	.373	.992
Error	60	1986.969	33.116		
Total	90	643577.087			
Corrected Total	89	3638.878			

a. R Squared = .454 (Adjusted R Squared = .190)

Favorable weather conditions, timely applications and the efficiency of insecticides had a positive effect on the crop yield (GOŠIĆ-DONDO *et al.*, 2016). Accordingly, the application on the second generation can only be justified when the pest population is more numerous and aggressive, which is economically and ecologically justified.

Based on the data obtained by using SPSS Statistics 20 (trial version) software, Table 2 shows whether the independent variables (hybrid and treatment) and their interaction (hybrid * treatment) have a statistically significant effect on the dependent variable (total percentage of *O. nubilalis* attack). It was found that there was no statistically significant difference between the hybrids in terms of the total percentage of pest attacks (sig. = 0.469), but statistically significant differences could be observed in treatments (sig. = 0.000). In the interaction between the hybrids and treatments, no statistical significance was found (sig. = 0.992). When the sig. value is lower than or equal to 0.05, there is a statistically significant difference between the arithmetic mean of the variable (PALLANT, 2007).

Table 3. Comparison of the differences between the treatments using the Tukey's test

Treatment	N	Subset	
		1	2
Fobos (I-2)	18	81.6233	
Fobos (I-1)	18	82.5356	
Match + Nurelle (II-2)	18	82.6689	
Match + Nurelle (II-1)	18	83.0689	
Control	18		91.7200
Sig.		.943	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 33.116.
a. Uses Harmonic Mean Sample Size = 18.000.
b. Alpha = 0.05.

By comparing the differences between the treatments with insecticides and the control group, shown in Table 3, we have found that there is a significant difference in the most cases. Namely, we have found a significant differences between the control group and all the four treatments, where sig = 0.000 (Table 4). By comparing the difference between the control group and Fobos (I-1), we have determined that there was significant difference (sig. = 0.000019). Also, significant difference was found between the control variant and Fobos (I-2) (sig. = 0.000109). A significant difference was also found between the control variant and Match + Nurelle (II-1) (sig. = 0.000289), and between the control variant and Match + Nurelle (II-2) (sig. = 0.000139). There was no significant statistical difference among the insecticide treatments, as presented in Table 4, where the values of sig. always exceeded 0.05.

Table 4. Multiple comparisons of the differences between the treatments using the Tukey's test Dependent Variable: Percentage of overal attack

(I) treatment	(J) treatment	Mean Difference (I-J)	Std. Error	Sig.	95% - Confidence Interval	
					Lower Bound	Upper Bound
Control	Fobos I-1	10.0967*	1.91822	.000	4.7017	15.4916
	Match + Nurelle – II-1	8.6511*	1.91822	.000	3.2562	14.0460
	Fobos – I-2	9.1844*	1.91822	.000	3.7895	14.5794
	Match + Nurelle – II-2	9.0511*	1.91822	.000	3.6562	14.4460
Fobos – I-1	Control	-10.0967	1.91822	.000	-15.4916	-4.7017
	Match + Nurelle – I-2	-1.4456	1.91822	.943	-6.8405	3.9494
	Fobos – II-1	-.9122	1.91822	.989	-6.3017	4.4827
	Match + Nurelle – II-2	-1.0456	1.91822	.982	-6.4405	4.3494
Match + Nurelle – II-1	Control	-8.6511	1.91822	.000	-14.0460	-3.2562
	Fobos – I-1	1.4456	1.91822	.943	-3.9494	6.8405
	Fobos – I-2	.5333	1.91822	.999	-4.8616	5.9283
	Match + Nurelle – II-2	.4000	1.91822	1.000	-4.9949	5.7949
Fobos – I-2	Control	-9.1844	1.91822	.000	-14.5794	-3.7895
	Fobos – I-1	.9122	1.91822	.989	-4.4827	6.3071
	Match + Nurelle – II-1	-.5333	1.91822	.999	-5.9283	4.8616
	Match + Nurelle – II-2	-.1333	1.91822	1.000	-5.5283	5.2616
Match + Nurelle – II-2	Control	-9.0511	1.91822	.000	-14.4460	-3.6562
	Fobos – I-1	1.0456	1.91822	.982	-4.3494	6.4405
	Match + Nurelle – II-1	-.4000	1.91822	1.000	-5.7949	4.9949
	Fobos – I-2	.1333	1.91822	1.000	-5.2616	5.5283

Based on observed means. The error term is Mean Square(Error) = 33.116. * The mean difference is significant at the 0.05 level

In this comparison, no statistically significant difference was found between the control variant and the variant where a combination of Match + Nurelle (II-1) insecticides was applied, while in this analysis, in all six hybrids, including the above-mentioned three hybrids, a statistically significant difference was found between the control variant and the variant treated with Match + Nurelle (II-1), sig. = 0.0000109. However, similar results were obtained for the remaining comparisons, so significant differences were found in comparisons of the control variant to the Fobos (I-1) variant, sig. = 0.011, the control variant to the variant treated with Fobos (I-2) sig. = 0.011, and the control variant to the variant treated with Match + Nurelle (II-2) sig. = 0.012.

The attack intensity of the first-generation of pests only (Figure 1). The highest intensity of attack was found in control variant for all hybrids (ZP 606 – 69.29%; ZP 434 – 64,36%). Comparing the attack intensity to the treatments, it was found that the application of insecticides in the first term (I-1, II-1) was more effective than the treatments in the second term (I-2, II-2). After the application of Fobos (I-1), the lowest attack intensity was found in ZP 666 hybrids, only in 13.07% of plants (which is also the lowest attack intensity registered in the first generation), whereas the highest attack intensity was found in ZP 427 hybrids (35.54%). The application of the same insecticide, Fobos (I-2), at a different time, showed less efficiency in controlling the attack of *O. nubilalis* in the maize hybrids studied. The lowest attack intensity was found in ZP 434 hybrids (44.22%), while the highest attack intensity was found in ZP 600 hybrids (52.86%). After the application of the Match + Nurelle (II-1) insecticide combination, the lowest attack intensity was found in ZP 434 hybrids (26.58%), and the highest attack intensity was found in ZP 606 hybrids (42.42%). The application of the Match + Nurelle (II-1) insecticide combination in the second term was less effective in controlling *O. nubilalis*. After the application of Match + Nurelle (II-2), the lowest attack intensity was found to be 46.56% in ZP 427 hybrids, and the highest attack intensity was 57.7%, which was found in ZP 666 hybrids.

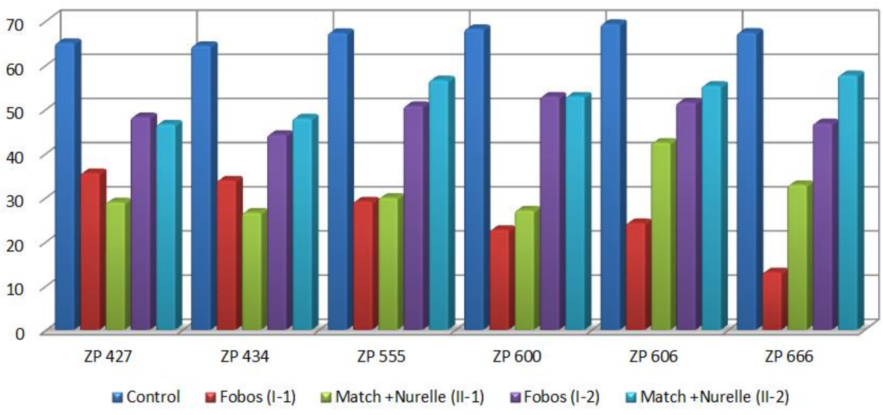

Figure 1. The attack intensity of the first-generation of the European corn borer (in percentage) on maize in various hybrids with appropriate treatments

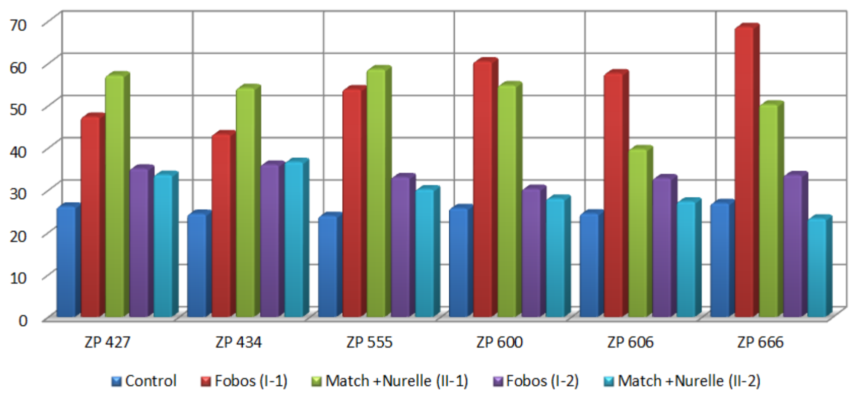

Figure 2. The attack intensity of the second-generation of the European corn borer (in percentage) on maize in various hybrids with appropriate treatments

The analysis of second-generation insect attacks in isolation is shown in Figure 2, which presents the intensity of *O. nubilalis* attacks (in %) only in plants that were not attacked at the time of the first generation of this pest, that is, plants that were attacked by the first generation of *O. nubilalis* were not included in the analysis regardless of whether they were attacked by the second-generation of *O. nubilalis* or not. The control variant was found to have the lowest intensity of attack because a large number of plants were attacked during the first generation of *O. nubilalis* . The highest attack intensity in the control variant was found in ZP 666 hybrids (26.93%), while the lowest attack intensity was found in ZP 555 hybrids (23.9%). After the treatment of plants with Fobos (I-1) insecticide in the first term, the lowest attack intensity was found in ZP 434 hybrids (43.24%), while the highest attack intensity was found in ZP 666 hybrids (68.62%). After the treatment of plants with Fobos (I-2) insecticide in the second term, the highest attack intensity was found in ZP 434 hybrids, in 36.04% of the plants attacked, while the lowest attack intensity was found in ZP 600 hybrids, in 30.3% of the plants attacked. After the application of the Match + Nurelle insecticide combination in the first term (II-1), the lowest attack intensity was found in ZP 606 hybrids (39.7%), and the highest attack intensity was found in ZP 555 hybrids (58.62%). After the application of the same combination of Match + Nurelle insecticides in the second term (II-2), the lowest attack intensity was found in ZP 666 hybrids (23.28%), and the highest in ZP 434 hybrids (36.69).

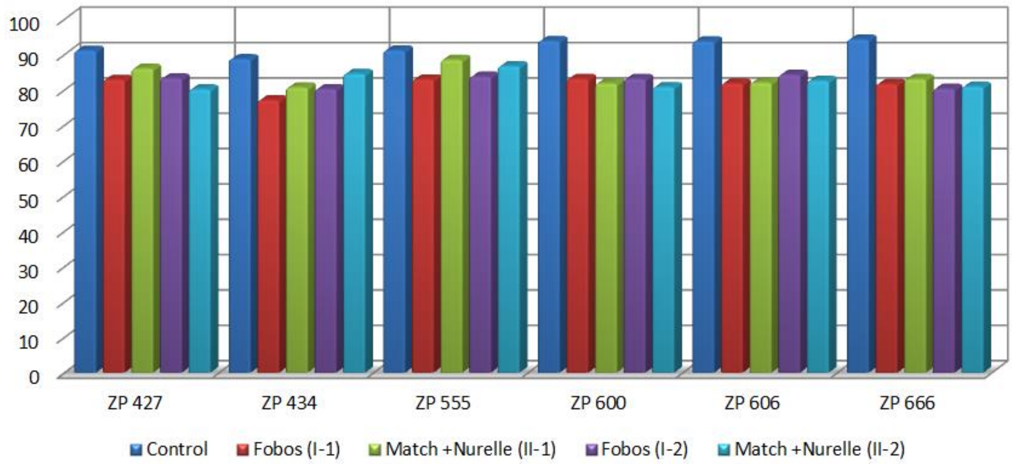

Figure 3. The total intensity of the European corn borer attack (in percentage) on maize in various hybrids with appropriate treatments

The analysis of the total intensity of the European corn borer attack, as a result of the sum of the total attacks of the first and second generations of *O. nubilalis* , has shown that the highest attack intensity was found in the control variant. The lowest total attack intensity of the control variant was found in ZP 434 (88.76%), while the highest total attack intensity was found in ZP 666 hybrids, in 94.27% of plants. After the application of Fobos (I-1) insecticide in the first term, a lower intensity of attack of *O. nubilalis* was found than after the application of Fobos (I-2) in the second term. Namely, after the application of Fobos insecticide in both terms, the lowest total intensity of attack was found in ZP 434 hybrids (77.12%) after the treatment with Fobos I-1, and the lowest attack intensity was found after the treatment with Fobos I-2, 80.26%. The highest intensity of attack after the treatment with Fobos I-1 in the first term was 83.16%, and after the treatment with Fobos (I-2) in the second term, the highest intensity of attack was 84.32%. After the Match + Nurelle insecticide application, it was found that there were no significant differences in the intensity of attack depending on the insecticide application terms. The lowest attack intensity after the application of Match + Nurelle (II-1) in the first term was found in ZP 434 hybrids with a total attack intensity of 80.74%, whereas in the second term (II-2), it was in ZP 427 hybrids with a total attack intensity of 80.2%. The highest total attack intensity in both treatments was found in ZP 555 hybrids with attacks up to 88.55% in II-1 treatment and an attack of 86.75% in II-2 treatment (Figure 3).

The lowest attack intensity in the control variant was found in ZP 434 hybrids, and after the application of Fobos in the first term (I-1), the average intensity of total attack was 77.12%.

In the insecticide application performed on the 18th of July, the average first-generation attack ranged from 13.07% to 57.70%. GOŠIĆ-DONDO *et al*. (2016) examined the efficacy of thiamethoxam-based and imidocloprid-based insecticide preparations during a two-year study on maize. Their results showed a positive effect on reducing the intensity of the European corn borer attack, with the attack ranging from 50.1% to 74.1%. By observing the influence of other active substances, a positive effect of dimethoate-based preparations was found in the experiment of RASPUDIĆ *et al*. (2013). FRANETA *et al*., (2018) examined the effect of various insecticides on the antioxidant defense system of *O. nubilalis* larvae, and concluded that chlorantraniliprol-based insecticides had the best results. Novaluron-based and spinosad-based insecticides have also shown satisfactory effects on the larvae of this pest (BOITEAU and NORONHA, 2007).

In a long-term field trial set up in Legnaro, Italy from 2011 to 2014, the effect of three foliar insecticides against *O. nubilalis* in maize crops in rotation was tested. The results show that the insecticide with the active substance of lambda-cyhalothrin had the highest efficiency, immediately followed by chlorantraniliprol, and there was no statistical significance between them (VASILEIADIS *et al*., 2016). The impact of diamine residues and traditional pyrethroid-based insecticides at different times of foliar application (1, 7, 10 and 14 days before the formation of pods) was examined in the beans crop in New York, USA, during 2015 and 2016. All treatments tested were better than control variants, whereas the treatment performed 14 days before the formation of pods, which consisted of chlorantraniliprole and chlorantraniliprole + lambda-cyhalothrin consistently sustained less damage and had a higher larval mortality than all other treatments. These studies have also demonstrated that insecticides containing chlorantraniliprole can only be applied once a season (no need for multiple uses) and the use of fungicides or herbicides is even recommend with this application. The results have also shown that anthranilic-diamides, especially chlorantraniliprole, have greater longevity and efficacy than pyrethroids, thus increasing the flexibility of treatment time (SCHMIDT-JEFFRIS and NAULT, 2017).

CONCLUSION

Based on the results, it can be concluded that the application of insecticides is effective in reducing damage caused by the European corn borer (*Ostrinia nubilalis* Hbn.), which was shown by significant differences between the treated variants and the control variants (areas with untreated plants).

In average for all six maize hybrids tested was found the lowest attack intensity after the Fobos (I-2) insecticide treatment, where the mean of the total attack percentage was 81.62% while the highest intensity of attack, found in the control variant, without the use of insecticides, on average for all hybrids, was 91.72% of the total number of plant attacked by *O. nubilalis*.

In terms of insecticide treatments, the lowest total attack was observed in ZP 434 hybrids, where 77.12% were attacked with Fobos (I-1) treatments; while ZP 555 hybrid had the highest total attack with 88.55% under the treatment by Match + Nurelle (II-1) insecticide.

In addition to effective influence of Fobos (I-1) treatments, the lowest attack was established in ZP434 after application Match +Nurelle (II-1)- 80.74%, and Fobos (I-2) - 83.3% while the highest attack was found in ZP 606 (84.32%) by treatment Fobos (I-2) insecticide. The effect of treatment by Match + Nurelle (II-2) was estimated and the lowest attack of *O. nubilalis* was found in ZP 427 (80.20%) while the highest attacked was eastablished in ZP 555 hybrid plants (86.75%).

The highest attack by European corn borer was found in control variant (without treatment by insectidides) and in average in ZP 666 hybrid (94.27%), while the lowest total attack was established in ZP 434 hybrid (88.76%).

In average the application of insecticides at the time of first-generation attack was the more efficient than application at the time of developed second generation of European corn borer (*Ostrinia nubilalis*).

The attack intensity of the first generation European corn borer, was the lowest in ZP 666 hybrids (13.07%) in the variant where Fobos (I-1) insecticide was applied, while it was the highest in ZP 427 hybrids - 35.54%.

The application Match +Nurelle (II-1) at the time of first generation attack was the most efficient in hybrid ZP 434 with the lowest number of damaged plants (26.58%), while the highest number of damaged plants was found in ZP 606 (42.42%).

The application Fobos (I-2) at the attack of first generation was the lowest, in hybrid ZP 434 (44.22%), while the highest in ZP 600 (52.86%).

After application Match +Nurelle (II-2) the lowest attack of first generation *O.nubillais* was in hybrid ZP 427 (46.56%) while the highest attack on plant was in hybrid ZP 666 (57.7%).

The attack of second generation was the lowest in ZP 434 hybrid (43.24%) and the highest in ZP 666 hybrids (68.62%) under treatment by Fobos (I-1) insecticide.

The treatment by Match +Nurelle (II-1) showed the smallest attack of second generation of *O. nubilalis* in ZP 606 (39.7 %) and thi highest attack in hybrid ZP555 (58.62%).

The attack of second generation was the lowest in ZP 600 hybrid (30.03%) and the highest in ZP 434 hybrids (36.04%) under treatment by Fobos (I-2) insecticide.

The lowest intensity attack of second generation was found in hybrid ZP 666 (23.28%) while the highest attack was in hybrid ZP 434 (36.39%).

The highest attack of first generation of Europena corn borer was found in control variant (without treatment by insectidides) and in average in ZP 666 hybrid (69.29%), while the lowest total attack of first generation was established in ZP 434 hybrid (64.36%). The lowest intensity of the attack by the second-generation larvae of the European corn borer (*O. nubilalis)* was found in ZP 555 hybrids (23.9%) of the control variant and the highest in ZP 666 hybrids (26.93%) on the control variant (without insecticide treatment).

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UTICAJ INSEKTICIDA NA UKUPAN PROCENAT NAPADA *Ostrinia nubilalis* Hbn KOD HIBRIDA KUKURUZA

Snežana GOŠIĆ DONDO[1], Dragan GRČAK[2], Milosav GRČAK[2],
Danijela KONDIĆ[3], Djuradj HAJDER[3], Željko POPOVIĆ[4], Desimir KNEŽEVIĆ[2*]

[1]Institut za kukuruz "Zemun Polje", Beograd, Srbija
[2]Univerzitet u Prištini, Poljoprivredni fakultet, Kosovska Mitrovica–Lešak, Kosovo i Metohija, Srbija
[3]Univerzitet Banjaluka, Poljoprivrendi fakultet Banjaluka, Banjaluka, Republika Srpska, BiH
[4]Univerzitet u Novom Sadu, PMF, Novi Sad, Srbija

Izvod

Cilj rada je bio da se utvrdi efekat insekticida na razvoj kukuruznog moljca (*Ostinia nubilalis* Hbn) i efekat oštećenja u šest hibrida kukuruza različitih grupa zrenja. Istraživanje je obuhvatilo sledeće hibride ZP 427, ZP 434, ZP 555, ZP 600, ZP 606 i ZP 666. U ogledu, insekticidi su primenjeni u dva termina i to: u vreme leta prve generacije *O. nubilalis* i posle toga u vreme letenja druge generacije *O. nubilalis*. U istraživanjima su korišćeni insekticidi: Fobos EC insekticid i kombinacija insekticida Match 050 EC + Nurelle D čije su aktivne supstance različite. Aktivna supstanca kod insekticida Fobos EC je bifentrin 100 g l^{-1}, kod Match 050 EC je lufenuron 50 g l^{-1}, a kod insekticida Nurelle D aktivna supstanca je kombinacija hlorpirifos 500 g l^{-1} i cipermetrin 50 g l^{-1}. Ocena oštećenja na biljkama je vršena u julu i septembru u godini eksperimenta. Insekticid Fobos je imao nabolji efekat zaštite biljaka. Ustanovljen je najbolji efekat Fobosa u zaštiti biljaka, posle čije primene je nadjeno oštećenje kod 81.62% prosečno za sve hibride, što je značajno različito od napada kukuruznog plamenca na kontrolnoj varijanti, bez upotrebe insekticida, na kojoj je nadjeno 91,72% napadnutih biljaka prosečno za sve hibride. U analizi tretmana insekticidima, najniži ukupni napad je nadjen kod ZP 434 hibrida i to 77,12% napadnutih biljaka posle tretmana Fobos (I-1); dok je najveći ukupni napad (88.55%) nadjen kod ZP 555 hibrid posle tretmana Match + Nurelle (II-1). U proseku primena insekticida u vreme prve generacije napada je bila efikasnija nego primena insekticida u vreme razvijene druge generacije kukuruznog plamenca (*Ostrinia nubilalis*). Intenzitet napada prve generacije kukuruznog plamenca, je bio najniži kod ZP 666 hibrida (13,07%) u varijanti primenjenog insekticida Fobos (I-1), dok je najviši u ZP 427 hibrida - 35.54%. Napad druge generacije je bio najmanjeg intenziteta kod ZP 434 hibrida (43,24%), a najviša u ZP 666 hibrida (68,62%) posle tretmana sa insekticidom Fobos (I-1). Prosečno za sve hibride najveći intenzitet napada u vreme prve, kao i u vreme druge generacije kukuruznog plamenca je ustanovljen u kontrolnoj varijanti (bez tretmana insekticidom) koji je bio veći u odnosu intenzitet napada na tretiranim varijantama sa insekticidom. Na kontrolnoj varijanti, intenzitet napada ocenjen u vreme prve generacije *O. nubilalis* je vrarirao u rasponu od najvećeg kod ZP 606 hibrida (69.29%), do najmanjeg kod ZP 434 hibrida (64.36%), dok je u vreme druge generacije intenzitet napada varirao u rasponu od najvećeg kod ZP 666 hibrida (26,93%) do najmanjeg kod kod ZP 555 hibrida (23.9%).

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