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Imaginal and ovicidal effect of some insecticides against *Bruchus pisorum L.* (*Coleoptera: Chrisomelidae*)

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Abstract

Trials were conducted in 2011 and 2012 at the Institute of Forage Crops, Pleven, Bulgaria, in order to study the imaginal and possible ovicidal effect of some insecticides against *Bruchus pisorum* under field conditions. Treatments with insecticides were started after the appearance of the first pea weevils eggs on pods located on the bottom two nodes. It was found that treatment with acetamiprid; thiacloprid; thiacloprid+deltamethrin; 50 g cypermethrin+480 g chlorpyrifos-ethyl, 50 g cypermethrin+500 g chlorpyrifosethyl and zeta-cypermethrin resulted in the cessation of additional oviposition on the lower nodes by *Bruchus pisorum*, due to the toxic effect of the insecticides on the pea weevil. It was found that spraying with acetamiprid and zeta-cypermethrin was the most effective. These insecticides significantly reduced the proportion of infected pods in comparison with the proportion of pods with eggs before the treatment by 30.2 and 27.4% and by 15.8 and 24.0% in 2011 and 2012, respectively. The use of acetamiprid and zeta-cypermethrin was also associated with the lowest percentage of infected seeds (21.7 and 23.6%, respectively), with the lowest percentage of infected seed in infected pods (40.5 and 42.5%, respectively) and the highest weight of 1000 infected seeds (161.94 and 182.04 g, respectively). It was concluded that the management of pea weevils in the crop with acetamiprid and zeta-cypermethrin can lead to satisfactory results when spray timing is chosen when the first eggs are visible.

Keywords

Bruchus pisorum • insecticides • imaginal • ovicidal effect

Introduction

Obtaining economically justifiable yields of high quality in pea crops is related to the implementation of rational, environmentally friendly plant protection. It is necessary to know the main pests, biology, habits and conditions of their development, means of controlling them and time of effective pesticide application in order to protect plants from harmful insects. *Bruchus pisorum* L. is one of the economically most dangerous pea pests in the environmental conditions of Bulgaria. The pea weevil is distributed widely across Europe and all countries where field peas are grown (Plantwise 2014). It spreads from one country to another mainly through weevil-infested seed materials, export trade, germplasm exchange, among others.

The biology of *B. pisorum* and its harmful activity have been recorded in many Bulgarian and foreign studies (Grigorov 1960; Popov and Fudulov 1961; Naneva and Donchev 1981; Posylaeva and Malahanov 1989; Dochkova *et al*. 1990; Dochkova and Ilieva 2000; Dochkova and Naneva 1995; Sapunaru *et al*. 1994; Brudea and Mateias 1998; Kaniuczak 2005). Many authors have found that pea weevil could cause enormous damage to yield potential, reducing the grain yield by 40% or more (Ermakov 1998; Alekhine and Ivanova 2007; Demkin and Dobronravova 2007). *B. pisorum* produces one generation per year and hibernates either inside the seeds, while in storage or in the field, under dead leaves, or under the bark of trees. Injury is caused by the larva, which destroys most of the grain during its full development, whereupon it also affects the embryo. Damaged seeds have a low germination percentage and are not suitable for sowing. The basic method of pea weevil management is still through chemical control, which is traditionally aimed at controlling adult beetle density in a crop before they lay eggs on pods (Horne and Bailey 1991; Smith 1992; Smith and Hepworth 1992). However, the efficacy of the chemical control treatment is largely determined by the timing of spraying, which is difficult to determine. It is not easy and reliable to monitor adults in pea fields (using sweep nets) at the time just before flowering or in the course of flowering (Seidenglanz et al., 2007). This leads to the poor timing of spray applications, which often miss the beetles themselves and the period of egg laying as well.

The appearance and flight period of beetles in the pea stands are influenced by many factors and the lack of captured individuals, when recording their density, does not guarantee that the pest is absent in the investigated areas. It is especially uncertain in situations when the

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captured adults are in low abundance, which might result in a danger of reaching the economic threshold level of damage (Seidenglanz and Jana, 2008). The application of insecticides which use an established ovicidal or repellent effect to control pea weevils, in addition to their toxic effects on adults, would solve the problem to a great extent. In the literature, there is not much information about the effects of insecticides on pea weevil eggs. Some insecticides applied to control the pea weevil have been found to have a strongly ovicidal effect against different phytophages (Piedallu and Roâ 1982), but there is no information about the ovicidal effect of the used preparations against bruchids in Bulgaria. Therefore, it was felt necessary to study the efficacy of new insecticides that should be effective not only against the *B. pisorum* adults, but also show a certain ovicidal effect.

The objective of this work was to study the imaginal and possible ovicidal effect of some insecticides against *B. pisorum* under field conditions.

Material and methods

The study was conducted during 2011 and 2012 in the experimental field of the Institute of Forage Crops, Pleven, Bulgaria. A field trial was carried out with pea (*Pisum sativum* L.), variety "Pleven 4" (standard) at a sowing rate of 120 seeds m^{-2} in order to control *B. pisorum* L. in spring forage pea. The experimental design was a randomised block with four replications and a natural background of soil supply with the major nutrients. The soil type was a leached chernozem with a $pH_{(KCl)}$ value of –5.49 and content of total N at 34.30 mg/1000 g soil, P_2O_5 at 3.72 mg/100 g soil and K_2O at 37.50 mg/100 g soil. The sowing dates were 25 March 2011 and 21 March 2012. The insecticides that were used are described in Table 1.

Monitoring of pea weevil eggs on lower fructiferous nodes began when the small green pods had appeared (in two- to three-day intervals). Immediately after appearance of the first eggs, accurate recording of their location on pods from the two lower nodes was made in order to calculate the following data:

1. PPE in %: The proportions of pods from the lower one or two nodes with eggs was recorded (four areas of 50 pods each) for each planned treatment separately just before the treatment. Pods were sampled by selecting whole vines rather than by picking individual pods, in order to avoid preference for the outermost pods (Smith and Hepworth, 1992).
2. The average numbers of eggs per pod on the lower one or two nodes was calculated for each planned treatment separately.
3. The average numbers of eggs per affected pod on lower one or two nodes was recorded.

Treatment with the insecticides chosen for the study was started after sighting the first pea weevil eggs on pods located on the lower two nodes according to the method of Horne and Bailey (1991). Just before harvest four samples × 50 pods from two lower nodes per plot were taken to obtain the following data:

1. PIP, %: The proportions of infected pods from the lower one or two nodes were determined for the individual treatments separately;
2. PIS, %: The proportions of infected seeds from the lower one or two nodes were determined for each pack of seeds;
3. PISIP, %: Proportion of infected seeds in infected pods sampled from the lower one or two nodes;
4. WIS: weight of 1000 infected seeds, g;
5. TIS, %: Total proportion of infected seeds.

The differences between the PPE and PIP values and the data were statistically analysed by one-way analysis of variance (ANOVA) and the significance of mean differences was determined by Fisher's LSD test at $P < 0.05$. The effectiveness of the individual treatments was calculated by the formula of Abbott (1925):

$$E\,\% = \left(1 - \frac{n \text{ in T after treatment}}{n \text{ in Co after treatment}}\right) * 100$$

where n = insect population , T = treated , Co = control

Table 1. Details of insecticide treatments

Commerical products	Active ingredients	Rates of the actives applied per ha	Manufacturer
	Neonicotinoids		
Mospilan 20 SP	200 g a.i. kg-1 acetamiprid	3000 g	*Nippon Soda*, Japan
Calypso 480 SC	480 g a.i.l-1 thiacloprid	300 ml	Bayer Crop Science, Germany
Proteus 110 OD	100 g a.i. l-1 thiacloprid +10 g a.i. l-1 deltamethrin	700 ml	Bayer CropScience, -Germany
	Pyrethroids		
Duet 530 EC	50 g a.i.l-1 cypermethrin + 480 g a.i.l-1 chlorpyrifos-ethyl	500 ml	**Agria** Corporation, **Bulgaria**
Nurelle D	50 g a.i. l-1 cypermethrin + 500 g a.i. l-1 chlorpyrifosethyl	40 ml	Dow AgroSciences, Indiana, USA
Fury 10 EC	100g a.i.l-1 zeta-cypermethrin	100 ml	FMS, USA

Results

2011

At the time of spraying, the proportion of pods on bottom nodes with pea weevil eggs (PPE) ranged from 73.3 to 79.3% (Table 3). There were no statistically significant differences among PPE values; the average numbers of eggs per pod on the lower nodes and the average number of eggs per affected pod before spraying in all treatments (Tables 2 and 3).

After the treatment with insecticides, it was found that oviposition continued in the control plots only, where the proportion of infected pods sampled from one or two nodes (PIP) significantly increased (P<0.05) by 15.9%. The additional oviposition on pods sampled from lower one or two nodes was reduced in the other treatments, due to the toxic effect of the insecticides on adult individuals and some of insecticides probably had a repellent effect on females (Table 3). It was obvious that all treatments significantly decreased (P<0.05) the PIP values compared to the control.

Table 2. Monitoring of pea weevil eggs (*B. pisorum*) on young pods from the two bottom parts of inflorescences immediately before the treatment

Treatment	Average number of eggs per pod on 1–2 nodes		Average number of eggs per affected pod on 1–2 nodes	
	2011	2012	2011	2012
200 g acetamiprid	1.89	1.74	2.55	2.52
480 g thiacloprid	1.87	1.83	2.35	2.47
100 g thiacloprid + 10 g deltamethrin	1.75	2.02	2.29	2.35
50 g cypermethrin+ 480 g chlorpyrifos-ethyl	1.72	2.10	2.29	2.49
50 g cypermethrin+ 500 g chlorpyrifosethyl	1.73	1.94	2.25	2.40
100 g zeta-cypermethrin	1.74	2.17	2.37	2.35
Control	1.79	2.14	2.35	2.55
Average	1.78	1.99	2.35	2.45
LSD $_{0.05\%}$	0.26	0.86	0.41	0.44

Table 3. Proportions of infected pods and seeds by pea weevil (*B. pisorum*) and effects of insecticide treatments on the pest, 2011

Treatment	PPE	PIP		LSD $_{0.05\%}$	E	PIS		E	PISIP		WIS		TIS		E
200 g acetamiprid	74.0	43.8	a**	11.24*	52.4	17.2	a	50.9	39.9	ab	224.6	b	24.5	a	58.44
480 g thiacloprid	79.3	73.1	c	9.12	20.4	24.0	bc	31.5	42.0	ab	180.1	a	34.3	bc	41.75
100 g thiacloprid + 10 g deltamethrin	76.0	69.4	c	8.60	24.5	23.1	bc	33.9	44.0	bc	170.3	a	35.6	bc	39.65
50 g cypermethrin + 480 g chlorpyrifos-ethyl	75.3	68.8	c	14.47	25.2	24.7	c	29.3	46.6	bc	172.2	a	39.7	c	32.63
50 g cypermethrin + 500 g chlorpyrifosethyl	76.7	74.4	c	8.06	19.1	25.8	c	26.1	44.7	bc	167.5	a	41.4	c	29.80
100 g zeta-cypermethrin	73.3	57.5	b	5.43*	37.4	18.1	a	48.2	36.6	a	264.5	c	26.9	ab	54.32
Control (C)	76.0	91.9	d	9.94	-	35.0	d	-	49.5	c	163.5	a	58.9	d	-
Average	75.8	68.4		-	25.6	24.0		36.7	43.3		191.8		37.3		42.76
LSD $_{0.05\%}$	7.43	10.13				4.66			6.94		37.18		8.90		

Legend: PIP, Proportion of infected pods sampled from one or two nodes, %;
PIS, Proportion of infected seeds sampled from one or two nodes, %;
PISIP, Proportion of infected seeds in infected pods sampled from one or two nodes, %;
WIS, weight of 1000 infected seeds, g;
TIS, Total proportion of infected seeds, %;
E, Efficacy according to Abbott, %
****PPE and PIP are significantly different (*P* > 0.05).***
*****Means in each column followed by the same letters are not significantly different (*P* > 0.05).***

The use of 50 g cypermethrin+500 g chlorpyrifosethyl had the least effect on oviposition on pods sampled from lower one or two nodes and the percentage of infected pods (PIP) was very close to the corresponding value of PPE before treatment. Small nonsignificant differences between PPE and PIP was observed also after application of thiacloprid+deltamethrin, 50 g cypermethrin+480 g chlorpyrifos-ethyl and thiacloprid at 6.6, 6.5 and 6.2%, respectively. Acetamiprid (neonicotinoid insecticide) and zeta-cypermethrin (peritroid) were observed to produce an effective treatment against the pods. These treatments resulted in a statistically significant decrease in the proportion of infected pods at 30.2 and 15.8%, respectively. These insecticides were characterized by the highest efficacy (acetamiprid –52.4% and zeta-cypermethrin –37.4%) and a significant difference (P<0.05) in terms of the infected pods in comparison with the other treatments. Specifically, in a comparison of acetamiprid and zeta-cypermethrin, acetamiprid showed a significantly higher (P<0.05) effect, which resulted in a lowest proportion of infected pods (PIP: 43.8%).

Treatment with insecticides resulted in a statistically significant reduction (P<0.05) in the proportion of infected seeds (PIS) compared to the untreated control. The PIS of thiacloprid, thiacloprid+deltamethrin, 50 g cypermethrin+480 g chlorpyrifos-ethyl and 50 g cypermethrin+500g chlorpyrifosethyl varied in a narrow range from 23.1 to 25.8%, and the recorded efficiency was 26.1 to 33.9%. There were no significant differences between the PIS values of these treatments. The proportion of infected seeds was the lowest in the treatments that received acetamiprid and zeta-cypermethrin (17.2 and 18.1%). The efficiency of these insecticides exceeded 50 and 48%, respectively. The application of zeta-cypermethrin and acetamiprid was also associated with the lowest proportion of infected seeds in infected pods (PISIP), as well as with the highest weight of 1000 infected seeds (WIS) exceeding the control by 61.8 and 37.4%, respectively. There were significant differences between the PISIP values of these treatments and the control, as well as between the WIS alues of these treatments and the control. The weight of 1000 infected seeds in the other treatments slightly exceeded the control from 2.5 to 10.2%.

In terms of the total proportion of infected seeds (TIS; recorded not only from the lower pods, but also the whole plant), there was a statistically significant decrease (P<0.05) between the untreated control and the other treatments. The highest effect was found after treatment with acetamiprid and zeta-cypermethrin (TIS: 24.5 and 26.9%, respectively) and the differences in TIS values between them and the other treatments were statistically significant (P<0.05).

2012

Before the insecticidal application, there were no significant differences among the PPEs, that is the average numbers of eggs per pod on lower nodes and the average number of eggs per affected pod in all the treatments (Tables 2 and 4). In comparison with the previous year, there was a higher average density of eggs laid on pods and affected pods of the lower one or two nodes, by 11.8 and 4.3% respectively, due to higher population density of pea weevil.

The treatments had a statistically significant effect (P<0.05) on the proportion of infected pods (PIP). Oviposition continued only in the control in which the PIP reached 97.5% with a significant increase in the control of 17.4% compared to the PPE value (Table. 4). The application of 50 g cypermethrin+500 g chlorpyrifosethyl, 50 g cypermethrin+480 g chlorpyrifos-ethyl and thiacloprid resulted in no significant decrease in the PIP compared with the PPE (decrease from 1.4 to 5.8%). The application of acetamiprid and zeta-cypermethrin was the most effective, where the proportions of infected pods were the lowest and the differences between PPE and PIP were statistically significant (P<0.05, decrease by 27.4 and 24.0%, respectively).

Almost all insecticidal applications (except 50 g cypermethrin+500 g chlorpyrifosethyl) resulted in a statistically significant decrease (P<0.05) in the PIS in comparison with the untreated control. The lowest PIS was achieved after applications of acetamiprid and zeta-cypermethrin (26.3 and 29.0%, respectively) and the differences between them and the other treatments were statistically significant (P<0.05). These insecticides had the lowest proportion of infected seeds in infected pods (PISIP: 41.0 and 48.4%, respectively), as well as the highest weight of 1000 infected seeds exceeding the control by 25.1 and 25.5%. There were significant differences (P<0.05) between the PISIP values of these treatments and the untreated control, as well as between the WIS values of these treatments and the untreated control.

As regards the total proportion of infected seeds (TIS), there was some decrease compared to untreated control. Statistically significant decreases in TIS (P<0.05) was achieved only after applications of acetamiprid and zeta-cypermethrin (TIS: 39.3 and 44.3%, respectively).

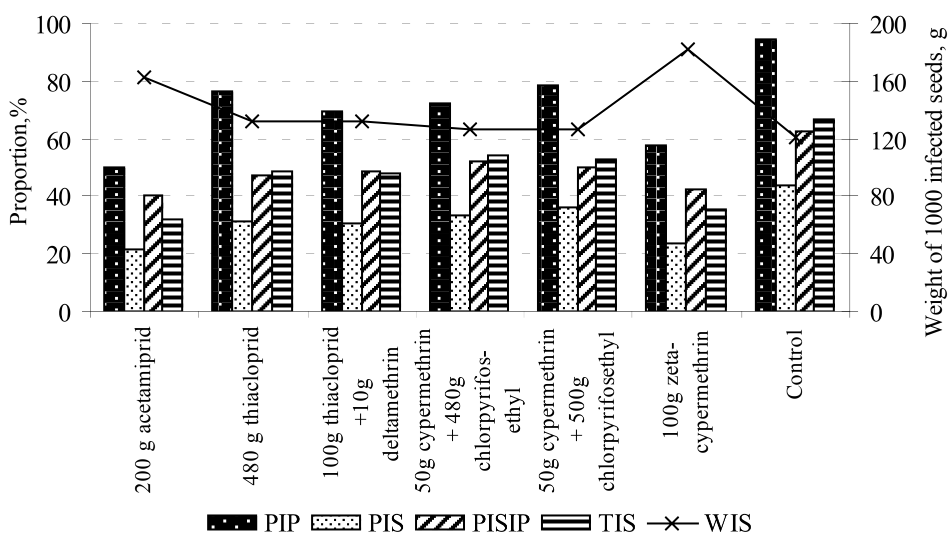
Based on a comparison of the PIS and TIS values in all the treatments, it was found that in both years, oviposition was less concentrated on pods of lower nodes and the females of *B. pisorum* preferred the upper areas (Table 4 and 5).

The use of acetamiprid and zeta-cypermethrin on average for the period was associated with the lowest values of PIP (50.0 and 57.5%, respectively), PIS (21.7 and 23.6%), PISIP (40.5 and 42.5%) and TIS (31.9 and 35.6%), and the highest value of WIS (161.94 and 182.04 g) (Figure 1). These insecticides not only suppressed additional oviposition on pods, but also most likely induced certain mortality of eggs manifesting an ovicidal effect.

Table 4. Proportions of infected pods and seeds by pea weevil (*B. pisorum*) and effects of insecticide treatments on the pest (2012)

Treatment	PPE	PIP		LSD 0.05%	E	PIS		E	PISIP		WIS		TIS		E
200 g acetamiprid	83.7	56.3	a**	12.03 *	42.3	26.3	a	50.2	41.0	a	99.27	d	39.3	a	46.77
480 g thiacloprid	85.1	80.0	bc	8.42	17.9	39.0	bc	26.1	52.1	a	82.65	ab	62.2	c	15.63
100 g thiacloprid + 10 g deltamethrin	79.6	70.0	b	8.72	28.2	38.2	b	27.7	53.1	a	92.71	c	60.4	bc	18.12
50 g cypermethrin + 480 g chlorpyrifos-ethyl	82.1	76.3	bc	15.35	21.8	41.6	bc	21.1	57.5	a	80.54	ab	68.9	c	6.53
50 g cypermethrin + 500 g chlorpyrifosethyl	83.9	82.5	c	14.38	15.4	46.4	cd	12.2	55.6	a	86.46	bc	63.6	c	13.75
100 g zeta-cypermethrin	81.5	57.5	a	3.05 *	41.0	29.0	a	45.0	48.4	ab	99.57	d	44.3	ab	39.89
Control (C)	80.1	97.5	d	4.79 *	-	52.8	d	-	76.0	c	79.34	a	73.8	c	-
Average	82.3	74.3			27.8	39.0		30.4	54.8		88.65		58.93		23.45
LSD 0.05%	6.12	11.23				7.84			10.61		6.38		17.62		

Legend: PIP, Proportion of infected pods sampled from one or two nodes, %;
PIS, Proportion of infected seeds sampled from one or two nodes, %;
PISIP, Proportion of infected seeds in infected pods sampled from one or two nodes, %;
WIS, weight of 1000 infected seeds, g;
TIS, Total proportion of infected seeds, %;
E, Efficacy according to Abbott, %
****PPE and PIP are significantly different (*P* > 0.05).***
*****Means in each column followed by the same letters are not significantly different (*P* > 0.05).***



Legend: PIP, Proportion of infected pods sampled from one or two nodes, %
PIS, Proportion of infected seeds sampled from one or two nodes, %;
PISIP, Proportion of infected seeds in infected pods sampled from one or two nodes, %;
WIS, weight of 1000 infected seeds, g;
TIS, Total proportion of infected seeds,%

Figure 1. Proportions of infected pods and seeds by pea weevil* B. pisorum*, average (2011 and 2012).

Discussion

Insecticidal spraying can cause a remarkable decrease of final seed infestation. Based on the comparison of the recorded PPE for the individual treatments before the insecticidal application and the recorded PIP just before the time of harvest, it is possible to establish how the individual insecticidal applications influenced the course of further oviposition (after the application). It is possible to follow the ovicidal effects of the individual insecticides. The results demonstrated that acetamiprid and zeta-cypermethrin not only inhibited further oviposition on the lower pods but very likely induced some egg mortality, manifesting in an ovicidal effect. The application of zeta-cypermethrin and acetamiprid was also associated with the highest weight of 1000 infected seeds (WIS). This is probably a result caused by not only an ovicidal effect, but also a larvicidal effect manifested by the insecticides. Of all the insecticides, the application of zeta-cypermethrin and acetamiprid was the most effective. The results of treatment with thiacloprid + deltamethrin were ambiguous. In 2012, the proportions of infected pods were significantly smaller than the corresponding control values, and the other tested parameters were below the average for the trial, which probably was due to an ovicidal effect, while in 2011, this trend was not observed. The use of thiacloprid, 50 g cypermethrin+480 g chlorpyrifos-ethyl and 50 g cypermethrin+500g chlorpyrifosethyl resulted in the cessation of additional oviposition on pods, but the insecticides had no ovicidal effect on the viability of eggs.

According to Smith (1992), the ovicidal effect of the insecticides could be influenced by other factors: crop density, position of eggs on the pod in relation to the direction of spraying, the mode of egg laying (single laid eggs and eggs laid in the form of two-egg clusters), pea variety and also the prevailing morphological stage of eggs at the time of spraying.

In 2012, there was a higher density of eggs and a higher degree of infected pods and seeds compared to 2011. Generally, the insecticides also showed lower efficiency in 2012. This phenomenon was related to the different weather conditions in each year, which had an influence on the population density of *B. pisorum,* as well as the impact of the insecticides. The sum of rainfall during the vegetation period of 2012 was 21.3% higher compared to 2011. In both years of study, the treatment with insecticides was conducted in the second or third 10-day period of June. In this period, the amount of rainfall reached 27.2 mm in 2012 as compared to 13.2 mm in 2011 (106.6% higher amount of rainfall in 2012). Thus, higher rainfall resulted in lower insecticide efficiency in the second year of the study. The density and duration of the time of presence of pea weevil in the crops were very important. In 2012, the duration was longer and the abundance of *B. pisorum* was higher. Despite the differences in weather between the two years, it should be taken into account that the recorded values of the studied parameters were the result of a single treatment against pea weevil.

Regardless of the effects of such treatments expressed in a decrease of the PISs values, it is possible to conclude that the insecticides applied on the lower pods did not succeed in preventing the egg laying on the upper nodes.

Some authors found that the ovipositing activity of pea weevil females was concentrated on the lower nodes predominantly (Seidenglanz and Jana 2008). This study showed that the ovipositing activity of pea weevil females was concentrated on the upper nodes predominantly.

It is possible to conclude that the management of pea weevils in the crop with acetamiprid and zeta-cypermethrin can lead to satisfactory results when the spray timing is chosen when the first eggs are visible.

Conclusions

Treatment with acetamiprid, thiacloprid, thiacloprid+deltamethrin, 50 g cypermethrin+480 g chlorpyrifos-ethyl, 50 g cypermethrin+500 g chlorpyrifosethyl and zeta-cypermethrin were associated with the cessation of additional oviposition on lower nodes by *B. pisorum*, due to the toxic effect of these insecticides on pea weevils.

It was found that acetamiprid and zeta-cypermethrin were the most effective insecticides. These insecticides significantly reduced the proportion of infected pods in comparison with the proportion of pods with eggs before the treatment by 30.2 and 27.5% and by 15.8 and 24.0% in 2011 and 2012, respectively. The use of acetamiprid and zeta-cypermethrin was also associated with the lowest percentage of infected seeds (21.7 and 23.6%, respectively), with the lowest percentage of infected seed in infected pods (40.5 and 42.5%, respectively) and the highest weight of 1000 infected seeds (161.94 and 182.04 g, respectively).

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