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Resistance of *Meligethes aeneus* to pyrethroids in Lithuania

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Abstract

The pollen beetle (*Meligethes aeneus* F.) is the most important pest in winter and spring oilseed rape crops in Lithuania. Laboratory experiments were conducted with the aim of testing the sensitivity of populations of pollen beetle, collected in different regions of Lithuania to different active substances of pyrethroids (λ-cyhalothrin, α-cypermethrin, deltamethrin and tau-fluvalinate). During 2008–2010, 101 populations (46 collected from winter and 55 from spring oilseed rape fields) were tested. Many Lithuanian pollen beetle populations showed decreased susceptibility to λ-cyhalothrin, α-cypermethrin, deltamethrin, especially those, collected from the Central agroecological zone, where winter and spring oilseed rape has been grown intensively for 20 years. Resistance of pollen beetle populations to tau-fluvalinate was lower. It was estimated that during 2008–2010 the sensitivity of pollen beetle to all active substances tested tended to decrease and resistance tended to increase.

Key words: pyrethroids, *Meligethes aeneus*, resistance, sensitivity, mortality.

Introduction

Pollen beetle (*Meligethes aeneus* F.) is one of the most significant pests of rape that is usually controlled by synthetic insecticides (Bromand, 1990; Cook et al., 2004). By 1990, extermination of different pests had been performed using insecticides belonging to the class of organophosphates toxic to bees and other helpful insects. To decrease the negative impact of chemical substances of organophosphates on useful insects and nature, around 1990, synthetic insecticides of pyrethroid class were developed on the basis of pyrethrin. The products stood out not only by high effectiveness and environmental friendliness, but also by a rather low price. In many countries this inspired pest control (including pollen beetle control in oilseed rape) registration and almost exceptional use of insecticides of pyrethroid class (Heimbach et al., 2006; Hansen, 2008; Węgorek, Zamojska, 2008). The data from the Lithuanian State Plant Protection Service indicate that in 2011 nine insecticides were included in the list of safe pesticides for use in oilseed rape crops. They were recommended for pollen beetle chemical control. All of them belong to the pyrethroid class, except for one that belongs to neonicotinoids (active substance tiakloprid).

Due to too frequent or even prophylactic use of pyrethroid insecticides for pollen beetle control, resistant populations of this pest emerged. The first data about pollen beetle resistance to pyrethroids were registered in 2000 in Sweden and Switzerland (Derron et al., 2004; Kazachkova et al., 2007). In Sweden, resistance to pyrethroids was first registered in the part of the country where winter and spring rape had been grown for several decades in large areas. Later on resistance of pollen beetle to pyrethroids was identified in Denmark (Hansen, 2003), France (Ballanger et al., 2003), Germany (Heimbach et al., 2006) and Poland (Węgorek, Zamojska, 2006).

In 2008, inquiry was carried out in twenty European countries. 12 countries (Belgium, Czech Republic, Croatia, Denmark, Germany, France, Latvia, the Netherlands, Norway, Poland, Sweden and United Kingdom) pointed out that resistance of pollen beetle to insecticides of the pyrethroid class existed or was expected. Nevertheless, some respondents said that bifentrin and tau-fluvalinate were effective for other populations resistant to pyrethroids (Richardson, 2008). There are data that in case of *M. aeneus* resistance to any active substance of pyrethroides, cross resistance to other active substances of this class of insecticides appears (Thieme et al., 2008; 2010).

A significant seed yield reduction ranging from 3.3% to 30.1%, resulting from the pollen beetle damage was identified in the field trials in Lithuania. Trends were noticed that the population of pollen beetle increased during 1999–2006 and the efficacy of pyrethroids used for their control tended to decrease (Petraitiene et al., 2008). However, pollen beetle resistance has not been monitored in Lithuania. The aim of our laboratory experiments was to determine the level of susceptibility of pollen beetle (*M. aeneus*) populations, collected from different regions, to four active substances of pyrethroid insecticides and either to confirm or ignore the fact of pollen beetle resistance to pyrethroids in Lithuania.

Materials and methods

This study was carried out at the Department of Plant Pathology and Protection, Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry. Adults of pollen beetle (*Meligethes aeneus* F.) were collected from different locations of Lithuania in winter (2009–2010) and spring (2008–2010) oilseed rape crops at flowering stage. Beetles were collected from an individual field on dry plants, approximately 1000 to 1500 adults across the infested field. Each sample was named after the district from which insects had been collected. The beetles were stored and transported in aerated plastic containers that had dry paper towel placed at the bottom to prevent excess moisture. Some oilseed rape leaves and rape inflorescences were added to the containers as a food source and as a shelter during transportation. The insects were not subjected to excessive temperature, humidity or starvation stress after collection, and physical handling of the beetles was reduced to a minimum. On arrival at the laboratory, the beetles were released into a ventilated holding cage and left to recover overnight.

In the laboratory experiments IRAC susceptibility test method No. 11-v.2 was used. Active substances of pyrethroids (λ-cyhalothrin, α-cypermethrin, deltamethrin and tau-fluvalinate) and 30 ml glass vials were used for the test. Prior to testing, the inner surface of the glass vials was coated with the active substance of pyrethroids dissolved in acetone in different concentrations. Two concentrations were used: deltamethrin and λ-cyhalothrin 0.075 μg cm^{-2} (100% of the typical field application rate) and 0.015 μg cm^{-2} (20% rate); α-cypermethrin 0.15 μg cm^{-2} (100% rate) and 0.03 μg cm^{-2} (20% rate); tau-fluvalinate 0.720 μg cm^{-2} (100% rate) and 0.144 μg cm^{-2} (20% rate). For control treatment acetone-only solution was used. 1.3 ml of the solution was poured into each vial and rotated on a rolling bank at room temperature for about 30 minutes until the acetone was completely evaporated, resulting in an even film of the active substance on the walls and bottom of the glass vials. After drying the vials were stored in the dark until required.

The experiment was set up in four replicates with about 15 unaffected and active adult beetles per replicate in average. Adult beetles were added to each test vial which was covered with a lid, having a small prick for ventilation. The vials with exposed beetles were kept at 20 ± 2°C. The number of beetles severely affected (dead and moribund) was scored after 24 h. The assessment was made by emptying the vial onto the centre of a piece of paper with a 15 cm circle drawn in the middle. The assessment was made in bright light to stimulate beetle movement out of the circle and insects which could not exit the circle before a period of one minute were considered severely affected. Results were expressed as percentage affected. If more than 20% of the beetles in the control treatment were affected, the study was considered as being invalid.

The data of efficacy of 20% label rate were used only for attribution of pollen beetle populations to the susceptibility groups and are not presented in detail in the manuscript. A susceptibility rating scheme (Table 1) was used to categorize the test sample as being: highly susceptible, susceptible, moderately resistant, resistant or highly resistant.

Statistical analyses. Two-way analysis of variance was used for estimating the effect of active substance and the effect of population on the mortality of pollen beetle (*M. aeneus*).

Table 1. Susceptibility categories used for determining pollen beetle resistance to pyrethroids (IRAC method No. 11-v.2)

Dose of substance (% of label rate)	Mortality of beetles %	Susceptibility group
100	100	highly susceptible
20	100	
100	100	susceptible
20	<100	
100	<100 to ≥90	moderately resistant
100	<90 to ≥50	resistant
100	<50	highly resistant

Results and discussion

Adults of pollen beetle collected from the fields of spring oilseed rape (2008) were highly susceptible to tau-fluvalinate (100% of label rate), where mortality of all ten populations tested achieved 100% (Table 2). The lowest mortality of pollen beetle as affected by λ-cyhalothrin was found in the Vilkaviškis population (79.5%), however the lowest effect of deltamethrin and α-cypermethrin was obtained in the Jonava population (mortality was 87.5 and 92.5%, respectively). Mortality of pollen beetle was significantly affected by the population and by active substance. In average significant differences in the susceptibility to active substances of pyrethroids between pollen beetle populations were obtained. The highest susceptibility to insecticides was shown by Anykščiai population; however the lowest – by pollen beetle populations from Jonava and Vilkaviškis, mortality of pollen beetle in these populations was significantly lower compared with other populations tested. In average, the highest efficacy showed tau-fluvalinate, the efficacy of λ-cyhalothrin and deltamethrin was significantly lower compared with tau-fluvalinate.

The effects of λ-cyhalothrin, α-cypermethrin, deltamethrin and tau-fluvalinate on the pollen beetle populations collected from winter rape fields (2009) show also differences between the 27 populations tested (Table 3). Significant differences were revealed between the populations when averaged data were compared. The highest susceptibility to active substances was shown by pollen beetle population from Alytus (mortality 98.8%); however the lowest mortality (less than 90%) was found in the Marijampolė, Jurbarkas and Vilkaviškis II populations. The efficacy of tau-fluvalinate was significantly higher, compared with λ-cyhalothrin and deltamethrin.

Very similar results were obtained with the pollen beetle populations collected from spring oilseed rape in the same season (Table 4). Pollen beetle populations showed the highest susceptibility to tau-fluvalinate, where the mortality in 6 populations reached 100%. Pollen beetle populations from Biržai and Pasvalys (Central agroecological zone) were highly susceptible to deltamethrin; the mortality of insects was also 100%. However, the highest resistance to λ-cyhalothrin was obtained in the pollen beetle populations from Alytus and Kaunas regions (mortality 70.0% and 79.9%), to α-cypermethrin – in the populations from Marijampolė and Alytus (79.9%), to deltamethrin – in the populations from Kaunas and Marijampolė (mortality was lower than 80%).

Table 2. Susceptibility of *M. aeneus* populations from spring oilseed rape (2008) to different active substances of pyrethroids (100% of label rate)

Agroecological zone	*M. aeneus* population	Active substance				In average
		λ-cyhalothrin	α-cypermethrin	deltamethrin	tau-fluvalinate	
		Mortality of pollen beetle %				
West	Kelmė	97.5	100	100	100	99.4
Central	Jonava	90.0	92.5	87.5	100	92.5
	Joniškis	94.7	97.4	100	100	98.0
	Kėdainiai	95.0	100	100	100	98.8
	Panevėžys	100	97.5	100	100	99.4
	Raseiniai	97.5	97.5	97.2	100	98.1
	Šakiai	100	100	95.0	100	98.8
	Vilkaviškis	79.5	97.4	94.7	100	92.9
East	Alytus	97.5	100	92.5	100	97.5
	Anykščiai	100	100	100	100	100
In average		95.2	98.2	96.7	100	97.5
		MS	F-act.	P_{05}	Probability	
Treatment		73.949	2.33**		0.000264	
M. aeneus population (A)		114.571	3.61**	2.646	0.000531	
Active substance (B)		172.013	5.42**	1.528	0.001583	
Interaction (A × B)		49.513	1.56	5.508	0.055135	

** – significant differences at 0.001 probability level

Table 3. Susceptibility of *M. aeneus* populations from winter oilseed rape (2009) to different active substances of pyrethroids (100% of label rate)

Agroecological zone	*M. aeneus* population	Active substance				In average
		λ-cyhalothrin	α-cypermethrin	deltamethrin	tau-fluvalinate	
		Mortality of pollen beetle %				
West	Kelmė	95.0	98.3	93.3	100	96.1
	Plungė	96.7	96.6	95.0	100	97.1
	Skuodas	96.6	100	91.6	95.0	95.8
	Tauragė	100	96.6	96.5	100	98.3
	Telšiai	98.3	91.6	100	98.3	97.0
Central	Biržai	98.2	98.3	96.6	93.3	96.6
	Jonava	95.2	100	93.2	96.7	96.3
	Joniškis	90.0	95.0	90.2	91.8	91.8
	Jurbarkas	86.3	92.9	84.9	93.3	89.4
	Kaunas I[a]	95.0	98.3	95.0	100	97.1
	Kaunas II	91.7	96.6	93.2	100	95.4
	Kėdainiai I	96.4	100	95.0	91.6	95.8
	Kėdainiai II	90.0	95.0	94.9	98.3	94,6
	Marijampolė	78.0	91.3	85.0	96.4	87.7
	Pakruojis	93.5	93.1	93.3	94.9	93.7
	Panevėžys	96.6	91.6	96.6	95.0	95.0
	Pasvalys	100	96.6	95.0	93.7	96.3
	Radviliškis	93.5	98.3	96.6	96.6	96.2
	Raseiniai	92.0	96.9	90.1	100	94.8
	Šakiai	91.7	95.0	88.3	91.7	91.7
	Šiauliai	91.6	91.9	93.3	96.6	93.4
	Vilkaviškis I	83.5	88.2	98.2	95.0	91.2
	Vilkaviškis II	84.7	90.4	86.6	96.4	89.5
East	Alytus	95.4	100	100	100	98.8
	Anykščiai	96.6	98.3	98.3	100	98.3
	Kupiškis	100	98.3	95.0	95.0	97.1
	Ukmergė	96.8	98.2	100	98.3	98.3
In average		93.4	95.8	93.9	96.6	94.9
		MS	F-act.	P_{05}	Probability	
Treatment		71.50	2.16**		0.000000	
M. aeneus population (A)		141.77	4.29**	2.776	0.000000	
Active substance (B)		255.98	7.74**	0.943	0.000053	
Interaction (A × B)		40.98	1.24	5.631	0.103704	

Note. [a] – samples of pollen beetle were collected from different rape fields in the same region; ** – significant differences at 0.001probability level.

Table 4. Susceptibility of *M. aeneus* populations from spring oilseed rape (2009) to different active substances of pyrethroids (100% of label rate)

Agroecological zone	*M. aeneus* population	Active substance				In average
		λ-cyhalothrin	α-cypermethrin	deltamethrin	tau-fluvalinate	
		Mortality of pollen beetle %				
West	Kelmė	96.7	98.3	96.7	94.9	96.6
	Klaipėda I[a]	92.5	87.5	85.0	97.5	90.6
	Klaipėda II	96.7	100	96.6	100	98.3
	Kretinga	98.3	96.6	96.9	100	97.9
	Skuodas	95.1	96.6	96.6	96.7	96.2
Central	Biržai	98.2	98.3	100	100	99.1
	Jurbarkas	91.5	98.3	95.1	94.8	94.9
	Kaunas	79.9	93.3	78.6	97.6	87.3
	Kėdainiai	98.4	91.4	89.5	92.9	93.0
	Marijampolė	88.3	79.9	78.3	95.0	85.4
	Pakruojis	93.6	93.3	90.4	100	94.3
	Panevėžys	96.5	96.3	91.4	98.2	95.6
	Pasvalys	98.4	96.7	100	100	98.8
	Radviliškis	81.1	89.6	93.3	80.3	86.1
	Raseiniai	96.6	91.4	98.3	100	96.6
	Šakiai	86.0	90.2	84.9	95.0	89.0
	Šiauliai	93.3	86.9	84.7	88.9	88.4
East	Alytus	70.0	79.9	80.0	96.6	81.6
	Prienai	87.9	91.7	93.3	98.3	92.8
In average		91.5	92.4	91.0	96.1	92.8
		MS	F-act.	P_{05}	Probability	
Treatment		177.103	3.46^{**}		0.000000	
M. aeneus population (A)		426.192	8.32^{**}	3.433	0.000000	
Active substance (B)		408.303	7.97^{**}	1.401	0.000045	
Interaction (A × B)		81.229	1.58^{*}	7.007	0.011101	

Note. [a] – samples of pollen beetle were collected from different rape fields in the same region; *, ** – significant differences at 0.05 and 0.001 probability levels, respectively.

In average, significant differences were revealed between the mortality of pollen beetle in different populations. The highest susceptibility was shown by the Biržai, Pasvalys, Klaipėda II and Kretinga populations (mortality of pollen beetle was 99.1–97.9%). The highest resistance to all active substances was shown by the pollen beetle populations from Alytus, Marijampolė, Kaunas, Radviliškis, Šakiai and Šiauliai, where the mortality of insects was significantly lower (less than 90.0%) in comparison with other populations tested. In average, the efficacy of tau-fluvalinate was significantly higher compared with other active substances used in the laboratory experiments. Earlier in Denmark it was determined that *M. aeneus* resistance was relatively higher to λ-cyhalothrin and lower to tau-fluvalinate, also pollen beetle populations were resistant to the phenitrotion (a.s. of organophosphorus insecticides) (Hansen, 2008). Polish research evidence showed that the populations of pollen beetle were rather resistant to pyrethroid β-cyfluthrin. Some experiments showed resistance to tau-fluvalinate and neonicotinoids, therefore, several sprays per season are often necessary for pollen beetle control (Węgorek, 2005; Węgorek et al., 2009).

In 2010, samples of pollen beetle were collected again from winter and spring oilseed rape. Among the *M. aeneus* populations from winter rape (19 populations tested), five populations (Kelmė, Raseiniai, Vilkaviškis, Anykščiai and Prienai I) were highly susceptible to tau-fluvalinate, two populations (Tauragė and Rokiškis) to λ-cyhalothrin, one (Rokiškis) to α-cypermethrin (Table 5). Mortality of pollen beetle in different populations differed significantly. In average, the highest mortality was recorded in the populations from Anykščiai and Tauragė (98.6% and 97.9%, respectively); however the lowest mortality of insects was found in the Marijampolė II population (mortality 76.9%), also in Marijampolė I population (mortality 80.9%). The efficacy of tau-fluvalinate was again higher, compared with λ-cyhalothrin, α-cypermethrin and deltamethrin, however the differences were not significant. Results were similar in all laboratory tests, indicating that *M. aeneus* populations show cross-resistance to the pyrethroids λ-cyhalothrin, α-cypermethrin and deltamethrin. Our data are supported by similar results of other researchers (Heimbach et al., 2006; Thieme et al., 2010).

Among the populations of *M. aenaeus* collected in spring oilseed rape in 2010, two populations (Biržai and Rokiškis) showed very high mortality (100%), affected by all active substances tested (Table 6). Although those two regions are attributed to different agroecological zones, both of them are located in the northern-eastern part of Lithuania. Five more populations of pollen beetle (Panevėžys, Pasvalys, Radviliškis, Šakiai and Vilkaviškis) were highly susceptible to tau-fluvalinate.

However, in all other populations the mortality of pollen beetle was lower. In 14 populations out of 26 tested, affected by λ-cyhalothrin, the mortality was less than 90%, very similar effect was shown by α-cypermethrin and deltamethrin. Significant differences were revealed between the mortality values of different pollen beetle populations. In average, the lowest mortality values were obtained in the pollen beetle samples, collected from spring oilseed rape fields in Kaunas, Kretinga and Plungė regions (mortality was 79.1%, 80.0% and 80.1%, respectively). Significant differences were obtained also between the efficacy of different active substances, however, in average, pollen beetle populations were mostly susceptible to tau-fluvalinate and mostly resistant to deltamethrin. The pyrethroids are divided into three groups. In our investigations four active substances of pyrethroids were tested which belonged to two groups: λ-cyhalothrin, α-cypermethrin, deltamethrin belonged to the third and tau-fluvalinate to the second group. In general, the pyrethroids share similar modes of action and work by keeping open the sodium channels in neuronal membranes. Pyrethroids affect both the peripheral and central nervous systems of the insect. They initially stimulate nerve cells to produce repetitive discharges and eventually cause paralysis.

Table 5. Susceptibility of *M. aeneus* populations from winter oilseed rape (2010) to different active substances of pyrethroids (100% of label rate)

Agroecological zone	*M. aeneus* population	Active substance				In average
		λ-cyhalothrin	α-cypermethrin	deltamethrin	tau-fluvalinate	
		Mortality of pollen beetle %				
West	Kelmė	96.7	98.3	96.7	94.9	96.3
	Tauragė	100	96.6	96.8	98.4	97.9
Central	Biržai	98.4	96.8	95.0	94.9	96.3
	Jurbarkas	96.6	90.1	93.4	98.3	94.6
	Kaunas	88.6	86.8	90.5	96.8	90.7
	Kėdainiai	85.0	90.0	94.6	90.0	89.9
	Marijampolė I[a]	77.5	81.4	71.4	93.4	80.9
	Marijampolė II	74.4	85.6	82.7	65.0	76.9
	Panevėžys	88.3	91.7	82.3	86.6	87.2
	Radviliškis	93.3	88.3	90.1	86.8	89.6
	Raseiniai	92.0	93.1	93.4	100	94.6
	Šakiai	88.6	88.6	88.6	95.0	90.2
	Vilkaviškis	85.2	91.6	91.4	100	92.0
East	Alytus	91.8	86.7	86.7	88.8	88.5
	Anykščiai	98.2	98.2	97.9	100	98.6
	Kupiškis	96.6	96.6	96.8	90.1	95.0
	Prienai I	83.4	89.0	87.3	100	89.9
	Prienai II	88.4	93.3	90.2	95.0	91.7
	Rokiškis	100	100	92.5	87.5	95.0
In average		90.7	91.6	90.2	93.0	91.376
		MS	F-act.	P_{05}	Probability	
Treatment		185.326	4.19**		0.000000	
M. aeneus population (A)		482.534	10.9**	3.19	0.000000	
Active substance (B)		114.570	2.59	1.302	0.053792	
Interaction (A × B)		90.187	2.04**	6.512	0.000166	

Note. [a] – samples of pollen beetle were collected from different rape fields in the same region; ** – significant differences at 0.001 probability level.

Many Lithuanian pollen beetle populations showed decreased susceptibility to λ-cyhalothrin, α-cypermethrin, deltamethrin and to a lower extent to tau-fluvalinate. The highest resistance to pyrethroids was revealed in the pollen beetle populations from Marijampolė, Vilkaviškis, Kaunas, Kėdainiai, Raseiniai, Radviliškis, Joniškis regions. Those regions are attributed to the Central agroecological zone, in which oilseed rape have been cultivated intensively for the last 20 years. The management of pollen beetle was relied only on synthetic pyrethroids, often they were applied routinely and this created favourable conditions for the development of resistant pollen beetle individuals. Another explanation might be that both winter and spring oilseed rape is grown in these regions, this prolongs the period with green bud stages also the period for pollen beetles to breed and increases the number of times they are exposed to pyrethroids.

The results showed changes of pollen beetle susceptibility to the active substances of pyrethroids between 2008 and 2010. During the experimental period, the amount of pollen beetle populations susceptible to λ-cyhalothrin decreased from 30% in 2008 to 8% in 2010, the amount of moderately resistant populations decreased from 60% to 39%, respectively (Fig. A). Conversely, the amount of pollen beetle populations resistant to λ-cyhalothrin tended to increase from 10% to 52%. In the case of α-cypermethrin, the amount of susceptible pollen beetle populations decreased from 50% to 8% during the experimental period, while the amount of moderately resistant populations increased at the beginning from 50% to 80% and later on started decreasing and at the end of the period reached 41% among the total number of populations from spring oilseed rape, tested in 2010 (Fig. B). Pollen beetle populations resistant to α-cypermethrin were not estimated in

2008; however their amount tended to increase during the experimental period and at the end of the period resistant populations reached 50% among the 26 pollen beetle populations, collected from spring oilseed rape fields in 2010. Similar trends were estimated when changes of pollen beetle resistance to deltametrin were analyzed (Fig. C). In 2008, only 10 by 10% of highly susceptible and resistant, also 40 by 40% of susceptible and moderately resistant populations of pollen beetle among the populations tested were obtained. During the experimental period resistance of pollen beetle populations to deltametrin tended to increase and at the end of the period only 2% of susceptible populations were estimated, while the amount of resistant populations rose up to 70%.

Table 6. Susceptibility of *M. aeneus* populations from spring oilseed rape (2010) to different active substances of pyrethroids (100% of label rate)

Agroecological zone	*M. aeneus* population	Active substance				In average
		λ-cyhalothrin	α-cypermethrin	deltamethrin	tau-fluvalinate	
		Mortality of pollen beetle, %				
West	Akmenė	86.8	90.2	81.8	95.1	88.5
	Kelmė	88.3	88.1	83.5	89.9	87.4
	Kretinga	77.9	82.7	78.7	80.9	80.0
	Mažeikiai	91.9	88.4	83.5	86.4	87.5
	Plungė	75.4	79.6	84.9	80.5	80.1
	Tauragė	95.2	98.2	98.4	98.2	97.5
Central	Biržai	100	100	100	100	100
	Jonava	89.4	95.0	77.6	98.3	90.1
	Joniškis	98.3	91.4	84.3	74.3	87.1
	Jurbarkas	95.2	96.7	96.9	96.6	96.4
	Kaunas	65.0	86.3	66.7	98.3	79.1
	Kėdainiai	92.0	90.4	90.3	93.5	91.6
	Marijampolė	80.0	86.5	87.0	90.6	86.0
	Pakruojis	85.0	93.5	82.5	82.8	86.0
	Panevėžys	91.6	96.7	90.0	100	94.6
	Pasvalys	98.3	96.6	96.6	100	97.9
	Radviliškis	80.0	88.7	88.0	100	89.2
	Raseiniai	95.1	81.2	70.7	93.2	85.0
	Šakiai	85.3	94.7	86.6	100	91.6
	Šiauliai	85.4	83.7	81.8	92.9	85.9
	Vilkaviškis	90.3	85.4	89.5	100	91.3
East	Alytus	83.6	86.7	79.8	93.4	85.9
	Anykščiai	90.2	98.3	88.3	98.3	93.8
	Prienai	88.7	89.5	89.8	93.4	90.3
	Rokiškis	100	100	100	100	100
	Ukmergė	86.6	87.2	95.1	90.2	89.8
In average		88.3	90.6	86.6	93.3	89.727
		MS	F-act.	P_{05}	Probability	
Treatment		243.016	4.63^{**}		0.000000	
M. aeneus population (A)		530.597	10.11^{**}	3.495	0.000000	
Active substance (B)		885.042	16.86^{**}	1.211	0.000000	
Interaction (A × B)		121.474	2.31^{**}	7.094	0.000000	

* – significant differences at 0.001 probability level

Conversely, at the beginning of the period all pollen beetle populations were susceptible (not highly susceptible) to tau-fluvalinate, however at the end of the experimental period the amount of susceptible populations decreased to 28%. Also there were obtained 50% of moderately resistant and 22% of resistant populations among 26 populations from spring oilseed rape in 2010 (Fig. D).

In general, the results from our research indicate that pollen beetle individuals developed some resistance to pyrethroids and populations from different regions exhibited different resistance level. Very similar results were obtained in other countries (Ballanger et al., 2003; Hansen, 2003; Heimbach et al., 2006; Węgorek, Zamojska, 2006). There were slight differences in pollen beetle susceptibility level to λ-cyhalothrin, α-cypermethrin and deltamethrin; however pollen beetle populations exhibited higher susceptibility to tau-fluvalinate. Also, in Germany and Poland, there were found differences in susceptibility of pollen beetle populations to pyrethroids (Heimbach et al., 2006; Węgorek et al., 2009). These results suggest that decrease of pollen beetle susceptibility to pyrethroids should be taken into consideration in oilseed rape protection programmes against very important pest of rape crops – pollen beetle.

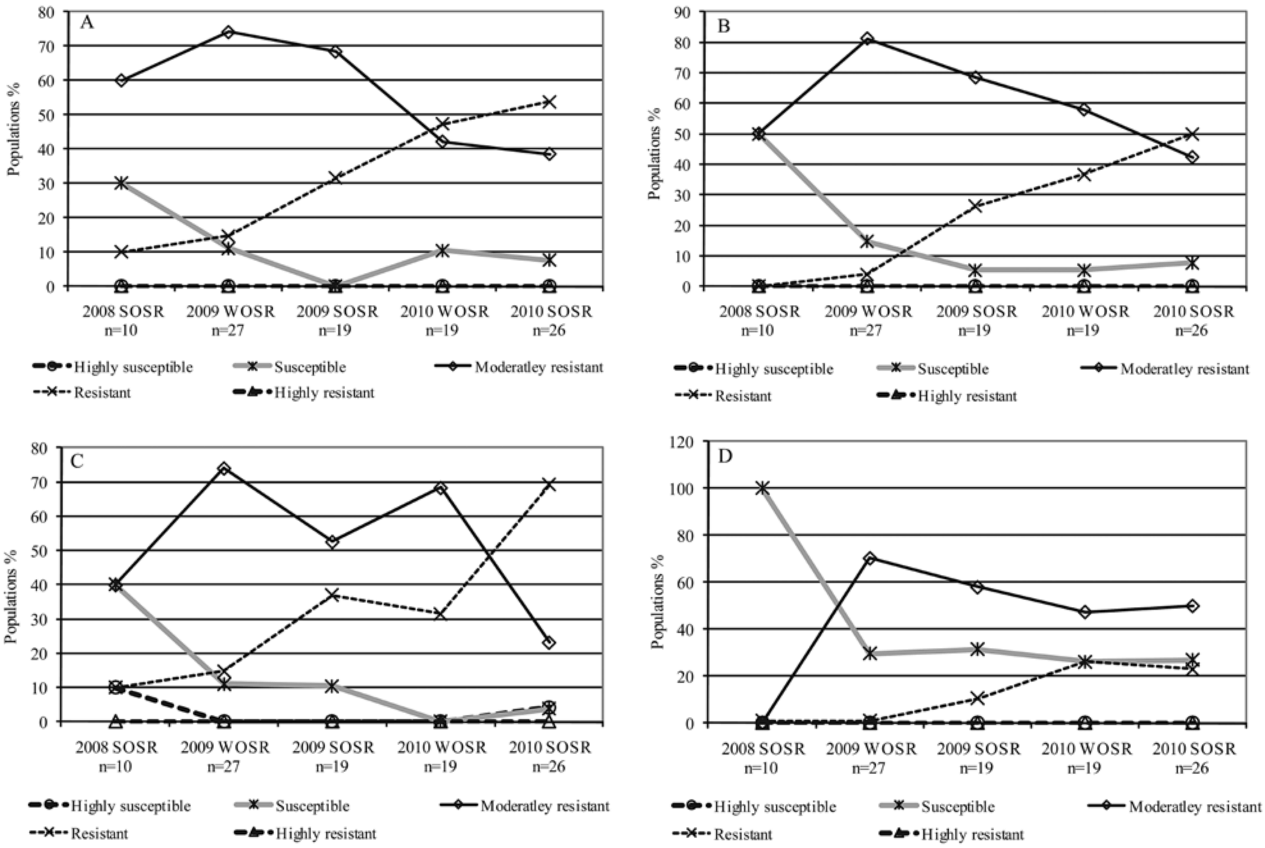

Figure. The trends in changes of pollen beetle susceptibility to different active substances of pyrethroids (A – λ-cyhalothrin, B – α-cypermethrin, C – deltamethrin, D – tau-fluvalinate) during 2008–2010

Conclusions

1. Our research results indicate that pollen beetle (*Meligethes aeneus* F.) in Lithuania has developed some resistance to pyrethroids. Many pollen beetle populations showed decreased susceptibility to λ-cyhalothrin, α-cypermethrin, deltamethrin and to a lower extent – to tau-fluvalinate.

2. The highest resistance to pyrethroids was revealed in the pollen beetle populations from Marijampolė and Kaunas (mortality of pollen beetle less than 80%), also from Vilkaviškis, Kėdainiai, Raseiniai, Radviliškis, Joniškis regions (mortality less than 90%).

3. The results showed changes of pollen beetle susceptibility to the active substances of pyrethroids between 2008 and 2010. It was estimated that during this period the resistance of pollen beetle to λ-cyhalothrin, α-cypermethrin, deltamethrin and to tau-fluvalinate tended to increase.

4. The decrease of pollen beetle susceptibility to pyrethroids should be taken into consideration in oilseed rape protection programmes against the pollen beetle, which is a very important pest of rape crops.

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Rapsinio žiedinuko (*Meligethes aeneus* F.) atsparumas piretroidams Lietuvoje

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Santrauka

Rapsinis žiedinukas (*Meligethes aeneus* F.) yra vienas pagrindinių žieminių ir vasarinių rapsų kenkėjų Lietuvoje. Tyrimų tikslas – IRAC metodu nustatyti rapsinio žiedinuko populiacijų, surinktų iš įvairių Lietuvos regionų, jautrumą piretroidų klasės insekticidų įvairioms veikliosioms medžiagoms (lambda-cihalotrinui, alfa-cipermetrinui, deltametrinui ir tau-fluvalinatui). Per 2008–2010 m. tyrimų laikotarpį laboratorinių eksperimentų metu tirta 101 rapsinio žiedinuko populiacija (46 surinktos iš žieminių rapsų ir 55 – iš vasarinių rapsų pasėlių). Rapsinio žiedinuko atsparumo piretroidams pirmieji tyrimų rezultatai parodė, kad daugelio tirtų rapsinio žiedinuko populiacijų, ypač iš centrinės agroekologinės zonos, kurioje žieminiai ir vasariniai rapsai intensyviai auginami jau 20 metų, jautrumas lambda-cihalotrinui, alfa-cipermetrinui ir deltametrinui yra sumažėjęs. Rapsinio žiedinuko populiacijų atsparumas tau-fluvalinatui buvo mažesnis nei lambda-cihalotrinui, alfa-cipermetrinui ir deltametrinui. Nustatyta, kad 2008–2010 m. laikotarpiu rapsinių žiedinukų jautrumas visoms tirtoms piretroidų klasės insekticidų veikliosioms medžiagoms turėjo tendenciją mažėti, o rezistentiškumas – didėti.

Reikšminiai žodžiai: piretroidai, *Meligethes aeneus*, atsparumas, jautrumas, mirtingumas.