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RESISTANCE OF POLLEN BEETLE (*MELIGETHES AENEUS* F.) TO SELECTED ACTIVE SUBSTANCES OF INSECTICIDES IN POLAND

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Abstract: Pollen beetle (*Meligethes aeneus* F.) (PB) is one of the most serious pest in rapeseed cultivations in Poland and in other European countries. The pest is known because of its high metabolic potency towards various toxins. Constant and strong selective pressure of different insecticides used to control this pest, has resulted in resistance of PB to many active substances. In connection with this situation, constant monitoring of pollen beetle susceptibility level to all recommended active substances of insecticides is necessary. The objective of the study was to determine the effectiveness of active substances, most often used in Western Poland for PB control. Resistance of pollen beetle to some pyrethroid active substances and organophosphorous insecticide – phosalone and high susceptibility to chlorpyrifos-ethyl was found. Resistance of pollen beetle requires constant insecticide susceptibility level monitoring and using IRM strategy.

Key words: *Meligethes aeneus*, pollen beetle, insecticide resistance, pyrethroids, organophosphates, neonicotinoids, oilseed rape, plant protection

INTRODUCTION

Synthetic insecticides have been widely used for controlling pollen beetle in Poland for over 50 years. The decrease of effectiveness of some active substances belonging to chlorinated hydrocarbons group (DDT, lindane, metoxychlor) against pollen beetle was found in Western Poland in the sixties and the seventies of the past century (Łąkocy 1967). These compounds were withdrawn in Poland and replaced with carbamates, organophosphates, pyrethroids and neonicotinoid insecticides. In connection with the information concerning the lack of effectiveness of numerous pyrethroid insecticides in PB control, the Institute of Plant Protection in Poznań started monitoring susceptibility level of PB to active substances of this chemical group and organophosphates and neonicotinoids as well. Nowadays, constant monitoring of PB susceptibility to insecticides is essential for working out insecticide resistance management strategies, necessary for maintaining the effectiveness of chemical control.

MATERIALS AND METHODS

Insecticides (commercially available products):

Pyrethroids:
- bifenthrin (Talstar 100 EC) – 100 g of active substance per 1 l of product; recommended field concentration against PB in Poland: 50 ppm,
- tau-fluvalinate (Mavrik 240 EW) – 240 g of active substance per 1 l of product; recommended field concentration against PB in Poland: 240 ppm,
- esfenvalerate (Sumi-Alpha 050 EC) – 50 g of active substance per 1 l of product; recommended field concentration against PB in Poland: 62.5 ppm,
- beta-cyfluthrin (Bulldock 025 EC) – 25 g of active substance per 1 l of product; recommended field concentration against PB in Poland: 31.25 ppm,
- zeta-cypermethrin (Fury 100 EW) – 100 g of active substance per 1 l of product; recommended field concentration against PB in Poland: 50 ppm.

Neonicotinoids:
- acetamiprid (Mospilan 20 SP) – 200 g of active substance per 1 kg of product; recommended field concentration against PB in Poland: 120 ppm.

Organophosphates:
- chlorpyrifos-ethyl (Pyrinex 480 EC) – 480 g of active substance per 1 l of product; recommended field concentration against PB in Poland: 1440 ppm,
- phosalone (Zolone 350 EC) – 350 g of active substance per 1 l of product; currently withdrawn – recommended field concentration against PB in Poland was: 3500 ppm.

Recommended field concentrations were calculated assuming that the highest recommended dose of a com-

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mercial product and 200 l of water are used per hectare. Recommended field concentrations (the concentrations giving about 100% mortality) were established during field experiments for the registration of a given insecticide.

MATERIALS AND METHODS

In 2005–2007 pollen beetles and non-infested, untreated plant material was collected for testing from 4 distant fields representing populations occurring in the Wielkopolska region (Western Poland): Nowy Tomyśl, Skoki, Winnagóra, Rogalinek. Plant material (leaves, stems and inflorescences) of about 30 cm in length, in the phases: from BBCH (Biologische Bundesanstalt, Bundessortenamt und Chemical Industry) 51 to BBCH 61 was collected to plastic boxes. Dependently on climate conditions and rape variety, this period takes place in Poland from the April 15th to the May 10th. Insects were collected from the same fields as plants and were placed into the insulators made of airy material and filled with rape plants. Plants and insects were then transported and kept in the laboratory for 24 hours. Insects were kept in the temperature of 10°C (climatic chamber), and plants were placed in containers with water.

In laboratory tests a standard method recommended by Insecticide Resistance Action Committee (IRAC method No. 7) was used. Demineralised water solutions of tested active substances of commercially available products were used in 5 to 8 selected concentrations, expressed in parts per million (ppm). The initial concentrations were different, depending on a particular insecticide. They were determined on the base of concentrations causing insect mortality above 50% and below 100%. In case of pyrethroids the initial concentrations were 200–300% of a field dose, depending on a particular active substance. In case of acetamiprid the initial concentration was 200% of a field dose and for chlorpyrifos-ethyl it was 0.2% of a field dose. Rape inflorescences and leaves were dipped in test solutions of the various insecticide concentrations for about five seconds, then placed on a paper towel to dry in the laboratory conditions (20–22°C) for 3 hours.

Control inflorescences and leaves were dipped in demineralised water. Untreated and treated dry plant material was placed into 0.9 l jars with 10 cm diameter filter paper lining on the bottoms. The length of plant material was of the height of a jar (15 cm), and its weight was 20 g. It was aimed at ensuring a frequent contact of plants with the insects. One hundred of beetles were placed in each jar. The jars were closed with airy material for ensuring a good evaporation and ventilation. Each concentration comprised of three replications and the control. A final assessment (lethal effects of the active substances of insecticides) was determined after 24 hours of insecticide application and expressed as per cent mortality of insects at each dose, in relation to untreated control mortalities using Abbott's formula (Abbott 1925) if needed (mortality above 10%). At each assessment, beetles were classified as either: (a) unaffected, giving a normal response (such as taking a coordinated step, able to fly) (b) dead or affected, giving an abnormal response to stimulation. Tests were performed in laboratory conditions at 20–22°C and photoperiod of 16:8 (L:D). Lethal concentrations (LC50 and LC95) were calculated using computer program based on Finney probit analysis method (Finney 1952) and expressed in ppm of active substance.

To assess the resistance of a given population of pollen beetle beetles, the resistance coefficient was calculated as follows:

Resistance coefficient (RC) = LC 95/recommended field dose

The following criteria for resistance assessment were assumed:

RC ≤ 1 – the lack of resistance
RC = 1.1–2 – low resistance
RC = 2.1–5 – medium resistance
RC = 5.1–10 – high resistance
RC > 10 – very high resistance

RESULTS

Research results (Tables 1–4) showed, that in many cases recommended doses of pyrethroid active substances did not cause 50% mortality of tested insects. It was indicated by calculations of LC50 values. Such results were obtained in all cases of beta-cyfluthrin, in one case of bifenthrin (Nowy Tomyśl 2007), in six cases of esfenvalerate (Winna Góra 2007, Nowy Tomyśl 2005, 2007, Rogalinek 2005, 2007, Skoki 2007) and in ten cases of zeta-cypermethrin (Winna Góra 2007, Nowy Tomyśl 2005, 2006, 2007, Rogalinek 2005, 2006, 2007, Skoki 2005, 2006, 2007). LC95 values calculated for tested pyrethroid active substances exceeded recommended doses in all cases.

There were significant differences among resistance coefficient values concerning tested pyrethroids. Resistance coefficient calculated for tau-fluvalinate indicated low resistance of pollen beetle in two cases (Winna Góra 2007, Nowy Tomyśl 2007) and medium resistance also in two cases (Rogalinek 2007, Skoki 2007). Differences in resistance coefficient values among populations were low.

Resistance coefficient values for bifenthrin were more variable than in case of tau-fluvalinate. Its values indicated low resistance in two cases (Winna Góra 2005, 2006), medium resistance in seven cases (Winna Góra 2007, Nowy Tomyśl 2005, 2006, 2007, Rogalinek 2005, 2006, Skoki 2005), and high resistance in three cases (Rogalinek 2007, Skoki 2006, 2007). Differences among populations were not high: resistance coefficient from 1,56 (Winna Góra 2006) to 8,92 (Skoki 2007).

Resistance coefficient for esfenvalerate showed medium resistance in three cases (Winna Góra 2005, Rogalinek 2006, Skoki 2005), high resistance also in three cases (Winna góra 2006, 2007, Skoki 2006) and very high resistance in the remaining six cases (Nowy Tomyśl 2005, 2006, 2007, Rogalinek 2005, 2007, Skoki 2007). Differences in resistance level among populations were significant: from 2.94 (Winna Góra 2005) to 15.07 (Rogalinek 2007).

Resistance of pollen beetles to zeta-cypermethrin was medium only in one case (Winna Góra 2005), high in two cases (Winna Góra 2006, Nowy Tomyśl 2007). In the remaining experiments resistance coefficient values showed a very high resistance (Winna Góra 2007, Nowy Tomyśl 2005, 2006, Rogalinek 2005, 2006, 2007, Skoki 2005, 2006,

Table 1. Susceptibility level of pollen beetles of Winna Góra population to tested insecticides, expressed as LC50, LC95 and resistance coefficient (LC95/recommended field dose)

Chemical group	Active substance	Recommended dose [ppm]	Years of research	LC 50 [ppm] (confidence interval, p = 0.95)	LC 95 [ppm]	Resistance coefficient (LC 95/recommended dose)
Pyrrthroids	beta-cyfluthrin	31.25	2007	45 (32.5–58)	1686	53.95
	bifenthrin	50	2005	8 (3.3–12.8)	94	1.88
			2006	12 (6.3–17.3)	78	1.56
			2007	41 (34.5–48.7)	120	2.4
	esfenvalerate	62.5	2005	43 (22.8–64.7)	184	2.94
			2006	28 (6.3–46.1)	337	5.39
			2007	80 (52.6–112.5)	443	7.08
	tau-fluvalinate	240	2007	18 (7.5–26.8)	376	1.56
	zeta-cypermethrin	50	2005	38 (23.6–69.06)	243	4.86
			2006	22 (17.73–27.08)	291	5.82
			2007	191 (143.23–338.95)	705	14.1
Neonicotinoids	acetamiprid	120	2005	21 (2.5–38.6)	180	1.5
			2006	64 (45.8–86.9)	280	2.33
			2007	38 (28.4–45.2)	189	1.57
Organophosphates	chlorpyrifos-ethyl	1440	2005	0.2 (0.1–0.3)	0.7	0.0004
			2006	0.2 (0.07–0.3)	1.0	0.0006
			2007	0.1 (0.05–0.24)	1.2	0.0008
	phosalone*	3500	2005	830 (226.06–1322.74)	25436	7.26
			2006	1250 (510.25–1775.8)	41562	11.87
			2007	2375 (1336.8–3003.2)	38133	10.89

*substance withdrawn

Table 2. Susceptibility level of pollen beetles of Nowy Tomyśl population to tested insecticides, expressed as LC50, LC95 and resistance coefficient (LC95/recommended field dose)

Chemical group	Active substance	Recommended dose [ppm]	Years of research	LC50 [ppm] (confidence interval, p = 0.95)	LC95 [ppm]	Resistance coefficient (LC95/recommended dose)
Pyrethroids	beta-cyfluthrin	31.25	2007	55 (40–72.8)	3027	96.86
	bifenthrin	50	2005	34 (20.9–52.5)	187	3.74
			2006	42 (28.6–64.5)	248	4.96
			2007	58 (53.7–63.8)	168	3.36
	esfenvalerate	62.5	2005	71 (34.5–110.8)	699	11.18
			2006	9 (0.7–17.2)	797	12.75
			2007	73 (46.7–104.6)	797	12.75
	tau-fluvalinate	240	2007	22 (6.7–37)	335	1.40
	zeta-cypermethrin	50	2005	80 (47.15–514.12)	657	13.14
			2006	299 (175.26–1041.78)	2640	52.80
			2007	124 (105.6–159.7)	426	8.52
Neonicotinoids	acetamiprid	120	2005	40 (34.16–46.06)	175	1.46
			2006	75 (38.3–119.08)	285	2.38
			2007	140 (91.7–361.1)	527	4.39
Organophosphates	chlorpyrifos-ethyl	1440	2005	0.1 (0.08–0.22)	1.5	0.001
			2006	0.2 (0.1–0.24)	1.3	0.0009
			2007	0.1 (0.09–0.23)	1.3	0.0009
	phosalone*	3500	2005	1520 (628.26–2122.8)	40974	11.77
			2006	1535 (724.5–2074.7)	94490	27.00
			2007	3892 (3114.3–5046.6)	58420	16.69

*substance withdrawn

Table 3. Susceptibility level of pollen beetles of Rogalinek population to tested insecticides, expressed as LC50, LC95 and resistance coefficient (LC95/recommended field dose)

Chemical group	Active substance	Recommended dose [ppm]	Years of research	LC50 [ppm] (confidence interval, p = 0,95)	LC95 [ppm]	Resistance coefficient (LC95/dawka zalecana)
Pyrethroids	beta-cyfluthrin	31.25	2007	87 (55.5–156.7)	1939	62.05
	bifenthrin	50	2005	11 (7.4–14.8)	201	4.02
			2006	16 (10.6–20.9)	157	3.14
			2007	50 (44.2–58.1)	266	5.32
	esfenvalerate	62.5	2005	132 (97.5–198.6)	671	10.74
			2006	27 (12.4–39.5)	176	2.82
			2007	85 (45.2–114.3)	942	15.07
	tau-fluvalinate	240	2007	31 (16.4–45.9)	597	2.49
	zeta-cypermethrin	50	2005	135 (88.03–267.37)	564	11.28
			2006	150 (113.02–272.08)	507	10.14
			2007	180 (126.7–416.9)	1040	20.80
Neonicotinoids	acetamiprid	120	2005	12 (1.7–23.25)	82	0.68
			2006	46 (32.9–59.3)	154	1.28
			2007	45 (37.9–53.03)	324	2.7
Organophosphates	chlorpyrifos-ethyl	1440	2005	0,1 (0.09–0.15)	1.3	0.0009
			2006	0.1 (0.06–0.17)	1.8	0.0012
			2007	0.1 (0.07–0.19)	2.8	0.002
	phosalone*	3500	2005	1856 (1257.7–2425.8)	70643	20.18
			2006	2002 (1384–2531.9)	64020	18.29
			2007	2517 (1505.3–3311.5)	86164	24.62

*substance withdrawn

Table 4. Susceptibility level of pollen beetles of Skoki population to tested insecticides, expressed as LC50, LC95 and resistance coefficient (LC95/recommended field dose)

Chemical group	Active substance	Recommended dose [ppm]	Years of research	LC50 [ppm] (confidence interval, p = 0,95)	LC95 [ppm]	Resistance coefficient (LC95/recommended dose)
Pyrethroids	beta-cyfluthrin	31.25	2007	99 (38.56–248.4)	1544	49.41
	bifenthrin	50	2005	18 (3.9–28.8)	165	3.3
			2006	14 (2.7–25.4)	360	7.2
			2007	50 (40.6–59.7)	446	8.92
	esfenvalerate	62.5	2005	61 (46.3–73.1)	240	3.84
			2006	20 (10.9–26.01)	432	6.91
			2007	85 (55.3–125.8)	650	10.40
	tau-fluvalinate	240	2007	18 (11.6–25.8)	670	2.79
	zeta-cypermethrin	50	2005	109 (85.04–143.11)	762	15.24
			2006	90 (67.24–145.96)	1591	31.82
			2007	170 (129.9–292.9)	2439	48.78
Neonicotinoids	acetamiprid	120	2005	27 (14.12–37.87)	219	1.83
			2006	47 (40.7–53.06)	227	1.89
			2007	138 (102.8–221.9)	584	4.87
Organophosphates	chlorpyrifos-ethyl	1440	2005	0.2 (0.14–0.23)	1.1	0.00076
			2006	0.1 (0.07–0.18)	0.9	0.00063
			2007	0.3 (0.22–0.37)	1.4	0.00097
	phosalone*	3500	2005	1814 (956.4–2403.87)	77247	22.07
			2006	2618 (1159.6–3429.5)	89000	25.42
			2007	3185 (1911.09–5054.15)	38000	10.85

*substance withdrawn

2007). Differences in resistance level among populations were rather high: resistance coefficient ranged from 4.86 (Winna Góra 2005) to 52.8 (Nowy Tomyśl 2006).

Beta-cyfluthrin demonstrated the worst action against pollen beetles in the experiments. In all experiments resistance coefficient showed a very high resistance of pollen beetle to this active substance (Winna Góra 2007, Nowy Tomyśl 2007, Rogalinek 2007, Skoki 2007). The lowest value was recorded for the population of Skoki (49.41) and the highest one for the population of Nowy Tomyśl (96.8).

Results of research on acetamiprid action, in which recommended dose of the active substance did not cause 50% mortality of beetles, were obtained only in two cases (Nowy Tomyśl 2007, Skoki 2007). In the remaining experiments LC50 level was recorded at doses lower than the recommended ones. LC95 was recorded at doses exceeding the recommended one, apart from the population of Rogalinek in 2005. Resistance coefficient values indicated the lack of pollen beetle resistance in one case (Rogalinek 2005), low resistance in six cases (Winna Góra 2005, 2007, Nowy Tomyśl 2005, Rogalinek 2006, Skoki 2005, 2006) and medium resistance in five cases (Winna Góra 2006, Nowy Tomyśl 2006, 2007, Rogalinek 2007, Skoki 2007). Differentiation in resistance coefficient values among populations was low and ranged: from 0.68 (Rogalinek 2005) to 4.87 (Skoki 2007).

Differences in the effectiveness of the two tested active substances of organophosphorous group were high. In case of chlorpyrifos-ethyl 50% mortality of insects (LC50) were observed at doses between 0.1 and 1.8 ppm (while recommended dose is 1440 ppm). The other active substance – phosalone – showed much worse toxicity than chlorpiryfos-ethyl. In one case LC50 was higher than the recommended dose (Nowy Tomyśl 2007). In the remaining cases LC50 values were lower than the recommended dose. While LC95 levels for chlorpiryfos-ethyl were always much lower than the recommended dose, for phosalone they were higher than the recommended dose in all cases. In case of chlorpiryfos-ethyl, all populations in all years of research showed the lack of resistance to this active substance. For phosalone, the resistance coefficient indicated a high resistance in one experiment (Winna Góra 2005) and in the remaining ones a very high resistance.

In our research PB populations from all four populations demonstrated the highest level of resistance to beta-cyfluthrin, zeta-cypermethrin, esfenvalerate and phosalone. Some level of resistance was noticed also to tau-fluvaslinate, bifenthrin and neonicotinoid insecticide – acetamiprid, however this PB resistance was low. Chlorpyrifos-ethyl was the most effective active substance and no resistance of pollen beetle was recorded in this case.

DISCUSSION

PB is the insect species that has a very strong evolutionary selected natural resistance. The resistance concerns many natural and synthetic toxins, so PB probably can develop a very strong resistance to some synthetic active substances used to control this pest in Poland and in other European countries (Hansen 2003; Hansen 2008; Łąkocy 1967; Richardson 2008; Tillikainen and Hokkanen 2008; Węgorek 2005; Węgorek and Zamojska 2006; Węgorek *et al*. 2006; Obrępalska-Stęplowska *et al*. 2006). Presented experiments were conducted in connection with many signals on the lack of effectiveness of chemical control of PB, in Western Poland. Many field experiments, conducted in our Institute confirmed these signals, especially in relation to pyrethroids (Mrówczyński 2003; Zamojska, unpublished data). PB populations tested in presented research, in many cases, tolerated recommended concentrations of selected pyrethroids and neonicotinoid substance – acetamiprid. LC95 concentration levels for pyrethroids were much higher than concentrations recommended in Poland. The pest showed a high tolerance also to phosalone. The results point to changes of PB susceptibility level between 2005 and 2007, but the changes are not significant. It can be concluded that detoxification mechanisms developed in the past by Polish PB populations reached the level which is not getting significantly higher, although, in our opinion, there is such a possibility. In each tested population, there were susceptible individuals (being killed at recommended dose), moderately resistant (distinctly affected at recommended dose) and resistant (unaffected at recommended dose). Proportions of these groups within a population determines its susceptibility to chemical treatment and the field effectiveness of insecticides.

Nowadays chlorpyrifos-ethyl is the only active substance showing a high toxicity towards PB in Poland. Unfortunately, during the research period, no pyrethroids susceptible population was found in the Country. Also, no population was less susceptible to chlorpyrifos-ethyl. That is why we can suppose that a very high susceptibility of PB to chlorpyrifos-ethyl in populations tolerant to pyrethroids and acetamiprid is caused by PB physiological resistance mechanism based on oxidative enzymes (Malinowski 2003; Różański 1992; Slater and Nauen 2007). When the main detoxification mechanism is the oxidative one (the mechanism was found in PB – Węgorek *et al*. 2007; Slater and Nauen 2007), oxidative desulfuration of chlorpyrifos-ethyl leads to creating a much more toxic metabolite. A high synergism of pyrethroid insecticides with piperonyl butoxid and low with carbaryl (Węgorek *et al*. 2007) have confirmed the above statements. It is the feature of other organophosphorous active substances too (Różański 1992), except phosalone. Results showing a low toxicity of some pyrethroids and a very high toxicity of chlorpyrifos-ethyl suggest the existance of negative cross-resistance phenomenon concerning chlorpyrifos-ethyl and pyrethroids at PB. However, this statement requires further research by using PB population susceptible to pyrethroids (that was not found in Poland). Interestingly, Colorado potato beetle which is also resistant to pyrethroids in Poland, in the contrary to PB, tolerates much higher concentrations of chlorpyrifos-ethyl but is not resistant to acetamiprid (Węgorek and Zamojska 2007).

In case of studied pyrethroids, and organophosphorous insecticide – phosalone the survival of PB beetles in laboratory tests achieved a very high level and tolerated doses were much higher than those recommended in Poland. There were differences in susceptibility level of PB among pyrethroid active substances. Also in Germany, differences in susceptibility level of PB populations to pyrethroids were found (Heimbach *et al.* 2006). In our research tau-fluvalinate and bifenthrin showed a stronger action and the worst action was observed in case of beta-cyfluthrin and zeta-cypermethrin. These results have suggested the possibility of chemical treatments failure under field conditions. Acetamiprid, which is the only neonicotinoid active substance recommended in Poland, was in our research more effective than pyrethroids. In spite of the fact that this substance has contact and oral action, a very quick contact action of this active substance against PB (comparable to pyrethroids) was observed. On the contrary to pyrethroids which caused excitement of surviving insects, individuals surviving the acetamiprid treatment showed slowness of reaction. It is noteworthy, because neonicotinoids, by acting on acetylocholine receptor, cause excitement of other insects (Nauen *et al.* 2001). Research on the dynamics of tested active substances' action prove that first 24 hours are essential for their effectiveness (Węgorek *et al.* 2007).

A high susceptibility of PB to chlorpyrifos-ethyl should be taken into consideration in insecticide plant protection programs. Nowadays, Insecticide Resistance Management (IRM) programm is obligatory to control a negative effect of PB resistance phenomenon in Poland. Strategy of insecticide use in practical conditions must take into account many factors. The most important are: effectiveness of insecticide application, short- and long-term influence on environment – especially on beneficial fauna (a very important factor in case of oilseed rape – Węgorek, unpublished data), the dynamics of action in different weather conditions, products' formulations and physicochemical properties of chemical compounds. The level of mortality effect is only one of the factors and not the most important one in long-term PB – IRM strategy. In 2008, in the Institute of Plant Protection in Poznań the strategy of PB control was worked out and recommended in Poland. In connection with the fact that rape protection against pests in Poland requires minimum 3–5 treatments, the following programme of PB control has been proposed:

First chemical treatment – BBCH 51–54 – insecticides containing chlorpyrifos-ethyl;

Next chemical treatment – BBCH 55–59 – insecticides containing pyrethroids or acetamiprid; if two treatments would be needed in this period, the second one should be carried out by using a chemical group that was not used before. The usage of chlorpyrifos-ethyl in these phases is permissible only in case of mass attack of PB or in case of strong field resistance of a local population to pyrethroids or acetamiprid.

Since BBCH 60 it is advisable to use insecticides containing tau-fluvalinate or acetamiprid, taking into consideration rotation of chemical groups of insecticides.

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POLISH SUMMARY

ODPORNOŚĆ SŁODYSZKA RZEPAKOWEGO (*MELIGETHES AENEUS* F.) NA WYBRANE SUBSTANCJE AKTYWNE INSEKTYCYDÓW W POLSCE

Słodyszek rzepakowy jest gatunkiem o dużej naturalnej odporności fizjologicznej na substancje toksyczne pochodzenia roślinnego. W związku z tą cechą wykształcił również odporność na syntetyczne substancje aktywne insektycydów. Przedstawione w pracy badania dotyczą poziomu wrażliwości wybranych populacji słodyszka rzepakowego zachodniej Polski na niektóre zalecane do jego zwalczania insektycydy. Wyniki badań wskazują na wykształcenie przez tego szkodnika odporności o różnym stopniu na substancje aktywne z grupy pyretroidów, oraz neonikotynoidów i związków fosforoorganicznych. Bardzo silna wrażliwość badanych populacji słodyszka rzepakowego na chloropiryfos etylowy sugeruje występowanie zjawiska negatywnej odporności krzyżowej tego owada w stosunku do insektycydów z grupy pyretroidów co może być związane z fizjologicznym mechanizmem detoksykacyjnym opartym na enzymach oksydacyjnych. Biorąc pod uwagę wykształcone pod wpływem nacisku selekcyjnego zjawisko odporności omawianego szkodnika jak również właściwości fizyko-chemiczne substancji aktywnych badanych insektycydów oraz ich toksyczność, selektywność i fazę rozwoju roślin, zaproponowano program ochrony rzepaku w Polsce.