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The Effect of Insecticides on Pest Control and Productivity of Winter and Spring Oilseed Rape (*Brassica napus* L.)

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1. Introduction

Oilseed rape (*Brassica napus* L.) is an important crop for food industry, bio-fuel industry and as a rotation plant in many countries (Williams, 2010). In Lithuania, oilseed rape is also one of the most promising crops. According to Lithuanian department of statistics, at the end of 2010, oilseed rape was cultivated on an area of 255 957 ha, of which spring rape accounted for 63.9% (163 600 ha) (Lithuanian Department of Statistics).

Various pests attack oilseed rape at different time and damage different plant parts (Williams, 2004). In Europe, chemical insecticides are usually used for pest management in oilseed rape crops and application of insecticides is still an integral part of insect pest management in this crop (Cook et al., 2004). Insecticides are used routinely and prophylactically independent of pest incidence. Insecticides are applied in oilseed rape crop several times during the plant vegetation. One of the most important targets for applying insecticides is a substantial seed yield increase (Williams, 2004).

1.1 Pollen beetle, *Meligethes aeneus* (Coleoptera, Nitidulidae)

Meligethes aeneus is one of the most important pests in Europe visiting oilseed rape. Pollen beetle damages flower buds and can cause significant seed yield losses (Ruther & Thiemann, 1997). Both adults and larvae can be harmful (Blight & Smart, 1999). Sometimes yield losses are of up to 50% (Kirch, 2006). In the United Kingdom, damage caused by pollen beetle was in the range 15.8 - 20.5% (Cook et al., 2004). In Germany, losses caused by *M. aeneus* in oilseed rape were from 20% to 100% (Heimbach et al., 2007) and in Sweden 70% (Kazachkova, 2007). Pollen beetle can cause serious yield losses, and for spring oilseed rape more than 80% yield reduction can occur (Hansen, 2003a; 2003b). Pests cause visible direct losses in seed yield and decrease strength of plant response to favourable environmental and agricultural conditions. The beetles are controlled with different insecticides, but mainly with pyrethroids. It was reported that *M. aeneus* is an example of insect species that can develop strong resistance mechanisms to most active ingredients used to control it in Europe (Hansen, 2003a; Wegorek, 2005; Heimbach, 2007).

Over the past few years, resistance of *M. aeneus* to pyrethroids has increased in Europe (Germany, Denmark, Switzerland and Sweden) (Hansen, 2003a; Derron et al., 2004; Heimbach et al., 2007; Kazachkova, 2007). In Poland, *M. aeneus* showed a high tolerance to beta – cyfluthrin, also tau-fluvalinate and neonicotinoid resistance were recorded, but just in some treatments, therefore several insecticide treatments are often necessary against pollen beetle (Wegorek et al., 2009).

The results from Denmark show that no insecticide resistance to the organophosphate fenitrothion has developed among the *M. aeneus*. However, a relatively high insecticide resistance to lambda-cyhalothrin and to a lesser extent to tau-fluvalinate was recorded. The most common insecticides used against *M. aeneus* are the pyrethroids and especially lambda-cyhalothrin, which have been used for many years. Tau-fluvalinate has been used very little against *M. aeneus* but over the last two years the use has been increasing. However, insecticide resistance has developed against tau-fluvalinate and this could be due to cross-resistance (Decoin, 2002). It has been concluded that many Danish populations of *M. aeneus* are resistant to the pyrethroid lambda-cyhalothrin and to a lesser extent to the pyrethroid tau-fluvalinate. However, no resistance to the organophosphate fenitrothion was found (Hansen, 2008).

In Estonia, the impact of minimized and standard cropping systems on the abundance of old and new generations of *M. aeneus* was assessed in spring oil seed rape. Insecticide treatments were done at or above the *M. aeneus* threshold level. Treatments reduced the size of the new generation, but not significantly, because the maximum numbers of new generation adults emerge from the soil from much lower old generation beetle densities. Application of insecticide not only results in more buds and flowers for feeding and egg-laying by *M. aeneus* but probably also kills its natural enemies, which have potential to decrease the size of the new generation of *M. aeneus* (Veromann et al., 2008).

In Lithuania, the findings of pest abundance assessments indicate that *M. aeneus* tended to occur in spring rape during the stem elongation – budding stages. The population of pollen beetle was found to be on the increase during the experimental period and the efficacy of the insecticides tested tended to decline. A significant yield reduction ranging from 3.3 to 30.1%, resulting from the damage of pollen beetle, was identified (Petraitiene et al., 2008).

1.2 Cabbage stem weevil, *Ceutorhynchus pallidactylus* (syn. *C. quadridens*) (Coleoptera, Curculionidae)

C. pallidactylus is one of the most important stem-mining pests. Cabbage stem weevil is widely distributed on oilseed rape crops in Central and Northern Europe (Eickermann, 2008). This pest attacks oilseed rape stems and can cause significant yield losses (Dechert & Ulber, 2004). Largest damages are caused by larvae of *C. pallidactylus,* they usually infest the lateral shoots of the oilseed rape (Barari et al., 2005). Later on larvae are tunnelling their way into the mid-rib of the leaf or the stem. Yield losses caused by *C. pallidactylus* larvae were recorded up to 50% in the United Kingdom (Alford et al., 2003) and 20% in Germany (Lanschreiber, 2005).

Synthetic pyrethroids are the predominant insecticides applied on oilseed rape. However, this group of insecticides is non-selective for non-target insects (Williams 2004). Further frequent usage of pyrethroids can result in insecticide resistance (Hansen, 2003a). Plant architecture and development can influence pest abundance (Büchs & Katzur, 2004; Williams, 2004). Infestation by *C. pallidactylus* increases as plant density decreases because a higher number of leaves and larger leaf size at low plant density increases oviposition (Nuss & Ulber, 2007). Generally, hybrid cultivars are considered to have higher compensation ability to pest damage by growing more vigorously (Lamb, 1989). Classical crop breeding can play an important role for developing oilseed rape cultivars being resistant to insect pests, which could reduce the need for insecticide application (Williams, 2004).

1.3 Cabbage seedpod weevil, *Ceutorhynchus obstrictus* (syn. *C. assimilis*) (Coleoptera: Curculionidae)

C. obstrictus is an important pest of flowering period causing yield losses (Carcamo et al., 2009). Oilseed rape growers in North America have significant seed yield reductions (15–35%) due to *C. obstrictus* (Buntin, 1999a). Cabbage seedpod weevil is more damaging to winter rape than to spring rape (Dosdall, 2009). Feeding by *C. obstrictus* larvae can cause yield losses of 19-80% (autorius). In Europe, this pest of oilseed rape reduces yield of infected pods by about 18% (Alford et al., 2003; Wiliams, 2004; Cook et al., 2006).

Neonicotinoid insecticides have been used for several years in oilseed rape as seed treatments for reducing damage of *C. obstrictus*. The neonicotinoids clothianidin and imidacloprid were investigated to determine their effects on preimaginal development and on emergence of new-generation adults of *C. obstrictus* in comparison with effects of lindane, a chlorinated hydrocarbon seed treatment. Mean numbers of second- and third-instar larvae were significantly higher in plants seed-treated with lindane than in plants treated with the neonicotinoid compounds, even though weevil oviposition was similar for all treatments. Emergence of new-generation adults was reduced by 52 and 39% for plants seed-treated with clothianidin and imidacloprid, respectively, compared with emergence from plants treated with lindane. Seed treatment with both clothianidin and imidacloprid produced systemic insecticidal effects on larvae of *C. obstrictus*, with clothianidin slightly more effective than imidacloprid. It has been concluded that use of clothianidin or imidacloprid as seed treatments can comprise an important component in the integrated management of *C. obstrictus* in oilseed rape (Dosdall, 2009).

Experiments examining the efficacy, timing and number of applications of various insecticides were used to assess the relationship between *C. obstrictus* pod infestation and yield loss in winter oilseed rape. The pyrethroid insecticides (permethrin, esfenvalerate, bifenthrin, and zeta-cypermethrin) were not significantly different in efficacy in any trial and were more effective in reducing *C. obstrictus* infestations than the organophosphate insecticides (Buntin, 1999b). Two insecticide applications during flowering were usually needed to effectively reduce the number of adults and to prevent seed injury. Larval injury primarily affected grain weight but did not consistently affect kernel weight or grain oil content. Yield loss increased linearly by about 1.7% for each 1% increase in percentage of infested pods, when larval infestation of pods exceeded 22% infested pods. These results support findings from Europe that canola can tolerate pod infestations of <26% without measurable yield loss (Lerin, 1984). Economic injury levels for varying control costs and commodity values ranged from 26 to 40% infested pods (Buntin, 1999b).

In Europe, pyrethroid insecticides including deltamethrin and alpha-cypermethrin were used to control *C. obstrictus* (Garthwaite et al., 1995). Pyrethroid insecticides were applied during flowering to kill adults before oviposition occurs and have less adverse impact on *C. obstrictus* parasitoids and canola pollinators than organophosphate insecticides (Murchie et al. 1997).

1.4 Brassica pod midge, *Dasineura brassicae* (Diptera: Cecidomyiidae)

D. brassicae is a serious pest of oilseed rape in many countries of Europe. It is one of the pests that infests oilseed rape at flowering and pod setting stages which is considered the most

suitable time for egg-laying (Murchie et al., 1997). As much as 82% of seed weight can be lost from *D. brassicae* infested pods (Williams, 2010).
The *D. brassicae* has three generations per year in Europe, two generations of *D. brassicae* can develop in winter oilseed rape (Kirch, 2006). In Czech, pesticide manufacturers recommend applying insecticides at the brassica pod midge flying activity or according to the oilseed rape growth stages during the period from first petals visible ("yellow bud") (GS 59) to full flowering stage (GS 65). Insecticide use against the brassica pod midge in the final stage of flowering (GS 67-68) shows significant yield increases. Researchers found that the best term of treatment pyrethroid Karate Zeon was at the final stage of flowering or according to catches in insect traps that signal the beginning of flight activity of the second generation. The damage done by the second generation seems to be very important economically (Pavela et al., 2007).
The study from Serbia showed that the incidence of brassica pod midge is still relatively low in this country. Brassica pod midge larvae were found in 0.95% of the pods in 2009, with 0.13 larvae per pod. In 2010, the pest was more numerous (0.61 larvae/pod) and its incidence was greater (4.7%) (Milovac et al., 2011).
The biological efficiency of botanical insecticide Nemm (azadirachtin) was compared with the efficiency of some synthetic insecticides (Pavela et al., 2009). It was ascertained that botanical insecticide was very efficient in decreasing the number of damaged oilseed rape pods (ranging from 56.5 to 85.9% compared to untreated plants) and its efficiency was comparable with synthetic insecticides based on Chloronicotinyl (thiacloprid) and Neonicotinoid (acetamiprid). Biological insecticide efficiency was, in some years, even significantly higher compared to pyrethroid (lamda-cyhalothrin). The yield increase resulting from azadirachtin application ranged between 9.3 and 19.4% compared to the control (Pavela et al., 2009).
In recent years, increasing areas of oilseed rape in Lithuania, spread stems and pods damage pests. It seems that the influence of stem and pod pests' damage has changed significantly and probably crossed the economic threshold.
The aim of our study was to present the data from the experiments on insecticides efficacy against pollen beetle (*M. aeneus*), cabbage stem weevil (*C. pallidactylus)* and pod pests (*C. assimilis*, *D. brassicae*) either their effect on the productivity of spring and winter oilseed rape.

2. Materials and methods

Ten field experiments were carried out from 2005 to 2009 at the Institute of Agriculture, Research Centre for Agriculture and Forestry (55° 24′33″ N, 23° 52′00″ E). Six field experiments were carried out in the spring oilseed rape and four experiments were performed in winter oilseed rape crops. Two commonly grown cultivars: spring oilseed rape cultivar Landmark and winter oilseed rape cultivar Libea were used in the experiments. The largest area is sown with these oilseed rape cultivars and the highest yields are produced in the central part of Lithuania. At the experimental site, the mean annual precipitation rate is about 700 mm and the mean daily temperature during the period of M. aeneus damage in May is 12.3°C, in June 15.6°C, and in July 17.7°C. The weather data are taken from the Dotnuva weather station, located at 1 km distance from the experimental fields.
The winter and spring oilseed rape crops were cultivated according to the conventional technology. All of the experiment trials were carried out in a randomized complete block

design with four replicates. Each treatment plot size was 25 m^2 x 4 replicates. For assessing the winter and spring oilseed rape growth stages (GS), the scale described by Lancashire (Lancashire et al., 1991) was used. Insecticides of different chemical classes were used against pollen beetles (*M. aeneus*) taking into account the economic threshold of harmfulness (1-2 beetles per plant). Table 1 presents the characteristics of insecticides used in the experiments. The tested insecticides were applied due to the incidence of pollen beetle usually at inflorescence emergence stage (GS 50-59) in the experiments of winter and spring oilseed rape. All experiments had a control treatment with no insecticides. The insecticides were sprayed with a Hardi trial sprayer at 400 l ha^{-1} spray solution, boom length 2.5 m, nozzle type IDK120 01 and the spraying pressure 3.0 bars per nozzle.

Insecticide	Active ingredients	Chemical class	Dose rates l, kg ha^{-1}
Decis 50 EW	deltamethrin 50 g l^{-1}	pyrethroid	0.125 and 0.15
Fastac EC	alpha-cypermethrin 100 g l^{-1}	pyrethroid	0.15
Bulldock 025 EC	beta-cyfluthrin 25 g l^{-1}	pyrethroid	0.225 and 0.3
Mavrik 2 F	tau-fluvalinate 240 g l^{-1}	pyrethroid	0.3
Proteus 110 OD	deltamethrin+thiacloprid 10+100 g l^{-1}	neonicotinoid + pyrethroid	0.6 and 0.75
Pyrinex Supreme	beta-cyfluthrin+chlorpyrifos 12+250 g l^{-1}	organophosphorus + pyrethroid	0.75, 1.0 and 1.25
Steward EC	indoxacarb 300 g l^{-1}	oxidiazines	0.0425, 0.0625 and 0.085

Table 1. Insecticides, used in the experiments.

In all trial plots, pollen beetle was counted 1, 4 and 7 days and in some cases 10 and 14 days after insecticide application. The assessments of pest abundance (counts of pollen beetles per plant) were done on ten successive plants in three chosen places per each plot.

At fruit development stage (GS 71-73) samples of winter and spring oilseed rape pods were analyzed. At least 200 pods per each plot were examined for presence of larvae. The number of pods infested with cabbage seedpod weevil (*C. obstrictus*) larvae and those infested with brassica pod midge (*D. brassicae*) larvae were estimated, also larvae of cabbage seedpod weevil and brassica pod midge were counted and average number of larvae per assessed pod was estimated.

Stem samples at fruit development stage (GS 73) were analyzed for the presence of cabbage stem weevil (*C. pallidactylus*) larvae damage and the number of larvae exit holes per stem. In each plot, twenty plants were selected at random. In the field, the plants were cut open in the stem area. The presence of larvae damage also and any exit holes were assessed.

The winter and spring oilseed rape seed yield from each plot was harvested separately by a Wintersteiger Classic harvester. Seed yield kg ha^{-1} was calculated and adjusted to 9% moisture content. Thousand seed weight (TSW) g was measured in the laboratory by a seed counter Contador and balance Explorer Ohaus.

The experimental data were analyzed separately for each year. Biological efficacy of insecticides against pollen beetle was calculated using Henderson-Tilton's formula (Henderson and Tilton, 1955). All data were analysed using an analysis of variance (ANOVA). The experimental data were log(X+1) or arcsin $\sqrt{X\%}$ transformed before analysis. The least significant difference (LSD) was calculated for P≤0.05, P≤0.01 levels. Analysis of variance was performed using the programme Statistica, 5.5 version.

3. Results and discussion

3.1 The efficacy of insecticides in the control of pollen beetle in spring and winter oilseed rape

M. aeneus was a very common and harmful pest in winter and spring rape crops every year. The date of arrival of first *M. aeneus* beetles to the rape field depended on the air temperature. The first beetles were usually detected in winter or spring rape crops at stem elongation stage (GS 30-39), but their amount reached spray threshold (1-2 beetles/plant) even later – at the inflorescence emergence growth stage (GS 50-53), except for 2008 when in spring oilseed rape their abundance reached threshold even earlier at the very end of stem elongation growth stage (GS 39) (Tables 2, 4). Pollen beetle was more abundant in spring rape and this is in agreement with the findings of other researchers (Alford et al., 2003). Depending on the year, one or two spray applications of insecticides were used to control *M. aeneus*. All insecticides used in the trials were effective against *M. aeneus* and significantly reduced the amount of pollen beetle in sprayed plots, compared with the unsprayed control plots (Tables 2-6). Insecticides Proteus 110 OD (a.i. deltamethrin+thiacloprid 10+100 g l^{-1}) 0.6 and 0.75 l ha^{-1}, Decis 50 EW (a.i. deltamethrin 50 g l^{-1}) 0.125 and 0.15 l ha^{-1} and Fastac EC (a.i. alpha-cypermethrin 100 g l^{-1}) 0.15 l ha^{-1} effectively controlled pollen beetle in spring oilseed rape for 10 days in 2005 (I spray application) and in 2006 (Table 2).

Higher doses of Proteus and Decis were more effective, compared with lower doses of these insecticides; however the differences were not significant. There were no significant differences in the efficacy against pollen beetle of pyrethroids (deltamethrin and alpha-cypermethrin) and neonicotinoid thiacloprid in 2005 and 2006 cropping seasons.

Similar results were obtained in 2007 and 2008 cropping seasons in spring and winter oilseed rape, where three dose rates of organophosphorus insecticide Pyrinex Supreme (a.i. beta-cyfluthrin+chlorpyrifos 12+250 g l^{-1}) were included into the trial (Tables 3 and 4). Efficacy of insecticide Pyrinex Supreme was compared with Buldock (a.i. beta-cyfluthrin 25 g l^{-1}) and Proteus 110 OD EC (a.i. deltamethrin+thiacloprid 10+100 g l^{-1}). The results show that all insecticides used in the trials were effective against *M. aeneus* and significantly reduced the amount of pollen beetle in sprayed plots, compared with unsprayed control plots 1-10 DAA. The differences between various insecticides and between their dose rates were not significant.

The efficacy of three dose rates of the new insecticide Steward (a.i. indoxacarb 300 g l^{-1}) from the chemical class of oxidiazines were tested in spring and winter oilseed rape crops in the 2008-2009 cropping seasons (Tables 5 and 6). The results show that all three doses of Steward were effective against pollen beetle in both spring and winter oilseed rape crops and significantly reduced the number of insects 1-7 DAA compared with the untreated plots. The efficacy of pyrethroid insecticide tau-fluvalinate (Mavrik) was on the same level as Steward.

Parameters		Untreated	Proteus 110 OD		Decis 50 EW		Fastac EC
			0.6 l ha^{-1}	0.75 l ha^{-1}	0.125 l ha^{-1}	0.15 l ha^{-1}	0.15 l ha^{-1}
		Meligethes aeneus					
		2005					
Adults per plant	before I spray	1.47 (10 June, GS 50)					
	1 DAA	1.24	0.00**	0.00**	0.00**	0.00**	0.00**
	4 DAA	1.47	0.00**	0.02**	0.02**	0.01**	0.05**
	7 DAA	1.13	0.18**	0.09**	0.15**	0.12**	0.26**
	10 DAA	1.95	0.39**	0.36**	0.35**	0.39**	0.30**
Biological efficacy %	1 DAA	-	100.0	100.0	100.0	100.0	100.0
	4 DAA	-	100.0	98.6	98.6	99.3	96.6
	7 DAA	-	84.1	92.0	86.7	89.4	77.0
	10 DAA	-	80.0	81.5	82.0	80.0	84.6
Adults per plant	before II spray	2.23 (22 June, GS 57)					
	1 DAA	3.00	0.17**	0.11**	0.06**	0.04**	0.40**
	4 DAA	1.11	0.14**	0.11**	0.19**	0.08**	0.31**
	7 DAA	1.03	0.17**	0.17**	0.14**	0.08**	0.18**
Biological efficacy %	1 DAA	-	94.3	96.3	98.0	98.7	86.7
	4 DAA	-	87.4	90.1	82.9	92.8	72.1
	7 DAA	-	83.5	83.5	86.4	92.2	82.5
		2006					
Adults per plant	before spray	1.10 (21 June, GS 53)					
	1 DAA	0.92	0.77	0.01**	0.03**	0.02**	0.03**
	4 DAA	1.11	0.05**	0.18**	0.03**	0.03**	0.07**
	7 DAA	1.29	0.19**	0.19**	0.22**	0.19**	0.19**
	10 DAA	1.24	0.17**	0.18**	0.12**	0.18**	0.14**
Biological efficacy %	1 DAA	-	16.3	98.9	96.7	97.8	96.7
	4 DAA	-	95.5	83.8	97.3	97.3	93.7
	7 DAA	-	85.3	85.3	83.0	85.3	85.3
	10 DAA	-	86.3	85.5	90.3	85.5	88.7
DAA – days after application; asterisks (*,**) denote significant difference at P≤0.05, P≤0.01 probability levels, respectively, using Fisher's least significant difference test; data were log(X+1) transformed before analysis, but non-transformed data are presented							

Table 2. The effect of insecticides Proteus 110 OD (a.i. deltamethrin+thiacloprid 10+100 g l^{-1}), Decis 50 EW (a.i. deltamethrin 50 g l^{-1}) and Fastac EC (a.i. alpha-cypermethrin 100 g l^{-1}) on the number of pollen beetle (*Meligethes aeneus*) adults per plant in spring oilseed rape in 2005 and 2006.

Parameters		Untreated	Pyrinex Supreme			Bulldock 025 EC		Proteus 110 OD
			0.75 $l\ ha^{-1}$	1.0 $l\ ha^{-1}$	1.25 $l\ ha^{-1}$	0.225 $l\ ha^{-1}$	0.3 $l\ ha^{-1}$	0.75 $l\ ha^{-1}$
		Meligethes aeneus						
		2007						
Adults per plant	before I spray	0.77 (1 June, GS 50)						
	1 DAA	0.10	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**
	4 DAA	1.13	0.22**	0.22**	0.20**	0.30**	0.24**	0.21**
Biological efficacy %	1 DAA	-	100.0	100.0	100.0	100.0	100.0	100.0
	4 DAA	-	80.5	80.5	82.3	73.4	78.8	81.4
Adults per plant	before II spray	2.57 (7 June, GS 55-57)						
	1 DAA	2.22	0.71**	0.65**	0.39**	0.52**	0.78**	0.53**
	4 DAA	1.37	0.05**	0.00**	0.00**	0.10**	0.08**	0.02**
	7 DAA	0.92	0.03**	0.00**	0.00**	0.02**	0.02**	0.01**
Biological efficacy %	1 DAA	-	68.0	70.7	82.4	76.6	64.9	76.1
	4 DAA	-	96.4	100.0	100.0	92.7	94.2	98.5
	7 DAA	-	96.7	100.0	100.0	97.8	97.8	98.9
		2008						
Adults per plant	before spray	1.37 (5 June, GS 39)						
	1 DAA	0.31	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**
	4 DAA	0.40	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**
	7 DAA	0.67	0.00**	0.00**	0.00**	0.00**	0.03**	0.24**
	10 DAA	0.73	0.34**	0.17**	0.19**	0.16**	0.23**	0.23**
	14 DAA	0.77	0.29**	0.18**	0.24**	0.30**	0.21**	0.23**
Biological efficacy %	1 DAA	-	100.0	100.0	100.0	100.0	100.0	100.0
	4 DAA	-	100.0	100.0	100.0	100.0	100.0	100.0
	7 DAA	-	100.0	100.0	100.0	100.0	95.5	64.2
	10 DAA	-	53.4	76.7	74.0	78.1	68.5	68.5
	14 DAA	-	62.3	76.6	68.8	61.0	72.7	70.1
DAA – days after application; asterisks (*,**) denote significant difference at $P \leq 0.05$, $P \leq 0.01$ probability levels, respectively, using Fisher's least significant difference test; data were log(X+1) transformed before analysis, but non-transformed data are presented								

Table 3. The effect of insecticides Pyrinex Supreme (a.i. beta-cyfluthrin+chlorpyrifos 12+250 g l^{-1}), Bulldock (a.i. beta-cyfluthrin 25 g l^{-1}) and Proteus 110 OD EC (a.i. deltamethrin+thiacloprid 10+100 g l^{-1}) on the number of pollen beetle (*Meligethes aeneus*) adults per plant in spring oilseed rape in 2007 and 2008.

Parameters		Untreated	Pyrinex Supreme			Bulldock 025 EC		Proteus 110 OD
			0.75 l ha^{-1}	1.0 l ha^{-1}	1.25 l ha^{-1}	0.225 l ha^{-1}	0.3 l ha^{-1}	0.75 l ha^{-1}
		Meligethes aeneus						
		2007						
Adults per plant	before spray	1.80 (24 April, GS 55)						
	1 DAA	2.20	0.03**	0.04**	0.02**	0.02**	0.02**	0.04**
	4 DAA	1.84	0.19**	0.14**	0.04**	0.12**	0.05**	0.08**
	7 DAA	0.66	0.14**	0.01**	0.00**	0.04**	0.02**	0.01**
	10 DAA	1.61	1.09**	0.93**	0.74**	0.59**	0.81**	0.79**
Biological efficacy %	1 DAA	-	98.6	98.2	99.1	99.1	99.1	98.2
	4 DAA	-	89.7	92.4	97.8	93.5	97.3	95.6
	7 DAA	-	78.8	98.5	100.0	93.9	97.0	98.5
	10 DAA	-	32.3	42.2	54.0	63.4	49.7	50.9
		2008						
Adults per plant	before I spray	2.70 (15 April, GS 50-51)						
	1 DAA	0.28	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**
	4 DAA	0.22	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**
	7 DAA	0.49	0.03**	0.03**	0.01**	0.02**	0.05**	0.06**
	10 DAA	0.48	0.06**	0.05**	0.06**	0.06**	0.03**	0.08**
Biological efficacy %	1 DAA	-	100.0	100.0	100.0	100.0	100.0	100.0
	4 DAA	-	100.0	100.0	100.0	100.0	100.0	100.0
	7 DAA	-	93.9	93.9	98.0	95.9	89.8	87.8
	10 DAA	-	87.5	89.6	87.5	87.5	93.8	83.3
Adults per plant	before II spray	1.30 (28 April, GS 53-55)						
	1 DAA	0.29	0.00**	0.01**	0.02**	0.01**	0.00**	0.00**
	4 DAA	0.59	0.03**	0.03**	0.04**	0.08**	0.03**	0.04**
	7 DAA	0.17	0.01**	0.08**	0.01**	0.03**	0.03**	0.00**
	10 DAA	0.28	0.03**	0.04**	0.02**	0.05**	0.04**	0.04**
Biological efficacy %	1 DAA	-	100.0	96.6	93.1	96.6	100.0	100.0
	4 DAA	-	94.9	94.9	93.2	86.4	94.9	93.2
	7 DAA	-	94.1	52.9	94.1	82.4	82.4	100.0
	10 DAA	-	89.3	85.7	92.9	82.1	85.7	85.7

DAA – days after application; asterisks (*,**) denote significant difference at P≤0.05, P≤0.01 probability levels, respectively, using Fisher's least significant difference test; data were log(X+1) transformed before analysis, but non-transformed data are presented

Table 4. The effect of insecticides Pyrinex Supreme (a.i. beta-cyfluthrin+chlorpyrifos 12+250 g l^{-1}), Bulldock (a.i. beta-cyfluthrin 25 g l^{-1}) and Proteus 110 OD (a.i. deltamethrin+thiacloprid 10+100 g l^{-1}) on the number of pollen beetle (*Meligethes aeneus*) adults per plant in winter oilseed rape in 2007 and 2008.

Parameters		Untreated	Steward EC			Mavrik 2 F
			0.0425 kg ha^{-1}	0.0625 kg ha^{-1}	0.085 kg ha^{-1}	0.3 l ha^{-1}
		Meligethes aeneus				
		2008				
Adults per plant before	before spray	1.36 (5 June, GS 39)				
	1 DAA	0.36	0.01**	0.02**	0.02**	0.01**
	4 DAA	0.43	0.00**	0.00**	0.00**	0.00**
	7 DAA	0.54	0.00**	0.21**	0.04**	0.07**
	10 DAA	0.25	0.25	0.21	0.25	0.21
	14 DAA	0.89	0.23**	0.21**	0.29**	0.32**
Biological efficacy %	1 DAA	-	97.2	94.4	94.4	97.2
	4 DAA	-	100.0	100.0	100.0	100.0
	7 DAA	-	100.0	61.1	92.6	87.0
	10 DAA	-	0.0	16.0	0.0	16.0
	14 DAA	-	74.2	76.4	67.4	64.0
		2009				
Adults per plant before	before spray	2.50 (13 June, GS 53)				
	1 DAA	2.90	0.24**	0.46**	0.57**	0.00**
	4 DAA	2.29	0.12**	0.15**	0.19**	0.00**
	7 DAA	1.30	0.12**	0.06**	0.11**	0.06**
	10 DAA	0.66	0.15**	0.12**	0.15**	0.15**
Biological efficacy %	1 DAA	-	91.7	84.1	80.3	100.0
	4 DAA	-	94.8	93.4	91.7	100.0
	7 DAA	-	90.8	95.4	91.5	95.4
	10 DAA	-	77.3	81.8	77.3	77.3
DAA – days after application; asterisks (*,**) denote significant difference at P≤0.05, P≤0.01 probability levels, respectively, using Fisher's least significant difference test; data were log(X+1) transformed before analysis, but non-transformed data are presented						

Table 5. The effect of insecticides Steward EC (a.i. indoxacarb 300 g l^{-1}) and Mavrik 2 F (a.i. tau-fluvalinate 240 g l^{-1}) on the number of pollen beetle (*Meligethes aeneus*) adults per plant in spring oilseed rape in 2008 and 2009.

Parameters		Untreated	Steward EC			Mavrik 2 F
			0.0425 kg ha^{-1}	0.0625 kg ha^{-1}	0.085 kg ha^{-1}	0.3 l ha^{-1}
		Meligethes aeneus				
		2008				
Adults per plant	before I spray	1.16 (25 April, GS 52-53)				
	1 DAA	0.08	0.01**	0.01**	0.02**	0.04
	4 DAA	0.45	0.17**	0.08**	0.24**	0.09**
	7 DAA	1.00	0.52**	0.45**	0.50**	0.21**
Biological efficacy %	1 DAA	-	87.5	87.5	75.0	50.0
	4 DAA	-	62.2	82.2	46.7	80.0
	7 DAA	-	48.0	55.0	50.0	79.0
Adults per plant	before II spray	0.54 (2 May, GS 57-59)				
	1 DAA	0.19	0.03**	0.01**	0.00**	0.01**
	4 DAA	0.38	0.00**	0.01**	0.03**	0.00**
Biological efficacy %	1 DAA	-	84.2	94.7	100.0	94.7
	4 DAA	-	100.0	97.4	92.1	100.0
		2009				
Adults per plant	before spray	2.50 (4 May, GS 57)				
	1 DAA	0.74	0.27**	0.24**	0.31**	0.00**
	4 DAA	0.81	0.31**	0.25**	0.25**	0.20**
	7 DAA	0.37	0.14**	0.14**	0.15**	0.09**
	10 DAA	0.21	0.14	0.15	0.11*	0.09*
Biological efficacy %	1 DAA	-	63.5	67.6	58.1	100.0
	4 DAA	-	61.7	69.1	69.1	75.3
	7 DAA	-	62.2	62.2	59.5	75.7
	10 DAA	-	33.3	28.6	47.6	57.1
DAA – days after application; asterisks (*,**) denote significant difference at P≤0.05, P≤0.01 probability levels, respectively, using Fisher's least significant difference test; data were log(X+1) transformed before analysis, but non-transformed data are presented						

Table 6. The effect of insecticides Steward EC (a.i. indoxacarb 300 g l^{-1}) and Mavrik 2 F (a.i. tau-fluvalinate 240 g l^{-1}) on the number of pollen beetle (*Meligethes aeneus*) adults per plant in winter oilseed rape in 2008 and 2009.

3.2 The effect of insecticides on the pod infestation by larvae of *Ceutorhynchus obstrictus* and *Dasineura brassicae* and on the number of stems damaged by *C. pallidactylus* larvae in spring and winter oilseed rape crops

Little is known about the harmfullness of stem and pod pests in winter and spring rape, earlier it was published that *Ceutorhynchus* species were of minor importance in rape crops in Lithuania (Tamutis, 1997). However, it seems that increasing production area of spring and winter oilseed rape has increased the incidence and severity of stem and pod pests in both crops. Our research evidenced that damage caused by larvae of *C. pallidactylus* was higher in winter rape, compared with spring rape. It was estimated, that during experimental period, *C. pallidactylus* larvae damaged 18.3 - 87.0% of winter rape and up to 32.5% of spring rape stems (Tables 7 – 11).

Parameters	Untreated	Proteus 110 OD		Decis 50 EW		Fastac EC
		0.6 l ha^{-1}	0.75 l ha^{-1}	0.125 l ha^{-1}	0.15 l ha^{-1}	0.15 l ha^{-1}
Ceutorhynchus obstrictus						
2005						
Infested pods %	0.3	0.4	0.0	0.1	0.1	0.4
Reduction %	-	0.0	100.0	66.7	66.7	0.0
Larvae per pod	0.01	0.01	0.00	0.01	0.01	0.01
Reduction %	-	0.0	100.0	0.0	0.0	0.0
2006						
Infested pods %	6.3	5.3*	5.0**	4.9**	4.8**	5.3*
Reduction %	-	15.9	20.6	22.2	23.8	15.9
Larvae per pod	0.06	0.04**	0.03**	0.03**	0.03**	0.04**
Reduction %	-	33.3	50.0	50.0	50.0	33.3
Dasineura brassicae						
2005						
Infested pods %	8.3	5.4**	4.1**	5.4**	4.8**	5.8**
Reduction %	-	34.9	50.6	34.9	42.2	30.1
Larvae per pod	2.31	0.70**	0.41**	0.75**	0.75**	0.79**
Reduction %	-	69.7	82.2	67.5	67.5	65.8
2006						
Infested pods %	3.3	3.0	3.1	3.1	3.0	3.1
Reduction %	-	9.1	6.1	6.1	9.1	6.1
Larvae per pod	0.61	0.37	0.42	0.39	0.35	0.38
Reduction %	-	39.3	31.2	36.1	42.6	37.7
Ceutorhyncus pallidactylus						
2005						
Damaged stems %	32.5	19.0**	17.3**	19.2**	18.4**	18.8**
Reduction %	-	41.5	46.8	40.9	43.4	42.2
Larvae exit holes per stem	0.33	0.19**	0.17**	0.19**	0.18**	0.19**
Reduction %	-	42.4	48.5	42.4	45.4	42.4
2006						
Damaged stems %	16.3	10.4**	8.7**	9.6**	8.3**	11.7**
Reduction %	-	36.2	46.6	41.1	49.1	28.2
Larvae exit holes per stem	0.17	0.11*	0.09*	0.01*	0.08*	0.12*
Reduction %	-	35.3	47.1	94.1	52.9	29.4
Asterisks (*,**) denote a significant difference at P≤0.05, P≤0.01 probability levels, respectively, using Fisher's least significant difference test; data were arcsin $\sqrt{X\%}$ transformed before analysis, but non-transformed data are presented						

Table 7. The effect of insecticides Proteus 110 OD (a.i. deltamethrin+thiacloprid 10+100 g l^{-1}), Decis 50 EW (a.i. deltamethrin 50 g l^{-1}) and Fastac EC (a.i. alpha-cypermethrin 100 g l^{-1}) on the pod infestation by larvae of cabbage seedpod weevil (*Ceutorhynchus obstrictus*) and brassica pod midge (*Dasineura brassicae*) and on the number of stems damaged by cabbage stem weevil (*Ceutorhyncus pallidactylus*) larvae in spring oilseed rape in 2005 and 2006.

Parameters	Untreated	Pyrinex Supreme			Bulldock 025 EC		Proteus 110 OD
		0.75 l ha^{-1}	1.0 l ha^{-1}	1.25 l ha^{-1}	0.225 l ha^{-1}	0.3 l ha^{-1}	0.75 l ha^{-1}
Ceutorhynchus obstrictus							
2007							
Infested pods %	0.3	0.3	0.1	0.0	0.0	0.6	0.8
Reduction %	-	0.0	66.7	100.0	100.0	0.0	0.0
Larvae per pod	<0.01	<0.01	<0.01	0.00	0.00	0.01	0.01
Reduction %	-	0.0	0.0	0.0	0.0	0.0	0.0
2008							
Infested pods %	2.0	0.3**	0.3**	1.0	1.5	1.3	0.5**
Reduction %	-	85.0	85.0	50.0	25.0	35.0	75.0
Larvae per pod	0.66	0.12	0.02**	0.36	0.84	0.62	0.17
Reduction %	-	81.8	97.0	45.4	0.0	6.1	74.2
Dasineura brassicae							
2007							
Infested pods %	3.6	4.4	2.8	2.8	3.5	4.1	2.1
Reduction %	-	0.0	22.2	22.2	2.8	0.0	41.7
Larvae per pod	1.30	1.38	0.90	0.78	1.24	1.44	0.74
Reduction %	-	0.0	30.8	40.0	4.6	0.0	43.1
2008							
Infested pods %	3.5	1.5	1.0*	0.0**	1.8	1.8	1.0*
Reduction %	-	57.1	71.4	100.0	48.6	48.6	71.4
Larvae per pod	0.04	0.02	0.01**	0.00**	0.02	0.02	0.01**
Reduction %	-	50.0	75.0	100.0	50.0	50.0	75.0
Ceutorhyncus pallidactylus							
2007							
Damaged stems %	11.3	12.5	11.9	11.7	9.6	8.8	11.7
Reduction %	-	0.0	0.0	0.0	15.0	22.1	0.0
Larvae exit holes per stem	0.11	0.13	0.12	0.12	0.08	0.11	0.12
Reduction %	-	0.0	0.0	0.0	27.3	0.0	0.0
2008							
Damaged stems %	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Reduction %	-	0.0	0.0	0.0	0.0	0.0	0.0
Larvae exit holes per stem	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reduction %	-	0.0	0.0	0.0	0.0	0.0	0.0

Asterisks (*,**) denote a significant difference at P≤0.05, P≤0.01 probability levels, respectively, using Fisher's least significant difference test; data were arcsin $\sqrt{X\%}$ transformed before analysis, but non-transformed data are presented

Table 8. The effect of insecticides Pyrinex Supreme (a.i. beta-cyfluthrin+chlorpyrifos 12+250 g l^{-1}), Bulldock 025 EC (a.i. beta-cyfluthrin 25 g l^{-1}) and Proteus 110 OD (a.i. deltamethrin+thiacloprid 10+100 g l^{-1}) on the pod infestation by larvae of cabbage seedpod weevil (*Ceutorhynchus obstrictus*) and brassica pod midge (*Dasineura brassicae*) and on the number of stems damaged by cabbage stem weevil (*Ceutorhyncus pallidactylus*) larvae in spring oilseed rape in 2007 and 2008.

Parameters	Untreated	Pyrinex Supreme			Bulldock 025 EC		Proteus 110 OD
		0.75 l ha^{-1}	1.0 l ha^{-1}	1.25 l ha^{-1}	0.225 l ha^{-1}	0.3 l ha^{-1}	0.75 l ha^{-1}
Ceutorhynchus obstrictus							
2007							
Infested pods %	1.0	1.5	0.3	0.6	0.8	0.3	0.00*
Reduction %	-	0.0	70.0	40.0	20.0	70.0	100.0
Larvae per pod	0.01	0.02	0.00	0.01	0.01	0.02	0.00
Reduction %	-	0.0	100.0	0.0	0.0	0.0	100.0
2008							
Infested pods %	5.5	1.8*	1.3*	2.5*	1.5*	1.3*	1.8*
Reduction %	-	67.3	76.4	54.5	72.7	76.4	67.3
Larvae per pod	0.06	0.02*	0.01*	0.03*	0.02*	0.01*	0.02*
Reduction %	-	66.7	83.3	50.0	66.7	83.3	66.7
Dasineura brassicae							
2007							
Infested pods %	13.4	9.9*	7.1**	9.5*	11.5	9.3*	8.0**
Reduction %	-	26.1	47.0	29.1	14.2	30.6	40.3
Larvae per pod	1.48	0.90*	0.64**	0.61**	1.20	0.96	0.72**
Reduction %	-	39.2	56.8	58.8	18.9	35.1	51.4
2008							
Infested pods %	8.5	5.5*	3.0**	3.0**	3.0**	4.8**	4.8**
Reduction %	-	35.3	64.7	64.7	64.7	43.5	43.5
Larvae per pod	0.83	0.21**	0.15**	0.11**	0.10**	0.17**	0.23**
Reduction %	-	74.70	81.9	86.8	88.0	79.5	72.3
Ceutorhyncus pallidactylus							
2007							
Damaged stems %	18.3	7.1**	4.6**	6.3**	7.1**	7.1**	7.5**
Reduction %	-	61.2	74.9	65.6	61.2	61.2	59.0
Larvae exit holes per stem	0.23	0.09**	0.05**	0.07**	0.09**	0.09**	0.08**
Reduction %	-	60.9	78.3	69.6	60.9	60.9	65.2
2008							
Damaged stems %	20.0	6.3**	1.3**	1.2**	0.0**	5.0**	0.0**
Reduction %	-	68.5	93.5	94.0	100.0	75.0	100.0
Larvae exit holes per stem	0.21	0.06**	0.02**	0.01**	0.00**	0.05**	0.00**
Reduction %	-	71.4	90.5	95.2	100.0	76.2	100.0

Asterisks (*,**) denote a significant difference at P≤0.05, P≤0.01 probability levels, respectively, using Fisher's least significant difference test; data were arcsin $\sqrt{X\%}$ transformed before analysis, but non-transformed data are presented

Table 9. The effect of insecticides Pyrinex Supreme (a.i. beta-cyfluthrin+chlorpyrifos 12+250 g l^{-1}), Bulldock (a.i. beta-cyfluthrin 25 g l^{-1}) and Proteus 110 OD (a.i. deltamethrin+thiacloprid 10+100 g l^{-1}) on the pod infestation by larvae of cabbage seedpod weevil (*Ceutorhynchus obstrictus*) and brassica pod midge (*Dasineura brassicae*) and on the number of stems damaged by cabbage stem weevil (*Ceutorhyncus pallidactylus*) larvae in winter oilseed rape in 2007 and 2008.

In the 2008 cropping season, in untreated plots of winter oilseed rape field we found 20.0 – 35.0% of stems damaged by *C. pallidactylus* larvae (Tables 9 and 11) while in the field of spring oilseed rape such stems were not observed at all (Tables 8 and 10). The highest amount of damaged stems (87.0%) was estimated in winter rape during the 2009 cropping season.

Pod pests – *C. obstrictus* and *Dasineura brassicae* were estimated to be of economic importance both in winter and spring oilseed rape. At the pod development stage (GS 73) *C. obstrictus* larvae were found in 6.3% of spring rape pods in untreated plots in the 2006 and 2009 cropping seasons (Tables 7 and 10) and the highest percentage of winter rape pods infested by this insect (5.5%) was observed in 2008 (Table 9). The larvae of *D. brassicae* were detected in the assessed pods with a higher frequency, compared to the *C. obstrictus*. Therefore, during experimental period, there were found 7.5 - 13.4% of winter rape and 1.8 - 8.3% of spring rape pods with the presence of *D. brassicae* larvae inside the pods. The average number of larvae/pod in winter rape in untreated plots ranged from 0.54 to 1.5 and in spring rape from 0.2 to 2.3 larvae/assessed pod. The number of *C. obstrictus* larvae/pod in untreated control plots was much lower, compared to the abundance of *D. brassicae* larvae. In general, this is not very high infestation of pods, compared to the data obtained in Czech Republic, where up to 86.0% of pods were found infested with larvae of *D. brassicae* in the control plots (Pavela et al., 2007).

All tested insecticides, used for the control of *M. aeneus*, also decreased the number of pods infested by larvae of *C. obstrictus* and *D. brassicae* and the number of stems, damaged by *C. pallidactylus*, in some cases these decreases were essential. Insecticide application in spring oilseed rape significantly decreased the number of stems damaged by *C. pallidactylus* larvae, the reduction of damaged stems was 40.9 - 46.8% during 2005 (two insecticide applications, at GS 50 and GS 57) and 36.2 – 49.1% during the 2006 cropping season (insecticide application at GS 53) (Table 7). However, the efficacy of insecticides on the control of *C. obstrictus* and *D. brassicae* varied during this experimental period. Insecticides essentially prevented pod infestation by *C. obstrictus* larvae and reduced the number of larvae/pod in 2006 and by *D. brassicae* larvae in 2005. Insecticides were not effective, when the infestation of pods was low in the control plots (in 2005 only 0.3% of *C. obstrictus* larvae-infested and in 2006 3.3% of *D. brassicae* larvae-infested pods). Obviously, the application time of insecticides was focused on the spray threshold of pollen beetle, while the best treatment time for the control of brassica pod midge is recorded to be later – at the flowering growth stage (GS 65-67) (Pavela et al., 2007). Our results show that the efficacy of Proteus (neonicotinoid class) was on the same level as pyrethroids (Decis and Fastac) in 2005 and 2006. However, other researchers have reported that the application of neonicotinoid insecticides had exhibited the highest efficacy in the control of the brassica pod midge (Pavela et al., 2007).

The infestation of winter rape pods with larvae of *C. obstrictus* and *D. brassicae* in the control untreated plots during the 2007 and 2008 cropping seasons was much higher, compared with spring oilseed rape pods (Table 8). In spring oilseed rape, Pyrinex Supreme (a.i. beta-cyfluthrin+chlorpyrifos 12+250 g l^{-1}), Bulldock 025 EC (a.i. beta-cyfluthrin 25 g l^{-1}) and Proteus 110 OD (a.i. deltamethrin+thiacloprid 10+100 g l^{-1}) used twice in 2007 against pollen beetle (at GS 50 and GS 55-57) had no significant effect on the pod infestation with *C. obstrictus* and *D. brassicae* larvae. However, a single early application of insecticides in 2008 (GS 39) effectively prevented pod infestation. Insecticides had no effect on the number of damaged stems by *C. pallidactylus* larvae in spring oilseed rape in both cropping seasons.

Parameters	Untreated	Steward EC			Mavrik 2 F
		0.0425 kg ha^{-1}	0.0625 kg ha^{-1}	0.085 kg ha^{-1}	0.3 l ha^{-1}
Ceutorhynchus obstrictus					
2008					
Infested pods %	1.8	0.8	1.3	1.5	2.0
Reduction %	-	55.6	27.8	16.7	0.0
Larvae per pod	0.02	0.01	0.01	0.02	0.07
Reduction %	-	50.0	50.0	0.0	0.0
2009					
Infested pods %	6.3	2.8	3.3	2.0**	4.5
Reduction %	-	55.6	47.6	68.2	28.6
Larvae per pod	0.06	0.03*	0.03*	0.03*	0.05
Reduction %	-	50.0	50.0	50.0	16.7
Dasineura brassicae					
2008					
Infested pods %	1.8	0.5	1.0	1.8	2.0
Reduction %	-	72.2	44.4	0.0	0.0
Larvae per pod	0.18	0.06	0.04	0.07	0.34
Reduction %	-	66.7	77.8	61.1	0.0
2009					
Infested pods %	8.5	2.5**	2.0**	2.0**	3.3**
Reduction %	-	70.6	76.5	76.5	61.2
Larvae per pod	1.19	0.24**	0.19**	0.21**	0.39**
Reduction %	-	79.8	84.0	82.4	67.2
Ceutorhyncus pallidactylus					
2008					
Damaged stems %	0.0	0.0	0.0	0.0	0.0
Reduction %	-	0.0	0.0	0.0	0.0
Larvae exit holes per stem	0.00	0.00	0.00	0.00	0.00
Reduction %	-	0.0	0.0	0.0	0.0
2009					
Damaged stems %	22.0	0.0**	7.0**	5.0**	1.0**
Reduction %	-	100.0	68.2	77.3	95.5
Larvae exit holes per stem	0.31	0.00**	0.07**	0.08**	0.02**
Reduction %	-	100.0	77.4	74.2	93.6
Asterisks (*,**) denote a significant difference at P≤0.05, P≤0.01 probability levels, respectively, using Fisher's least significant difference test; data were arcsin $\sqrt{X\%}$ transformed before analysis, but non-transformed data are presented					

Table 10. The effect of insecticides Steward EC (a.i. indoxacarb 300 g l^{-1}) and Mavrik 2 F (a.i. tau-fluvalinate 240 g l^{-1}) on the pod infestation with larvae of cabbage seedpod weevil (*Ceutorhynchus obstrictus*) and brassica pod midge (*Dasineura brassicae*) and on the number of stems damaged by cabbage stem weevil (*Ceutorhyncus pallidactylus*) larvae in spring oilseed rape during the 2008 and 2009 cropping seasons.

Parameters	Untreated	Steward EC			Mavrik 2 F
		0.0425 kg ha^{-1}	0.0625 kg ha^{-1}	0.085 kg ha^{-1}	0.3 l ha^{-1}
Ceutorhynchus obstrictus					
2008					
Infested pods %	4.3	0.8**	1.8	2.5	0.8**
Reduction %	-	81.4	58.1	41.9	81.4
Larvae per pod	0.13	0.01*	0.02	0.03	0.01*
Reduction %	-	92.3	84.6	76.9	92.3
2009					
Infested pods %	2.5	2.1	1.8	2.0	1.6
Reduction %	-	16.0	28.0	20.0	36.0
Larvae per pod	0.03	0.02	0.02	0.02	0.02
Reduction %	-	33.3	33.3	33.3	33.3
Dasineura brassicae					
2008					
Infested pods %	7.5	2.8**	3.3**	3.0**	2.5**
Reduction %	-	62.7	56.0	60.0	66.7
Larvae per pod	0.54	0.11**	0.13**	0.10**	0.08**
Reduction %	-	79.6	75.9	81.5	85.2
2009					
Infested pods %	7.8	2.0**	4.0*	2.1**	2.0**
Reduction %	-	74.4	48.7	73.1	74.4
Larvae per pod	0.70	0.11**	0.19**	0.08**	0.12**
Reduction %	-	84.3	72.9	88.6	82.9
Ceutorhyncus pallidactylus					
2008					
Damaged stems %	35.0	15.0**	20.0**	25.0	26.3
Reduction %	-	57.1	42.9	28.6	24.9
Larvae exit holes per stem	0.54	0.19**	0.24**	0.29**	0.33*
Reduction %	-	64.8	55.6	46.3	38.9
2009					
Damaged stems %	87.0	76.0*	67.0**	67.0**	71.0**
Reduction %	-	12.6	23.0	23.0	18.4
Larvae exit holes per stem	2.05	1.19**	1.03**	.97**	1.04**
Reduction %	-	42.0	49.8	52.7	49.3
Asterisks (*,**) denote significant difference at P≤0.05, P≤0.01 probability levels, respectively, using Fisher's least significant difference test; data were arcsin $\sqrt{X\%}$ transformed before analysis, but non-transformed data are presented					

Table 11. The effect of insecticides Steward EC (a.i. indoxacarb 300 g l^{-1}) and Mavrik 2 F (a.i. tau-fluvalinate 240 g l^{-1}) on the pod infestation by larvae of cabbage seedpod weevil (*Ceutorhynchus obstrictus*) and brassica pod midge (*Dasineura brassicae*) and on the number of stems damaged by cabbage stem weevil (*Ceutorhyncus pallidactylus*) larvae in winter oilseed rape during the 2008 and 2009 cropping seasons.

As it has been mentioned above, winter oilseed rape crop was more heavily infested with pod and stem pest larvae, compared with spring rape. The insecticides for *M. aeneus* control in winter rape in 2007 were used once (GS 55) and in 2008 twice (GS 50-51 and GS 53-55). All insecticides (Pyrinex Supreme (a.i. beta-cyfluthrin+chlorpyrifos 12+250 g l^{-1}), Bulldock 025 EC (a.i. beta-cyfluthrin 25 g l^{-1}) and Proteus 110 OD (a.i. deltamethrin+thiacloprid 10+100 g l^{-1}) used at all dose rates effectively reduced pod infestation with larvae of *C. obstrictus* and *D. brassicae*, also the number of stems damaged by *C. pallidactylus* larvae (Table 9). Due to different insecticide application the number of pods infested with *C. obstrictus* larvae was reduced by 0 - 100.0% and by 54.5 - 76.4% and pod infestation with *D. brassicae* larvae was reduced by 14.2 – 47.0% and by 35.3 – 64.7 % in the 2007 and 2008 cropping seasons, respectively.

The number of stems damaged by *C. pallidactylus* larvae was reduced by 59.0 – 74.9% in 2007 and by 68.5 – 100.0% in 2008. It seems that the application of insecticides against pollen beetle twice in 2008 gave a more effective control of also pod and stem pests, compared with a single application in 2007. However, significant differences between the different class insecticides were not revealed.

Insecticides Steward EC (a.i. indoxacarb 300 g l^{-1}) and Mavrik 2 F (a.i. tau-fluvalinate 240 g l^{-1}) were used for the control of pollen beetle and other pests in spring and winter oilseed rape in the 2008 and 2009 cropping seasons. The infestation of pods with larvae of *C. obstrictus* and *D. brassicae* in the control untreated plots in winter oilseed rape during the 2008 cropping season was higher, compared with spring rape; however, in 2009 higher infestation in spring rape was observed (Tables 10, 11). In spring rape, insecticides were used once in the 2008 and 2009 cropping seasons, at GS 39 and GS 53, respectively. The results show higher infestation of pods with *C. obstrictus* and *D. brassicae* larvae and stems with *C. pallidactylus* larvae in 2009, compared with the 2008 cropping season. Due to the application of insecticide Steward, pod infestation with *C. obstrictus* larvae was reduced by 16.7-55.6% and by 47.6 – 68.2% in 2008 and 2009, respectively; however, this reduction was not essential (Table 10). Pyrethroid insecticide Mavrik was less effective in preventing pod infestation with *C. obstrictus* larvae, compared with Steward (indoxacarb chemical class). The effect of different dose rates of Steward on *D. brassicae* was very variable in 2008, although in 2009 all three dose rates of Steward showed high efficacy in the reduction of pods infested with larvae of *D. brassicae.* Insecticides Steward and Mavrik also effectively reduced the number of stems, damaged by *C. pallidactylus* larvae in the 2009 cropping season (reduction was 68.2 – 100.0%).

In winter rape, insecticides were used twice in 2008 (at GS 52-53 and GS 57-59) and once in the 2009 cropping season, at GS 57. The results show that pod infestation with *C. obstrictus* larvae in untreated control plots was much higher in 2008, compared with 2009 (4.3 and 2.5%, respectively) and pod infestation with larvae of *D. brassicae* was very similar in both experimental years (7.5 and 7.8%). Very high number of stems damaged by *C. pallidactylus* larvae (87.0%) was observed in 2009, while only 35.0% of such stems were found in the 2008 cropping season. Insecticide Steward reduced pod infestation with *C. obstrictus* larvae by 41.9 – 81.4% and by 16.0 – 28.0% in 2008 and 2009, respectively; however, this reduction in most cases was not essential (Table 11). Pod infestation with *D. brassicae* larvae was controlled more effectively. The reduction of infested pods and the number of larvae/pod was essential in both cropping seasons. The efficacy of Steward and of Mavrik was on the same level and no remarkable differences were obtained between the efficacy of insecticides from different chemical classes. Other researchers have reported that the pyrethroid insecticides were more effective than endosulfan and methyl parathion at reducing adult numbers and preventing pod infestation by larvae (Buntin, 1999a). Different dose rates of Steward showed very similar efficacy in controlling pod infestation with *C. obstrictus* and *D. brassicae* larvae. Usually optimal time for controlling of pod pests is during flowering (Buntin, 1999a); however our research evidenced that insecticide application against pollen beetle during inflorescence emergence growth stage also effectively prevented pod infestation with larvae of *C. obstrictus* and *D. brassicae*.

Insecticide application at inflorescence emergence growth stage (GS 52-59) also reduced the number of stems damaged by *C. pallidactylus* larvae. The highest reduction (42.9 – 57.1%) was obtained in the 2008 cropping season where the lower dose rates of Steward showed higher efficacy and this reduction was essential, compared with the untreated plots. In 2009, when winter rape stem infestation with this pest was very high, the number of infested stems in insecticide treated plots was reduced only by 12.6 – 23.0%, however this reduction was essential in all cases. Despite the fact that insecticides were effective against *C. pallidactylus*, the number of damaged stems remained very high (67.0 -76.0%) in the insecticide treated plots in winter rape during the 2009 cropping season. It seems that the application of insecticides at GS 52-59 was not optimal for the effective control of *C. pallidactylus*.

3.3 The effect of insecticides on the productivity of spring and winter oilseed rape

Insecticide treatment had a positive effect on the seed yield of spring and winter oilseed rape; however, only in some cases substantial seed yield increase resulting from insecticide application was obtained. It seems that the effect of different insecticides on the productivity of spring and winter oilseed rape was highly dependent on the year. Insecticide Proteus (a.i. deltamethrin+thiacloprid) at a dose rate of 0.75 l ha^{-1} significantly ($P \leq 0.01$) increased the seed yield of spring rape in 2005 (by 19.7%), 2006 (25.7%) and in 2007 (21.6%) (Tables 12 and 13). Proteus application also provided a substantial increase in the seed yield of winter oilseed rape in the 2007 cropping season (the yield increased by 30.5%, compared with the unsprayed control) (Table 13). The higher dose rate of Proteus provided the higher seed yield increase. However, during the 2008 cropping season the seed yield obtained in Proteus sprayed plots was of the same level as in unsprayed control plots in both spring and winter oilseed rape.

Insecticide Pyrinex Supreme (a.i. beta-cyfluthrin+chlorpyrifos) belonging to the organophosphorus chemical class, used at three dose rates (0.75; 1.0 and 1.25 l ha^{-1}) provided substantial yield and TSW increase in spring and winter oilseed rape, but only in one of the two years. Application of this insecticide caused a 16.9 - 20.6% seed yield increase in the 2007 cropping season in spring rape and in winter rape 24.4 – 26.2%, compared with the untreated control plots (Table 13). Pyrethroids Decis (a.i. deltamethrin) and Fastac (a.i. alpha-cypermethrin) were used in the trials in the 2005 and 2006 cropping seasons and their application in all cases caused a substantial seed yield increase in spring oilseed rape (Table 12). The efficacy of Decis and Fastac was of the same level as Proteus, belonging to the neonicotinoid chemical class.

In the other group of trials, during the 2007 and 2008 cropping seasons another pyrethroid Bulldock (a.i. beta-cyfluthrin) was compared with the insecticides Pyrinex Supreme (organophosphorus chemical class) and Proteus (neonicotinoid chemical class). The results show that in both cropping seasons the effect of Bulldock on the seed yield of spring and winter oilseed rape was on the same level as in the plots, treated by Pyrinex Supreme and Proteus (Table 13).

Parameters	Untreated	Proteus 110 OD		Decis 50 EW		Fastac EC
		0.6 l ha^{-1}	0.75 l ha^{-1}	0.125 l ha^{-1}	0.15 l ha^{-1}	0.15 l ha^{-1}
2005						
Seed yield, kg ha^{-1}	2254	2532	2698**	2769**	2682**	2519
% to untreated	100.0	112.4	119.7	122.9	119.0	111.8
TSW, g	3.67	3.77	3.76	3.72	3.73	3.73
% to untreated	100.0	102.7	102.4	101.2	101.4	101.4
2006						
Seed yield, kg ha^{-1}	1392	1742**	1749**	1680**	1735**	1618**
% to untreated	100.0	125.1	125.7	120.7	124.7	116.3
TSW, g	4.50	4.63**	4.63**	4.65**	4.65**	4.55
% to untreated	100.0	103.0	103.0	103.4	103.3	101.1
Asterisks (*,**) denote significant difference at P≤0.05, P≤0.01 probability levels, respectively, using Fisher's least significant difference test						

Table 12. The effect of insecticides Proteus 110 OD (a.i. deltamethrin+thiacloprid 10+100 g l^{-1}), Decis 50 EW (a.i. deltamethrin 50 g l^{-1}) and Fastac EC (a.i. alpha-cypermethrin 100 g l^{-1}) on the seed yield and thousand seed weight (TSW) of spring oilseed rape in 2005 and 2006.

Parameters	Untreated	Pyrinex Supreme			Bulldock 025 EC		Proteus 110 OD
		0.75 l ha^{-1}	1.0 l ha^{-1}	1.25 l ha^{-1}	0.225 l ha^{-1}	0.3 l ha^{-1}	0.75 l ha^{-1}
	Spring oilseed rape						
	2007						
Seed yield, kg ha^{-1}	2328	2722**	2760**	2807**	2626**	2653**	2830**
% to untreated	100.0	116.9	118.6	120.6	112.8	114.0	121.6
TSW, g	3.68	3.85**	3.89**	3.90**	3.80**	3.89**	3.93**
% to untreated	100.0	104.6	105.8	105.9	103.2	105.6	106.7
	2008						
Seed yield, kg ha^{-1}	3552	3602	3546	3552	3553	3552	3552
% to untreated	100.0	101.4	99.8	100.0	100.0	100.0	100.0
TSW, g	3.84	3.91**	3.85	3.91**	3.94**	3.91**	3.90**
% to untreated	100.0	102.0	100.3	101.9	102.7	101.9	101.6
	Winter oilseed rape						
	2007						
Seed yield kg ha^{-1}	1950	2427**	2482**	2462**	2364**	2461**	2544**
% to untreated	100.0	124.4	127.3	126.2	121.2	126.2	130.5
TSW, g	4.48	4.65**	4.67**	4.67**	4.65**	4.66**	4.68**
% to untreated	100.0	103.7	104.2	104.3	103.7	104.1	104.4
	2008						
Seed yield kg ha^{-1}	5034	4771	5118	5079	5138	5110	4963
% to untreated	100.0	94.8	101.7	100.9	102.1	101.5	98.6
TSW, g	4.34	4.53**	4.56**	4.56**	4.50*	4.48*	4.51*
% to untreated	100.0	104.4	105.2	105.1	103.8	103.3	104.0
An asterisks (*,**) denotes a significant difference at P≤0.05, P≤0.01 probability levels, respectively, using Fisher's least significant difference test							

Table 13. The effect of insecticides Pyrinex Supreme (a.i. beta-cyfluthrin+chlorpyrifos 12+250 g l^{-1}), Bulldock (a.i. beta-cyfluthrin 25 g l^{-1}) and Proteus 110 OD (a.i. deltamethrin+thiacloprid 10+100 g l^{-1}) on the seed yield and thousand seed weight (TSW) of spring and winter oilseed rape in 2007 and 2008.

Parameters	Untreated	Steward EC			Mavrik 2 F
		0.0425 kg ha^{-1}	0.0625 kg ha^{-1}	0.085 kg ha^{-1}	0.3 l ha^{-1}
Spring oilseed rape					
2008					
Seed yield, kg ha^{-1}	3471	3444	3480	3396	3436
% to untreated	100.0	99.4	98.5	100.1	101.5
TSW, g	4.10	4.07	4.04	4.10	4.16
% to untreated	100.0	99.4	98.5	100.1	101.5
2009					
Seed yield, kg ha^{-1}	1936	2145	2107	2158	2108
% to untreated	100.0	110.8	108.9	111.5	108.9
TSW, g	5.68	6.08**	6.04**	5.97*	5.68
% to untreated	100.0	107.0	106.4	105.1	100.0
Winter oilseed rape					
2008					
Seed yield, kg ha^{-1}	4826	4764	4943	4891	4777
% to untreated	100.0	98.7	102.4	101.3	99.0
TSW, g	4.23	4.36**	4.35**	4.41**	4.41**
% to untreated	100.0	103.0	102.8	104.2	104.3
2009					
Seed yield, kg ha^{-1}	3942	3954	3978	4075	4017
% to untreated	100.0	100.3	100.9	103.4	101.9
TSW, g	4.54	4.55	4.59	4.62	4.59
% to untreated	100.0	100.2	101.0	101.8	101.1
Asterisks (*,**) denote significant difference at P≤0.05, P≤0.01 probability levels, respectively, using Fisher's least significant difference test					

Table 14. The effect of insecticides Steward EC (a.i. indoxacarb 300 g l^{-1}) and Mavrik 2 F (a.i. tau-fluvalinate 240 g l^{-1}) on the seed yield and thousand seed weight (TSW) of spring and winter oilseed rape in 2008 and 2009.

The efficacy of insecticides Steward EC (a.i. indoxacarb 300 g l^{-1}) and Mavrik 2 F (a.i. tau-fluvalinate 240 g l^{-1}) tested in the 2008 and 2009 cropping seasons was lower and yield increases obtained in both spring and winter oilseed rape crops were not substantial, despite the fact that in some cases substantial increase in TSW was achieved (Table 14). Our research support the findings that oilseed rape can tolerate pod infestations of < 26 % without measurable yield loss (Lerin, 1984; Buntin, 1999a).

4. Conclusions

M. aeneus was a very common and devastating pest in winter and spring rape crops every year. The research findings of the investigation on the efficacy of insecticides belonging to the different chemical classes (pyrethroids, nenicotinoids, organophosphorus and oxidiazines) for pest control in spring and winter oilseed rape suggest that all insecticides tested gave good and similar control of *M. aeneus.* Depending on the year, one or two spray applications of insecticides were used to control pollen beetle.

Our research evidenced that pod infestation by larvae of *D. brassicae*, also stem infestation by *C. pallidactylus* larvae were higher in winter oilseed rape, compared with spring rape. In general, the incidence of *C. obstrictus* infested pods was very similar in both crops, while it was variable among the crops within the same cropping season. The larvae of *D. brassicae*

were found in the assessed pods at a higher frequency, compared with *C. obstrictus*. It was estimated that the highest pod infestation by *C.obstrictus* larvae reached 6.3% in spring rape and 5.5% in winter rape, the highest pod infestation by *D. brassicae* larvae reached 8.5% and 13.4%, respectively. The number of *C. obstrictus* larvae/pod in untreated control plots was much lower, compared with the abundance of *D. brassicae* larvae. *C. pallidactylus* larvae infested 18.3-87.0% of winter rape and 0-32.5% of spring rape stems.
All tested insecticides, used for the control of *M. aeneus*, also decreased the number of pods infested by larvae of *C. obstrictus* and *D. brassicae* and decreased the number of stems, damaged by *C. pallidactylus*, in some cases these decreases were essential. The effect of different insecticides on the productivity of spring and winter oilseed rape highly depended on the cropping season and insecticide application did not always result in substantial yield increase.

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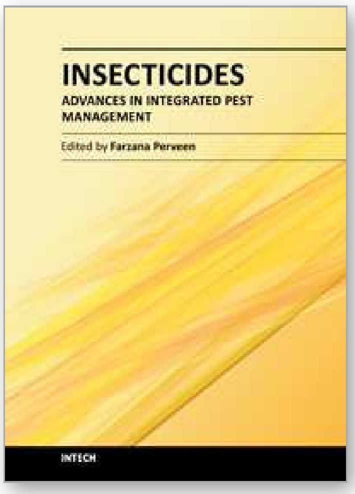

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