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INFLUENCE OF SEED TREATMENTS AND FOLIAR INSECTICIDES USED AGAINST *Oscinella frit* L. IN MAIZE ON THE POPULATION OF THRIPS

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ABSTRACT

Background. Thrips constitute a group of common maize pests in Poland. Although in recent years their population and harmfulness in maize fields have increased, they are still not covered by chemical control due to the lack of approved insecticides.
Material and methods. A study was carried out in 2010-2012 in southeastern Poland to test the potential indirect effects of non-selective seed dressings and foliar insecticides applied in the spring to control the frit fly (*Oscinella frit* L.) on the population of thrips without the need for separate treatments. Seed dressings containing imidacloprid (Gaucho 600 FS and Couraze 350 FS) and methiocarb (Mesurol 500 FS), as well as foliar insecticides containing lambda-cyhalothrin (Karate Zeon 050 CS) and a mixture of thiacloprid with deltamethrin (Proteus 110 OD) were used in the experiment.
Results. In the study years thrips infested maize plants from mid-May to the first ten days of October. They were most abundant from the end of June to mid-August, with a single population peak between 11 and 20 July. All the tested insecticides used in spring to control *O. frit* had an indirect insecticidal effect on thrips. The highest effectiveness of seed dressings and foliar insecticides was observed until mid-June, which did not allow for the effective protection of maize plants against feeding thrips.
Conclusion. The insecticidal effect of the tested products ended before the most abundant occurrence of thrips, and, therefore, these pests have to be controlled separately with chemical treatments on later dates.

Key words: chemical control, effectiveness, occurrence, Thysanoptera, *Zea mays*

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important crops in the world and its biggest producers, the United States of America, China and Brazil, produce in total about 563 to 717 million tonnes per year (Ranum *et al.*, 2014). This plant is also gaining in importance in Europe, including in the European Union (EU) member states. The cropping area within the then 27 member states of the EU reached 8.3 million hectares in 2007 for grain maize and 5.0 million hectares for silage maize (Rüdelsheim and Smets, 2011). The leading producers of maize in the EU are France, Romania, Germany, Hungary and Italy (Meissle *et al.*, 2010).

In Poland, maize, together with winter wheat and oilseed rape are the most important agricultural crops. Since 2012 the acreage of maize has been

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slightly more than one million hectares, and grain production is approximately 4-4.5 million tonnes per year (GUS, 2013, 2014, 2015). As the acreage for growing maize increases, production is intensified, and agricultural techniques have become simplified (especially towards long-term monoculture and non--tillage systems), this crop is also more exposed to harmful organisms (Bereś and Pruszyński, 2008). Currently, the volume and quality of maize yields in Poland may be negatively affected by over 100 weed species, about 400 pathogen species, and about 50 pest species (Bereś *et al.*, 2013a). In recent years, the economic importance of pests has been growing rapidly, and they, together with diseases, may cause up to 20-50% direct losses in grain yield, additionally deteriorating the quality of the crop, also because of the increased risk of contamination with mycotoxins (Lisowicz and Tekiela, 2004).

In the spring the greatest losses in maize crops are caused by the frit fly (*Oscinella frit* L.), whose larvae damage leaf buds and the growth cone in juvenile maize plants, and additionally increase the susceptibility of plants to the invasion of pathogens, particularly fungal ones such as *Ustilago maydis* (D.C.) Corda (Lisowicz, 1984; Ptaszyńska and Sulewska, 2007). In Poland, the estimated loss in maize yield caused by feeding *O. frit* larvae is about 10% (Lisowicz and Tekiela, 2004). The frit fly on maize has also been reported in other European countries, e.g. Hungary, France, Spain, Italy, Germany, Denmark and the Netherlands, but in recent years the highest damage was observed in France, the Netherlands and Poland (Meissle *et al.*, 2010). Due to its great harmfulness across Poland, almost every year the frit fly is controlled with chemical methods such as seed treatments or foliar insecticides.

Apart from the frit fly, maize plants are also infested by thrips that feed on above-ground parts of plants from spring until the end of the maize growing season (Lisowicz and Tekiela, 2004). Recent observations demonstrated a growing number of these insects that locally cause severe damage to maize leaves, thereby limiting the photosynthetic area of plants, which is particularly dangerous in periods of drought. So far, in the soil and climatic conditions of Poland, 21 species of thrips have been detected with *Frankliniella tenuicornis* (Uzel) and *Haplothrips aculeatus* (F.) being the most abundant (Kucharczyk *et al.*, 2011). Although thrips currently do not cause direct losses in maize yield in Poland (Lisowicz and Tekiela, 2004), it is being suggested that they may increase the susceptibility of plants to invasion by pathogens (indirect harmfulness), including fungi of the genus *Fusarium* that produce mycotoxins dangerous to human and animal health and viruses that can cause serious diseases in maize (Farrar and Davis, 1991; Mailhot *et al.*, 2007a; Parsons and Munkvold, 2010; Parikka *et al.*, 2012; Zhao *et al.*, 2014). Lisowicz (2001) reported the important role of thrips as fodder maize pests and the need for their control in the south-eastern part of Poland.

In view of the increasing number of thrips on maize it is necessary to develop an integrated protection plan for this plant against Thysanoptera, which would also include chemical methods of pest control. Currently, no products for the control of thrips have been approved for the integrated management of maize pests in Poland. Therefore, a study was carried out to test the potential indirect effect of non-selective seed treatments and foliar insecticides applied to control the frit fly on limiting the population of thrips during the whole maize growing period.

MATERIAL AND METHODS

The study was carried out in 2010-2012 in Krzeczowice (49°59' N; 22°27' E), southeastern Poland, on a maize field of the San variety (FAO 240). The experiment on the use of insecticides was designed as a system of completely randomized blocks in four replicates. Maize was sown on four--row 50 m^2 plots (3.0 m × 16.7 m; width × length) at a seeding rate of 80,000 seeds$\cdot$$ha^{-1}$. Maize was planted at the optimum dates for this part of the country, i.e. on 30 April (2010), 28 April (2011), and 27 April (2012).

Three products with systemic activity approved for the control of the frit fly on maize were used in the experiment on the indirect insecticidal effects of seed treatments on thrips: the insecticide Gaucho 600 FS, in a dose 0.6 $dm^3\cdot 100\ kg^{-1}$ of seeds, contains imidacloprid (360 g active ingredient in 0.6 dm^3) which is from the class of neonicotinoids, Couraze 350 FS, applied at two dose levels of 1.1 and 1.7 $dm^3\cdot 100\ kg^{-1}$ of seeds, also contains imidacloprid

(385 g and 595 g active ingredient in 1.1 and 1.7 dm^3 respectively) and Mesurol 500 FS, in a dose 1.0 $dm^3 \cdot 100\ kg^{-1}$ of seeds, contains methiocarb (500 g active ingredient in 1.0 dm^3) from the class of carbamates. Doses of the insecticides used for seed treatments are also presented in tables 2-5. The maize grain was treated with the insecticides three weeks before sowing. The effectiveness of seed dressings in the control of thrips was assessed after the occurrence of insects, which began three weeks after maize sowing. Observations on the occurrence of thrips were carried out up to 9 weeks after maize sowing.

Two foliar insecticides used against the frit fly were used in the experiment to test their indirect effects on thrips. The first product (Karate Zeon 050 CS applied at two dose levels: 0.1 and 0.2 $dm^3 \cdot ha^{-1}$) contains lambda-cyhalothrin (5 g and 10 g active ingredient in 0.1 and 0.2 dm^3 respectively), from the class of pyrethroids, and has a contact activity. The second product (Proteus 110 OD in a total dose of 0.5 $dm^3 \cdot ha^{-1}$) contains a mixture of thiacloprid (50 g active ingredient in 0.5 dm^3) with deltamethrin (5 g active ingredient in 0.5 dm^3), from the class of chloronicotinils and pyrethroids, and has a contact and systemic insecticidal activity. Doses of both insecticides are presented also in tables 6-9. Foliar insecticides were used on the plots that had no prior seed dressings. Plants were sprayed on 17 May (2010), 16 May (2011) and 14 May (2012), when the maize had 2-3 leaves developed (BBCH 12-13) (Meier 1997), using 300 litres of water per hectare. The mean number of thrips was estimated directly before each chemical treatment on individual plots, including on control plots where no chemical treatment was used. The effectiveness of foliar insecticides was assessed on days 3, 7, 14, 21, 28 and 35 after treatment.

The effectiveness of seed treatments and foliar insecticides in the control of thrips was estimated by sampling 10 random plants from two central rows on each plot on each observation date. The mean number of insects per plant for each experimental plot was calculated in a laboratory.

Results were statistically analysed using Statistica 10.0 PL software from StatSoft company (StatSoft 2010). One-way analysis of variance ANOVA in a random block design was used. The significance of differences between means was verified with the Student-Newman-Keuls test at a significance level of $p = 0.05$. The variability of data in study years was considered as a random effect. The effectiveness of insecticides in the control of thrips was calculated from mean values according to Abbott's formula and expressed in percent.

In addition to the control plots used in the experiment on the effects of the chemical control of thrips, a separate 0.5 ha part of the field was left without insecticidal treatment and used for the observation of the further development of thrips and the identification of the dates of their occurrence on maize. For that purpose, from the end of May, when plants had developed 1-2 leaves (BBCH 11-12) to the beginning of October, when plants reached full kernel maturity (BBCH 97), 2 random plants were sampled diagonally once a week from the field from 5 sites (10 plants in total). Maize plants packed in sealed bags were transported to a laboratory and inspected for the presence of thrips on all external plant parts, as well as in sheaths, under cob husks, on silk, between kernels and in tassels, including individual spikelets. All collected thrips were counted. The dates of first pest occurrence on plants, abundant occurrence, as well as the end of feeding on maize were identified.

RESULTS

In 2010-2012 the first thrips infested maize in mid-May, when plants had 2-3 leaves developed (BBCH 12-13). A rapid population expansion usually occurred in late June or early July and lasted to mid-August. A single population peak was identified during the Thysanoptera development on maize and it took place between the 11th to the 20th of July. Thrips ended feeding on maize in September or in early October (Table 1).

In 2010 and 2012 the seed dressings used for the control of frit fly larvae also significantly limited the number of thrips. The investigated non-selective insecticides effectively reduced the population of Thysanoptera for up to 4-6 weeks after the date of maize sowing. However, 2011 was an exception, and at that time no significant difference in the number of thrips between the control plots and the chemically treated plots were found (Tables 2-4).

Table 1. Dates of thrips occurrence on maize plants at different developmental stages, expressed using the BBCH scale

Year	Dates of thrips occurrence on maize plants			
	first occurrence	abundant occurrence	population peak	end of occurrence
2010	17 May [BBCH 13]	06 July-04 August [BBCH 33–73]	12 July [BBCH 51]	05 October [BBCH 89]
2011	17 May [BBCH 12]	29 July-02 August [BBCH 32–73]	20 July [BBCH 67]	15 September [BBCH 87]
2012	14 May [BBCH 12]	27 July-16 August [BBCH 19–83]	11 July [BBCH 51]	26 September [BBCH 89]

The analysis focused on the effectiveness of seed treatments demonstrated that products containing imidacloprid fully protected the plants against thrips for up to 4-5 weeks after maize sowing. As for the product containing methiocarb, it was most effective in the control of thrips up to 4 weeks after sowing, except in 2012 when as early as 3 weeks after sowing it showed only a 50% efficiency in protecting plants against the invading thrips (Tables 2-4).

The analysis of data from the 3-year-long study indicated that Couraze 350 FS in a dose of 595 grams of imidacloprid per 100 kg^{-1}of seeds was the most effective seed dressing for the protection of maize against thrips, while the weakest effects were obtained after the use of Mesurol 500 FS containing methiocarb. Seed treatment with Couraze 350 FS in a dose of 595 grams of imidacloprid per 100 kg of seeds provided at least moderate protection (60-80%) of maize against thrips for up to 6 weeks after sowing, while Mesurol 500 FS in a dose of 500 grams of methiocarb per 100 kg of seeds was effective for up to 5 weeks after sowing. The study demonstrated a significant reduction in the effectiveness of Mesurol 500 FS as early as in week 4 after sowing. Starting from week 7 after sowing, all investigated seed treatments no longer provided effective protection of maize against thrips. From that moment the population of thrips increased, both in the control plot, and on the plots where the tested insecticidal seed treatments were used (Table 5).

Table 2. Effectiveness of seed treatments used against Oscinella frit in the control of thrips on maize in 2010

Experimental treatment	Active ingredient	Dose of active ingredient g·100 kg^{-1} seeds	Mean number of thrips per plant in subsequent weeks after sowing						
			3	4	5	6	7	8	9
Untreated control	–	–	0.50 a	0.75 a	1.25 a	2.00 a	1.75 a	3.25 a	5.75 a
Gaucho 600 FS	imidacloprid	360.0	0.00 a	0.00 b	0.00 b	0.25 b	0.50 a	2.75 a	5.25 a
Couraze 350 FS	imidacloprid	385.0	0.00 a	0.00 b	0.00 b	0.50 b	1.00 a	3.25 a	6.25 a
Couraze 350 FS	imidacloprid	595.0	0.00 a	0.00 b	0.00 b	0.25 b	0.75 a	3.00 a	5.00 a
Mesurol 500 FS	methiocarb	500.0	0.00 a	0.00 b	0.25 b	0.75 b	1.00 a	3.50 a	6.00 a
			Effectiveness according to Abbott's formula, %						
Untreated control	–	–	–	–	–	–	–	–	–
Gaucho 600 FS	imidacloprid	360.0	100.0	100.0	100.0	87.5	71.4	15.4	8.7
Couraze 350 FS	imidacloprid	385.0	100.0	100.0	100.0	75.0	42.9	0.0	0.0
Couraze 350 FS	imidacloprid	595.0	100.0	100.0	100.0	87.5	57.1	7.7	13.0
Mesurol 500 FS	methiocarb	500.0	100.0	100.0	80.0	62.5	42.9	0.0	0.0

Means in columns followed by the same letter do not differ at 5% level of significance Student-Newman-Keuls test

Table 3. Effectiveness of seed treatments used against *Oscinella frit* in the control of thrips on maize in 2011

Experimental treatment	Active ingredient	Dose of active ingredient g·100 kg^{-1} seeds	Mean number of thrips per plant in subsequent weeks after sowing						
			3	4	5	6	7	8	9
Untreated control	–	–	0.25 a	0.50 a	1.00 a	2.75 a	6.25 a	11.75 a	17.25 a
Gaucho 600 FS	imidacloprid	360.0	0.00 a	0.00 a	0.25 a	1.00 a	3.75 a	7.25 a	13.50 a
Couraze 350 FS	imidacloprid	385.0	0.00 a	0.00 a	0.25 a	1.25 a	5.00 a	9.50 a	15.75 a
Couraze 350 FS	imidacloprid	595.0	0.00 a	0.00 a	0.00 a	0.75 a	3.25 a	7.25 a	13.25 a
Mesurol 500 FS	methiocarb	500.0	0.00 a	0.00 a	0.50 a	1.50 a	6.00 a	8.00 a	15.50 a
			Effectiveness according to Abbott's formula, %						
Untreated control	–	–	–	–	–	–	–	–	–
Gaucho 600 FS	imidacloprid	360.0	100.0	100.0	75.0	63.6	40.0	38.3	21.7
Couraze 350 FS	imidacloprid	385.0	100.0	100.0	75.0	54.5	20.0	19.1	8.7
Couraze 350 FS	imidacloprid	595.0	100.0	100.0	100.0	72.7	48.0	38.3	23.2
Mesurol 500 FS	methiocarb	500.0	100.0	100.0	50.0	45.5	4.0	31.9	10.1

Means in columns followed by the same letter do not differ at 5% level of significance Student-Newman-Keuls test

Table 4. Effectiveness of seed treatments used against *Oscinella frit* in the control of thrips on maize in 2012

Experimental treatment	Active ingredient	Dose of active ingredient g·100 kg^{-1} seeds	Mean number of thrips per plant in subsequent weeks after sowing						
			3	4	5	6	7	8	9
Untreated control	–	–	0.50 a	1.25 a	1.25 a	0.75 a	1.50 a	6.75 a	10.50 a
Gaucho 600 FS	imidacloprid	360.0	0.00 a	0.00 b	0.25 a	0.50 a	1.00 a	7.50 a	8.75 a
Couraze 350 FS	imidacloprid	385.0	0.00 a	0.00 b	0.50 a	0.25 a	1.25 a	5.50 a	11.50 a
Couraze 350 FS	imidacloprid	595.0	0.00 a	0.00 b	0.25 a	0.25 a	1.50 a	6.25 a	9.75 a
Mesurol 500 FS	methiocarb	500.0	0.25 a	0.25 b	0.50 a	0.75 a	1.00 a	7.50 a	11.25 a
			Effectiveness according to Abbott's formula, %						
Untreated control	–	–	–	–	–	–	–	–	–
Gaucho 600 FS	imidacloprid	360.0	100.0	100.0	80.0	33.3	33.3	0.0	16.7
Couraze 350 FS	imidacloprid	385.0	100.0	100.0	60.0	66.7	16.7	18.5	0.0
Couraze 350 FS	imidacloprid	595.0	100.0	100.0	80.0	66.7	0.0	7.4	7.1
Mesurol 500 FS	methiocarb	500.0	50.0	80.0	60.0	0.0	33.3	0.0	0.0

Means in columns followed by the same letter do not differ at 5% level of significance Student-Newman-Keuls test

Table 5. Effectiveness of seed treatments used against *Oscinella frit* in the control of thrips on maize (overall results for 2010-2012)

Experimental treatment	Active ingredient	Dose of active ingredient g·100 kg^{-1} seeds	Mean number of thrips per plant in subsequent weeks after sowing						
			3	4	5	6	7	8	9
Untreated control	–	–	0.42 a	0.83 a	1.17 a	1.83 a	3.17 a	7.25 a	11.17 a
Gaucho 600 FS	imidacloprid	360.0	0.00 b	0.00 b	0.17 bc	0.58 b	1.75 a	5.83 a	9.17 b
Couraze 350 FS	imidacloprid	385.0	0.00 b	0.00 b	0.25 bc	0.67 b	2.42 a	6.08 a	11.17 a
Couraze 350 FS	imidacloprid	595.0	0.00 b	0.00 b	0.08 c	0.42 b	1.83 a	5.50 a	9.33 b
Mesurol 500 FS	methiocarb	500.0	0.08 b	0.08 b	0.42 b	1.00 b	2.67 a	6.33 a	10.92 a
			Effectiveness according to Abbott's formula, %						
Untreated control	–	–	–	–	–	–	–	–	–
Gaucho 600 FS	imidacloprid	360.0	100.0	100.0	85.7	68.2	44.7	19.5	17.9
Couraze 350 FS	imidacloprid	385.0	100.0	100.0	78.6	63.6	23.7	16.1	0.0
Couraze 350 FS	imidacloprid	595.0	100.0	100.0	92.9	77.3	42.1	24.1	16.4
Mesurol 500 FS	methiocarb	500.0	80.0	90.0	64.3	45.5	15.8	12.6	2.2

Means in columns followed by the same letter do not differ at 5% level of significance Student-Newman-Keuls test

In the experiment with foliar insecticides the mean number of thrips on plants on all plots was estimated directly before treatments. There were no significant differences between the number of Thysanoptera on control plots and the plots to be treated with the investigated insecticides.

In the study years the spraying of plants with either insecticide provided full (100%) protection of plants against thrips, usually for up to 7 days (in 2010 and 2012), and sometimes for up to 14 days after treatment (in 2011). Moreover, in 2011 a high effectiveness of the used products (80%) was also observed on day 21 after treatment (Tables 6-8).

Table 6. Effectiveness of foliar insecticides used against *Oscinella frit* in the control of thrips on maize in 2010

Experimental treatment	Active ingredient	Dose of active ingredient g·ha^{-1}	Mean number of thrips per plant in subsequent days after treatment						
			0*	3	7	14	21	28	35
1	2	3	4	5	6	7	8	9	10
Untreated control	–	–	0.25 a	0.50 a	0.50 a	0.50 a	1.50 a	1.25 a	1.25 a
Karate Zeon 050 CS	lambda-cyhalothrin	5.0	0.25 a	0.00 a	0.00 a	0.25 a	1.25 a	1.50 a	1.00 a
Karate Zeon 050 CS	lambda-cyhalothrin	10.0	0.25 a	0.00 a	0.00 a	0.25 a	1.25 a	1.25 a	1.25 a
Proteus 110 OD	thiacloprid + deltamethrin	50.0 + 5.0	0.25 a	0.00 a	0.00 a	0.25 a	1.00 a	1.25 a	1.25 a

Table 6 cont.

1	2	3	4	5	6	7	8	9	10
			Effectiveness according to Abbott's formula, %						
Untreated control	–	–	–	–	–	–	–	–	–
Karate Zeon 050 CS	lambda-cyhalothrin	5.0	0.0	100.0	100.0	50.0	16.7	0.0	20.0
Karate Zeon 050 CS	lambda-cyhalothrin	10.0	0.0	100.0	100.0	50.0	16.7	0.0	0.0
Proteus 110 OD	thiacloprid + deltamethrin	50.0 + 5.0	0.0	100.0	100.0	50.0	33.3	0.0	0.0

* Mean number of thrips per plant on treatment day: 17.05.2010
Means in columns followed by the same letter do not differ at 5% level of significance Student-Newman-Keuls test

Table 7. Effectiveness of foliar insecticides used against *Oscinella frit* in the control of thrips on maize in 2011

Experimental treatment	Active ingredient	Dose of active ingredient $g \cdot ha^{-1}$	Mean number of thrips per plant in subsequent days after treatment						
			0*	3	7	14	21	28	35
Untreated control	–	–	0.25 a	0.25 a	0.25 a	0.50 a	1.25 a	4.00 a	6.50 a
Karate Zeon 050 CS	lambda-cyhalothrin	5.0	0.25 a	0.00 a	0.00 a	0.00 a	0.25 b	2.25 a	6.75 a
Karate Zeon 050 CS	lambda-cyhalothrin	10.0	0.25 a	0.00 a	0.00 a	0.00 a	0.25 b	3.00 a	5.25 a
Proteus 110 OD	thiacloprid + deltamethrin	50.0 + 5.0	0.25 a	0.00 a	0.00 a	0.00 a	0.25 b	2.50 a	5.50 a
			Effectiveness according to Abbott's formula, %						
Untreated control	–	–	–	–	–	–	–	–	–
Karate Zeon 050 CS	lambda-cyhalothrin	5.0	0.0	100.0	100.0	100.0	80.0	43.8	0.0
Karate Zeon 050 CS	lambda-cyhalothrin	10.0	0.0	100.0	100.0	100.0	80.0	25.0	19.2
Proteus 110 OD	thiacloprid + deltamethrin	50.0 + 5.0	0.0	100.0	100.0	100.0	80.0	37.5	15.4

* Mean number of thrips per plant on treatment day: 16.05.2011
Means in columns followed by the same letter do not differ at 5% level of significance Student-Newman-Keuls test

Table 8. Effectiveness of foliar insecticides used against *Oscinella fr*it in the control of thrips on maize in 2012

Experimental treatment	Active ingredient	Dose of active ingredient g·ha^{-1}	Mean number of thrips per plant in subsequent days after treatment						
			0*	3	7	14	21	28	35
Untreated control	–	–	0.25 a	0.50 a	0.75 a	1.50 a	1.25 a	1.00 a	1.50 a
Karate Zeon 050 CS	lambda-cyhalothrin	5.0	0.25 a	0.00 a	0.00 b	0.50 a	1.00 a	0.50 a	1.75 a
Karate Zeon 050 CS	lambda-cyhalothrin	10.0	0.25 a	0.00 a	0.00 b	0.25 a	0.75 a	1.00 a	2.00 a
Proteus 110 OD	thiacloprid + deltamethrin	50.0 + 5.0	0.25 a	0.00 a	0.00 b	0.25 a	1.00 a	0.75 a	1.25 a
			Effectiveness according to Abbott's formula, %						
Untreated control	–	–	–	–	–	–	–	–	–
Karate Zeon 050 CS	lambda-cyhalothrin	5.0	0.0	100.0	100.0	66.7	20.0	50.0	0.0
Karate Zeon 050 CS	lambda-cyhalothrin	10.0	0.0	100.0	100.0	83.3	40.0	0.0	0.0
Proteus 110 OD	thiacloprid + deltamethrin	50.0 + 5.0	0.0	100.0	100.0	83.3	20.0	25.0	16.7

* Mean number of thrips per plant on treatment day: 14.05.2012
Means in columns followed by the same letter do not differ at 5% level of significance Student-Newman-Keuls test

The analysis of data for the 3-year-long study demonstrated that non-selective insecticides containing lambda-cyhalothrin or a mixture of thiacloprid with deltamethrin used for the control of the frit fly were indirectly effective in limiting the number of thrips for up to 2 weeks after treatment. In the third week after plant spraying the insecticidal effect of the tested products on thrips reduced to a very low level. The number of thrips gradually increased on the control plot, and also on the chemically treated plots starting from the third week after treatment (Table 9).

Table 9. Effectiveness of foliar insecticides used against *Oscinella frit* in the control of thrips on maize (overall results for 2010-2012)

Experimental treatment	Active ingredient	Dose of active ingredient g·ha^{-1}	Mean number of thrips per plant in subsequent days after treatment						
			0*	3	7	14	21	28	35
1	2	3	4	5	6	7	8	9	10
Untreated control	–	–	0.25 a	0.42 a	0.50 a	0.83 a	1.33 a	2.08 a	3.08 a
Karate Zeon 050 CS	lambda-cyhalothrin	5.0	0.25 a	0.00 b	0.00 b	0.25 b	0.83 a	1.42 a	3.17 a
Karate Zeon 050 CS	lambda-cyhalothrin	10.0	0.25 a	0.00 b	0.00 b	0.17 b	0.75 a	1.75 a	2.83 a

Table 9 cont.

1	2	3	4	5	6	7	8	9	10
Proteus 110 OD	thiacloprid + deltamethrin	50.0 + 5.0	0.25 a	0.00 b	0.00 b	0.17 b	0.75 a	1.50 a	2.67 a
			Effectiveness according to Abbott's formula, %						
Untreated control	–	–	–	–	–	–	–	–	–
Karate Zeon 050 CS	lambda-cyhalothrin	5.0	0.0	100.0	100.0	70.0	37.5	32.0	0.0
Karate Zeon 050 CS	lambda-cyhalothrin	10.0	0.0	100.0	100.0	80.0	43.8	16.0	8.1
Proteus 110 OD	thiacloprid + deltamethrin	50.0 + 5.0	0.0	100.0	100.0	80.0	43.8	28.0	13.5

* Mean number of thrips per plant on treatment day
Means in columns followed by the same letter do not differ at 5% level of significance Student-Newman-Keuls test

DISCUSSION

Since the implementation of integrated pest management (IPM) in the European Union in 2014, a strong emphasis has been put not only on the use of selective products for the control of organisms harmful to plants, but also on a general reduction in pesticide use in agriculture (Meissle *et al.*, 2010).

In Poland, as well as in many other countries, the range of selective chemical insecticides approved for the protection of maize against pests is limited. Most available insecticides are broad-spectrum, non-selective products. Such insecticides, due to their non-selective activity, may influence not only target species, but also other non-target harmful organisms (occurring on the plants at the same time), neutral species, as well as useful entomofauna (Perfecto, 1990; Aktar *et al.*, 2009; Cloyd, 2012). In this case, it is reasonable to restrict the number of treatments by using non--selective insecticides during the growing season of maize, and at the same time to take advantage of their broad spectrum of activity on arthropods, in order to limit the number and harmfulness of more than one pest at a time by using a single chemical treatment.

Currently, in Poland, foliar insecticides for the protection of maize contain mainly non-selective active ingredients such as lambda-cyhalothrin, thiacloprid and deltamethrin (IOR, 2014). Insecticides containing these active ingredients may also indirectly affect other harmful insects coexisting on maize plants, such as thrips. Moreover, the recommendations on the chemical protection of maize against spring pests currently indicate one approved seed dressing containing methiocarb, which is intended to deter birds and reduce the harmfulness of the *Oscinella frit*. Until the end of 2013 it was also possible to use 3 seed dressings containing imidacloprid (used in the present study) to protect maize plants against click beetles (Elateridae), grubs (Melolonthinae), owlet moths (Noctuinae) and frit fly. However, the regulation of the European Commission of 24 May 2013 enforced, as of 1 December 2013, a two-year ban on the use of neonicotinoids: clothianidin, thiamethoxam and imidacloprid for the treatment of maize and oilseed rape seed material (European Commission, 2013). The ban on the use of imidacloprid for the treatment of maize seeds is still in force in Poland. However, dressings containing this active ingredient are approved, for example, for use in potato for the control of *Leptinotarsa decemlineata* (Say), Aphidoidea spp., Elateridae and Melolonthinae. Imidacloprid seed dressings are also used in Poland to protect sugar beet and fodder beet against *Atomaria linearis* (Stephens), *Chaetocnema concina* (Marsham), *Pegomyja hyosciami* Panz., *Aphis fabae* Scop. and against click beetles and grubs (IOR, 2014).

Currently in Poland there is no insecticide approved for the control of thrips on maize, and the economic injury level for this pest has not been established. Thrips are now controlled using only agrotechnical methods to prevent the increase in their population size. Methods recommended for farmers include mainly crop rotation, location of maize fields away from other host plants for thrips (mainly cereals and perennial grasses), as well as eradication of weeds on which this pest can develop (Bereś *et al.*, 2013a). Non-chemical methods used in other countries, e.g. the USA, are focused on the fact that cultivating nearby weedy areas before corn emerges will reduce the potential of a thrips problem when the weeds begin to dry out, keeping crop plants in good health and the protection of beneficial organisms (Godfrey *et al.*, 2011).

In Poland, non-chemical methods do not always allow for effective reduction in the number of thrips. In the last few years an increase in the thrips population has been observed, for example, in south-eastern Poland, which led researchers to investigate the suitability of various insecticides for the control of this pest. Such experiments rely on data from studies carried out to identify the dates of thrips occurrence on maize in order to establish the optimum date on which chemical treatments should be applied.

As demonstrated by the monitoring of thrips on chemically untreated plants, insects began to infest maize fields from mid-May, but their occurrence was abundant from not earlier than the end of June to mid-August. A single population peak was identified during pest development, and it took place between 11 and 20 July. The pests ended feeding on plants in late September or in early October. Our observations on the dates of Thysanoptera occurrence on maize are consistent with findings from studies by Lisowicz (1995) carried out in the same region of Poland on fodder maize, and studies by Bereś *et al.* (2013b) on sweet maize.

The control of frit fly on maize, both with insecticidal seed dressings and foliar insecticides, coincided with the time when thrips were just began to infest the plants, so the population of this pest on the control plot was small at this time. The present study demonstrates that seed dressings, especially those containing imidacloprid, effectively protected juvenile maize plants against the invasion of thrips, which, when migrating, can transmit *Fusarium* spores, and by feeding on maize facilitate their penetration into the plant tissues (Farrar and Davis, 1991; Osekre *et al.*, 2009). However, the investigated seed treatments had a relatively short insecticidal effect on Thysanoptera, and did not provide effective reduction in the population of the pest during the whole growing season of maize. The analysis of data from the 3-year-long study indicated that the high effectiveness of seed dressings containing imidacloprid and methiocarb usually lasted for no longer than 5 or 6 weeks after maize sowing, i.e. until the first half of June, while the significant increase in the population of thrips on maize was observed not earlier than at he end of June or the first ten days of July. As soon as the active ingredients ceased to produce an insecticidal effect, the number of thrips on chemically protected plots increased rapidly to the level observed on the control plots.

Lisowicz (1995) investigated the effects of seed dressings containing imidacloprid (Gaucho 70 WS), and also observed their high effectiveness in limiting the number of thrips during the initial period of plant growth. That author found that imidacloprid remained highly effective until the end of June, or early July in some cases, and after that time the population of thrips increased and no longer differed significantly from that in the control plot.

Other studies carried out by Lisowicz and Myślicki (2004) investigating the effects of seed dressings containing thiamethoxam (Cruiser 350 FS) and furathiocarb (Promet 400 CS) also showed good performance of these products in the control of thrips. The quoted researchers reported that furathiocarb seed treatment significantly reduced the number of thrips for two months, starting from the end of May, i.e. when the pests began infesting the maize field. Furathiocarb remained highly effective until mid-July. In contrast to that, thiamethoxam seed treatment limited the population of thrips for the whole period of maize growth, i.e. until early September. However, in our study we found no such long term insecticidal effect of imidacloprid or methiocarb on the population of Thysanoptera.

The significant effects of insecticidal seed treatments in limiting the invasion of some maize pests during spring were indicated in studies by other authors. In Catalonia, Pons and Albajes (2002) found imidacloprid as a seed treatment suitable for the control of, for example, the *Rhopalosiphum padi* L. aphid. In Poland, Sulewska *et al.* (2009) demonstrated the good effectiveness of imidacloprid, and the lower effectiveness of methiocarb used on maize fields in the control of frit fly larvae and caterpillars of the *Ostrinia nubilalis* Hbn. A study by Wilde *et al.*

(2004), carried out in Kansas, indicated the good suitability of seed dressings containing imidacloprid, thiamethoxam and clothianidin, as well as granular soil-applied insecticides containing tefluthrin and fipronil in the control of spring maize pests such as wireworm (*Melanotus cribulosus* LeConte), white grub (Phyllophaga spp.), flea beetle (*Epitrix cucumeris* Harris), chinch bug (*Blissus leucopterus leucopterus* Say), and southern corn leaf beetle (*Myochrous denticollis* Say).

Despite the identified temporary effectiveness of imidacloprid in the indirect control of thrips infesting maize, the future use of this active ingredient for the protection of maize against spring pests is still uncertain. This is associated with the controversial effect of neonicotinoids on honey bees and wild bees (Schnier *et al.*, 2003; Nguyen *et al.*, 2009; Lu *et al.*, 2014; Woodcock *et al.*, 2016), and studies are being initiated to find alternative methods of crop protection against pests (Furlan and Kreutzweiser, 2015).

Seed dressings containing imidacloprid for the control of frit fly can be replaced by foliar insecticides containing lambda-cyhalothrin and a mixture of thiacloprid with deltamethrin, which are used in late April or in May, when maize plants have 2-3 leaves developed (IOR, 2014). The active ingredients from the class of synthetic pyrethroids have a broad spectrum of activity on arthropods, and are used worldwide to control different pest species, including thrips (Thatheyus and Deborah Gnana Selvam, 2013).

In our study we also found that foliar insecticides, similar to seed treatments, used for the control of *O. frit* provided indirect control of thrips. In addition, the temporary insecticidal effect of the active ingredients was observed. The analysis of data from the 3-year-long study demonstrated that the used insecticides were most effective in the control of Thysanoptera for 2 weeks after treatment. From the end of June no significant differences were found between control plots and plots treated with chemical agents. This means that the insecticidal effect of the used products ended before the abundant occurrence of thrips on maize.

The available literature provides no information on the indirect effects of insecticides used against *O. frit* on thrips. Similar studies were carried out by Lisowicz (1995), who applied an insecticide containing lambda-cyhalothrin (Karate 025 EC) to control aphids in the last ten days of June and found that this treatment also indirectly controlled thrips feeding on maize. However, as Lisowicz (1995) reported, a single spraying of plants with the investigated insecticide reduced the number of thrips for a very short time (several days), after which the population of the pest recovered. Apart from maize fields, synthetic pyrethroids, including lambda-cyhalothrin are being used for the control of thrips, mainly *Frankliniella tritici* (Fitch) on cotton in Florida. The use of this insecticide reduced the population of adult thrips by 20-90%, depending on the number of treatments (10-28 sprayings). It was also found that this pesticide had no significant effect on the population of *Orius insidiosus* Say, a natural enemy of thrips (Mailhot *et al.*, 2007b). Additionally, deltamethrin has been reported to be useful in the control of *Thrips tabaci* Lindeman on early white cabbage (Trdan *et al.*, 2007).

The widespread use of synthetic pyrethroids by farmers may, however, increase the resistance of thrips to insecticides, which has already been reported for *Thrips tabaci* (Lind.) and *Frankliniella occidentalis* (Per.) feeding on different crops (Reitz and Funderburk, 2012).

CONCLUSIONS

1. Thrips infested plants for almost the whole period of maize growth, i.e. from mid-May to the first ten days of October, with a single population peak in July.
2. Seed dressings containing imidacloprid and methiocarb, as well as foliar insecticides containing lambda-cyhalothrin and a mixture of thiacloprid with deltamethrin used for the control of the frit fly had an indirect insecticidal effect on the population of thrips that began infesting maize in the spring.
3. The tested insecticides effectively limited the population of thrips only in the early stages of pest development on maize. Their strong insecticidal effect usually ceased in mid-June, which was before the abundant occurrence of thrips on maize.
4. None of the tested insecticides allowed for a permanent reduction in the number of thrips throughout the growing season of maize. Therefore, in the context of a potential reduction in pesticide use, the control of frit fly and the effective control of thrips cannot be combined. The two pests have to be controlled separately.

5. In order to limit thrips populations on maize, appropriate insecticides must be registered. It is also necessary to start research on economic thresholds for thrips feeding on maize.

REFERENCES

Aktar, W., Sengupta, D., Chowdhury, A. (2009). Impact of pesticide use in agriculture: their benefits and hazards. Interdiscip. Toxicol., 2(1), 1–12.

Bereś, P.K., Korbas, M., Michalski, T., Gaj, R., Wachowiak, M., Siódmiak, J., Paradowski, A. (2013a). Integrowana ochrona kukurydzy. In: M. Mrówczyński (ed.), Integrowana ochrona upraw rolniczych. Tom 2. Zastosowanie integrowanej ochrony. Poznań: Państwowe Wydawnictwo Rolnicze i Leśne, 83–155.

Bereś, P.K., Kucharczyk, H., Kucharczyk, M. (2013b). Thrips abundance on sweet corn in southeastern Poland and the impact of weather conditions on their population dynamics. Bull. Insectology, 66(1), 143–152.

Bereś, P.K., Pruszyński, G. (2008). Ochrona kukurydzy przed szkodnikami w produkcji integrowanej. Acta Sci. Pol. Agricultura, 7(4), 19–32.

Cloyd, R.A. (2012). Indirect effects of pesticides on natural enemies. In: R.P. Soundararajan (ed.), Pesticides – advances in chemical and botanical pesticides. Rijeka: InTech, Croatia, 127–150.

European Commission (2013). Commission Implementing Regulation (EU) No 485/2013 of 24 May 2013 amending Implementing Regulation (EU) No 540/ 2011, as regards the conditions of approval of the active substances clothianidin, thiamethoxam and imidacloprid, and prohibiting the use and sale of seeds treated with plant protection products containing those active substances. Off. J. Eur. Union, L 139, 12–26.

Farrar, J.J., Davis, R.M. (1991). Relationships among ear morphology, Western flower thrips, and Fusarium ear rot of corn. Phytopathology, 81, 661–666.

Furlan, L., Kreutzweiser, D. (2015). Alternatives to neonicotinoid insecticides for pest control: case studies in agriculture and forestry. Environ. Sci. Pollut. Res., 22, 135–147.

Godfrey, L.D., Wright, S.D., Summers, C.G. Frate, C.A. (2011). Insects and Mites, 3-21. In: UC IPM Pest Management Guidelines: Corn. University of California, UC ANR Publication 3443.

GUS (2013). Results of plant production in 2012. Warsaw: Główny Urząd Statystyczny.

GUS (2014). Results of plant production in 2013. Warsaw: Główny Urząd Statystyczny.

GUS (2015). Results of plant production in 2014. Warsaw: Główny Urząd Statystyczny.

IOR (2014). Zalecenia ochrony roślin na lata 2014/15 dotyczące zwalczania chorób, szkodników oraz chwastów. Część II. Rośliny rolnicze. Poznań: Instytut Ochrony Roślin – PIB.

Kucharczyk, H., Bereś, P.K., Dąbrowski, Z.T. (2011). The species composition and seasonal dynamics of thrips (Thysanoptera) populations on maize (*Zea mays* L.) in southeastern Poland. J. Plant Prot. Res., 51(3), 210–216.

Lisowicz, F. (1984). Noxiousness of frit fly (*Oscinella frit* L.) to corn in Poland. Z. Pflanzenkr. Pfianzenschutz,, 91(4), 431–437.

Lisowicz, F. (1995). Teoretyczne i praktyczne podstawy zastosowania metod integrowanych w ochronie kukurydzy przed szkodnikami. Prace Naukowe Instytutu Ochrony Roślin, 36(1–2), 5–46.

Lisowicz, F. (2001). The occurrence of economically important corn pests in south-eastern Poland. J. Plant Prot. Res., 41(3), 250-255.

Lisowicz, F., Myślicki, M. (2004). Przydatność zaprawy Cruiser 350 FS w ochronie kukurydzy przed szkodnikami. Prog. Plant Prot./Post. Ochr. Roślin, 44(2), 915–917.

Lisowicz, F., Tekiela, A. (2004). Szkodniki i choroby kukurydzy oraz ich zwalczanie. In A. Dubas (ed.), Technologia uprawy kukurydzy. Warsaw: Wieś Jutra, 52–64.

Lu, C., Warchol, K.M., Callahan, C.A. (2014). Sub-lethal exposure to neonicotinoids impaired honey bees winterization before proceeding to colony collapse disorder. Bull. Insectology, 67(1), 125–130.

Mailhot, D.J., Marois, J.J., Wright, D.L. (2007a). Influence of flower thrips on Fusarium hardlock severity. Plant Disease, 91, 1423–1429.

Mailhot, D., Marois, J., Wright, D. (2007b). Arthropod management and applied ecology. Species of thrips associated with cotton flowers. J. Cotton Sci., 11, 186– –198.

Meier, U. (1997). Growth stages of mono-and dicotyledonous plants: BBCH Monograph. Berlin: Blackwell Wissenschafts--Verlag, 622.

Meissle, M., Mouron, P., Musa, T., Bigler, F., Pons, X., *et al*. (2010). Pests, pesticide use and alternative options in European maize production: current status and future prospects. J. Appl. Entomol., 134, 357–375.

Nguyen, B.K., Saegerman, C., Pirard, C., Mignon, J., Widart, J., *et al*. (2009). Does imidacloprid seed-treated maize have an impact on honey bee mortality? J. Econ. Entomol., 102(2), 616–623.

Osekre, E.A., Wright, D.L., Marois, J.J., Funderburk, J. (2009). Flower-inhabiting *Frankliniella* thrips (Thysanoptera: Thripidae), pesticides, and Fusarium hardlock in cotton. J. Econ. Entomol., 102(3), 887–896.

Parikka, P., Hakala, K., Tiilikkala, K. (2012). Expected shifts in Fusarium species' composition on cereal grain in Northern Europe due to climatic change. Food Addit. Contam., Part A 29, 1543–1555.

Perfecto, I. (1990). Indirect and direct effects in a tropical agroecosystem: the maize-pest-ant system in Nicaragua. Ecology, 71(6), 2125–2134.

Parsons, M.W., Munkvold, G.P. (2010). Relationships of immature and adult thrips with silk-cut, Fusarium ear rot and fumonisin B1 contamination of corn in California and Hawaii. Plant Pathology, 59(6), 1099–1106.

Pons, X., Albajes, R. (2002). Control of maize pests with imidacloprid seed dressing treatment in Catalonia (NE Iberian Peninsula) under traditional crop conditions. Crop Protection, 21, 943–950.

Ptaszyńska, G., Sulewska, H. (2007). Influence of weather conditions on maize infeststion by fungus *Ustilago zeae* Unger. Prog. Plant Prot./Post. Ochr. Roślin, 47(2), 280–283.

Ranum, P., Peña-Rosas, J.P., Garcia-Casal, M.N. (2014). Global maize production, utilization, and consumption. Ann. New York Acad. Sci., 1312, 105–112.

Reitz, S.R., Funderburk, J. (2012). Management strategies for western flower thrips and the role of insecticides. In: F. Perveen (ed.), Insecticides – Pest Engineering (Ed.). InTech Europe, Croatia, 355–384.

Rüdelsheim, P.L.J., Smets, G. (2011). Baseline information on agricultural practices in the EU maize (*Zea mays* L.). [online] URL: http://www.europabio.org/sites/default/files/report/120702_report_eu_farming_practices_maize.pdf (accessed: 01 July 2016).

Schnier, H.F., Wenig, G., Laubert, F., Simon, V., Schmuck, R. (2003). Honey bee safety of imidacloprid corn seed treatment. Bull. Insectology, 56(1), 73–75.

Sulewska, H., Szymańska, G., Panasiewicz, K. (2009). Ocena skuteczności zapraw insektycydowych stosowanych w kukurydzy. Prog. Plant Prot./Post. Ochr. Roślin, 49(1), 150–153.

StatSoft (2010). Statistica data analysis software system, version 10. Tulsa: StatSoft Inc., USA.

Thatheyus, A.J., Deborah Gnana Selvam, A. (2013). Synthetic pyrethroids: toxicity and biodegradation. Appl. Ecol. Environ. Sci., 1(3), 33–36.

Trdan, S., Valič, N., Žnidarčič, D. (2007). Field efficacy of deltamethrin in reducing damage caused by *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) on early white cabbage. J. Pest Sci., 80(4), 217–223.

Wilde, G., Roozeboom, K., Claassen, M., Janssen, K., Witt, M. (2004). Seed treatment for control of early-season pests of corn and its effect on yield. J. Agr. Urban Entomol., 21(2), 75–85.

Woodcock, B.A., Isaac, N.J.B., Bullock, J.M., Roy, D.B., Garthwaite, D.G., Crowe, A. and Pywell, R.F. (2016). Impacts of neonicotinoid use on long-term population changes in wild bees in England. Nature Communications, 7, 12459.

Zhao, M., Ho, H., Wu, Y., He, Y. and Li, M. (2014). Western flower thrips (*Frankliniella occidentalis*) transmits Maize chlorotic mottle virus. J. Phytopathol., 162, 532–536.

WPŁYW ZAPRAW NASIENNYCH I INSEKTYCYDÓW NALISTNYCH STOSOWANYCH W KUKURYDZY PRZECIWKO *Oscinella frit* L. NA LICZEBNOŚĆ WCIORNASTKÓW

Streszczenie

Wciornastki należą do grupy powszechnie występujących szkodników kukurydzy w Polsce. Choć w ostatnich latach wzrosła ich liczebność i szkodliwość na polach kukurydzy, to nie są objęte zwalczaniem chemicznym z powodu braku zarejestrowanych insektycydów. W związku z tym w latach 2010-2012 w południowo-wschodniej Polsce wykonano badania, których celem było sprawdzenie, czy nieselektywne zaprawy nasienne i insektycydy nalistne stosowane w okresie wiosennym do zwalczania ploniarki zbożówki (*Oscinella frit* L.) mogą pośrednio redukować również liczebność wciornastków bez konieczności ich odrębnego zwalczania. W doświadczeniu wykorzystano zaprawy nasienne zawierające imidachlopryd (Gaucho 600 FS oraz Couraze 350 FS) oraz metiokarb (Mesurol 500 FS), a także insektycydy nalistne zawierające lambda-cyhalotrynę (Karate Zeon 050 CS) oraz mieszaninę tiachloprydu i deltametryny (Proteus 110 OD). W latach badań wciornastki zasiedlały kukurydzę od połowy maja do pierwszej dekady października. Okres ich najliczniejszego występowania przypadał od końca czerwca do połowy sierpnia, z jednym szczytem liczebności przypadającym pomiędzy 11 a 20 lipca. Wszystkie badane insektycydy stosowane wiosną przeciwko *O. frit* wykazały pośrednie oddziaływanie owadobójcze na wciornastki.

Najwyższą skuteczność zapraw nasiennych oraz preparatów nalistnych obserwowano do połowy czerwca, co nie pozwalało skutecznie zabezpieczyć roślin kukurydzy przed żerowaniem wciornastków. Owadobójcze oddziaływanie badanych insektycydów zakończyło się przed licznym pojawem wciornastków, stąd też owady te muszą być zwalczane oddzielnie zabiegami chemicznymi wykonywanymi w późniejszym czasie.

Słowa kluczowe: ochrona chemiczna, skuteczność, Thysanoptera, występowanie, *Zea mays*