Original article

Efficacy of spirotetramat for control of blackcurrant leaf midge *Dasineura tetensi* (Rübs.), its effects on phytoseiid predatory mites and residues in fruits

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Summary

The blackcurrant leaf midge *Dasineura tetensi* is an important pest in young blackcurrant plantations as well as nurseries. Its larvae cause curling and twisting of young leaves into a distinctive leaf galls, older galls becoming necrotic. In established crops, infestation with larvae reduces bush vigour, killing out terminals and causing a proliferation of side shoots from lateral buds. In mother plantations, *D. tetensi* attack may cause up to 60% reduction in the growth of shoots, and in the nurseries the infested plants are weakened and do not grow to a suitable size. The objective of the work reported here was to evaluate the efficacy of spirotetramat for control of *D. tetensi*, its effects, on phytoseiid predatory mite populations and residues in blackcurrant fruits.

Between 2012 and 2014 four field experiments were conducted in commercial blackcurrant plantations comparing three programs of spirotetramat with two reference active ingredients, thiacloprid and lambda cyhalothrin, and untreated controls. All of the products were applied once or twice against the 1st or the 1st and 2nd generations of the pest. Furthermore, the effects of the programs on phytoseiid predatory mites and the residues of spirotetramat in blackcurrant fruits were checked. The spirotetramat treatment applied once against the 1st pest generation gave 90.3–100% control of larvae of that generation, which then resulted in a 79.5–100% reduction in the 2nd generation larvae. Two treatments of spirotetramat used at the dosages 0.45 and 0.75 L ha⁻¹ reduced larvae of *D. tetensi* by 87.1–100% and 96.8–100%, respectively, and its effectiveness was similar to that obtained with lambda cyhalothrin (88.0–100%) and higher than the thiacloprid treatment (34.4–85.2%). One application of spirotetramat resulted in a 24.2–35.0% reduction in phytoseiid mites approximately three weeks after treatment. Two applications of this active substance at the dosages 0.45 and 0.75 L ha⁻¹ reduced the number of phytoseiids by 33.3–66.7% and 57.6–77.4%, respectively. Thiacloprid or lambda cyhalothrin were less selective than spirotetramat and reduced the population of phytoseiid mites by 82.8–95.0% and 77.4–97.0%, respectively, one week after each treatment. Spirotetramat gave residues well below maximum residue levels (MRLs).

Significance of this study

What is already known on this subject?

- Blackcurrant leaf midge is an important pest of young blackcurrant plantations and nurseries, but there is no effective and safe (for beneficial insects) product for controlling it in the blackcurrant plant protection program.

What are the new findings?

- A new and effective control program for blackcurrant leaf midge utilising spirotetramat was developed. Effects on phytoseiid predatory mite populations were reduced in comparison with reference materials lambda cyhalothrin and thiacloprid and residue levels of the active ingredient and its metabolites in blackcurrant fruits were well below Maximum Residue Levels.

What is the expected impact on horticulture?

- The research has implications for better management of the blackcurrant leaf midge with less environmental contamination with pesticides. One application of spirotetramat is enough to control both the 1st and 2nd pest generations, while with neonicotinoids one application is needed for each pest generation. In addition, after spirotetramat use there will be less of a problem with spider mites, because this active substance is a selective spider mite acaricide, which is safer to naturally occurring phytoseiid predatory mites. After registration of spirotetramat in blackcurrant it will be possible to control the pest using spirotetramat which is from another chemical group, reducing the risk of the development of pesticide resistance.

Keywords

blackcurrant, *Dasineura tetensi*, lambda cyhalothrin, phytoseiid mites, spirotetramat, thiacloprid

Introduction

Blackcurrant (*Ribes nigrum* L.) is an important fruit crop (Brennan, 2008). It is widely cultivated in the temperate climate zone of Europe, Russia, New Zealand and parts of Asia (Mitchell et al., 2011; Vagiri, 2012). Poland is a world leader in the production of this fruit species (Pluta et al., 2012).

The berries are used for large-scale production of fruit juices, jams, jellies and syrups (Liu et al., 2014). Blackcurrant fruits are rich in antioxidants, including vitamin C, and they contain many beneficial phenolic compounds (Brennan, 2008; Szajdek and Borowska, 2008).

Blackcurrant leaf midge, *Dasineura tetensi* Rübs. (Diptera: Cecidomyiidae) is a common blackcurrant pest in Poland, Europe and New Zealand (Łabanowska, 1981, 2013; Mitchell et al., 2011; Cross et al., 2016; Piotrowski et al., 2016). The larvae are the most noticeable stage of this pest, which are transparent when they are small, but change to white as they mature, and which feed gregariously within the shelter of young furled leaf galls at the shoot tips (Cross and Crook, 1999). Larval saliva contains enzymes, which cause dissolution of the tissue on the upper side of the leaf, such liquid food being suitable for them (Łabanowska, 2013). Depending on the number of infesting larvae, part or the whole of the leaf becomes folded and twisted into a distinctive leaf gall, older galls becoming necrotic. Several adjacent leaves on a shoot may be galled, strong, vigorous shoots being most likely to be attacked (Łabanowska, 1983; Alford, 2007; Cross et al., 2016). The first signs of colonization can be spotted on the lowest buds at the base of the bush that are the earliest to break in the spring. The base parts of the bush are close to the soil, thus offering better protection against wind and more favourable conditions for leaf midge development (Cross and Crook, 1999).

There are, depending on climatic conditions, 2–4 generations of the pest a year, with the first generation oviposition occurring about the time of blackcurrant flowering, depending on season and variety (Łabanowska, 1983; Crook et al., 2001; Hellqvist, 2001a, b). The first pest generation flight and start of emergence of the second generation flight are distinct, but later generations may overlap (Łabanowska, 1983; Keep, 1985; Hellqvist and Larsson, 1998). This pest overwinters as larvae in cocoons in the soil, which pupate in early spring (Łabanowska, 1983; Cross et al., 2016).

In established crops, infestation with blackcurrant leaf midge larvae reduces bush vigour, killing out terminals and causing a proliferation of side shoots from lateral buds (Alford, 2007; Łabanowska, 2013). Galling damage also has a significant effect on photosynthesis of blackcurrant bushes, because the assimilation area of leaves is reduced (Cross and Crook, 1999). Although the malformed leaves look unattractive, the established bushes can counteract the damage by growing extra shoots and therefore control is less important than in the case of seedlings (Łabanowska et al., 1984; Hellqvist, 2005; Mitchell et al., 2011). The actual effect of this pest on blackcurrant yield and growth has been assessed recently by Cross et al. (2016), where the insecticides sprays did not result in significant increases in yield or growth in established commercial plantations, but the average age of plantations in this work was more than eight years. However, the work showed that control in re-growing cut-down plantations (and by analogy in new establishing plantations) is vital. Łabanowska et al. (1984) reported that in mother plantations, *D. tetensi* attack may cause up to 60% reduction in the growth of shoots, and in the nurseries the infested plants are weakened and do not grow to a suitable size. To conclude, the blackcurrant leaf midge seems to be the most damaging to young establishing plants where severe infestation can lead to serious reductions and weakening of shoots growth or even complete destruction of the crop (Mitchell et al., 2011).

Differences in the susceptibility of blackcurrant cultivars

to leaf midge colonization have been shown by Greenslade (1941), Keep (1985) and North (1967). Different manifestations of antibiosis resistance were observed in different genotypes, from no gall formation and high larval mortality, to complete galling and delayed larval development. Resistance is controlled by a dominant gene, *Dt*, identified in *Ribes dikuscha* (Keep, 1985). Two strains of *D. tetensi* have been recorded in Sweden (Hellqvist, 2001a): a virulent strain, which adapted to the resistant host and an avirulent strain that has not. The first strain was found on the susceptible host and appeared to perform equally well as the avirulent strain. The virulent strain is dominant despite most of the blackcurrant cultivars grown having a susceptible genotype. These results suggest that it is not possible to rely on the use of resistant cultivars but that other control methods are required. The susceptibility assessment of blackcurrant cultivars commercially grown in Poland by the midge has been made recently by Piotrowski et al. (2016), where all of the 11 cultivars were colonized by the pest. In Poland, blackcurrant leaf midge was a serious, damaging pest in the 1970s and 1980s (Łabanowska, 1983). It was common in mother plantations, in nurseries and in commercial plantations (Łabanowska and Iwanek, 1983). When broad-spectrum insecticides (e.g., fenitrothion, dichlorvos, diazinon, etc.) were introduced, this pest ceased to be of economic interest for many years (Łabanowska et al., 1984). After the withdrawal of the last organophosphate agents from the blackcurrant plant protection program in 2007, populations of blackcurrant leaf midge increased again.

In the past, the monitoring of *D. tetensi* (adult) was carried out by the Research Institute of Horticulture using special cages trimmed with chiffon, which were deployed on the soil at the base of the bushes. However, such monitoring method was too difficult for growers and was not implemented in practice (B.H. Łabanowska, pers. commun.). A much simpler method of pest monitoring and scheduling spraying is the use of sex pheromone traps (Amarawardana, 2009). However, such technology is only available to UK growers, who funded the development of the pheromone (R. Saunders, GlaxoSmithKline, pers. commun.). Because Polish blackcurrant growers do not have access to the sex pheromone traps, they control the pest by two insecticide sprays (one for each generation), based on the appearance of first leaf damage in shoot tips and observation of larvae in curled (youngest) leaves. A threshold level of 10% of shoots tips damaged with larvae present in galls is used. Usually in Poland, the first generation of the pest occurs shortly after flowering (first half of May), and the second in June or beginning of July.

Up to 2014, Polish blackcurrant growers could use only synthetic pyrethroid (SP) insecticides including lambda cyhalothrin and cypermethrin for control *D. tetensi* (a maximum of 2 applications of each active substance was permitted per season). The neonicotinoid insecticides thiacloprid and acetamiprid have been registered since 2013 and 2014, respectively, for control the pest (a maximum of 2 applications of each active substance is permitted per season). However, the SP insecticides were more effective than neonicotinoids, but have been withdrawn from use in 2014. The reason for the withdrawal of approval of the SPs was their harmful effects on the midge's key natural enemies including the parasitoid *Platygaster demades* Walker and anthocorid predatory bugs, which are listed as the most important natural enemies by Mitchell et al. (2011). Commercial neonicotinoid insecticides containing thiacloprid and acetamiprid which are routine-

ly used in blackcurrant for control currant clearwing moth (*Synanthedon tipuliformis* Clerck.), blackcurrant stem midge (*Resseliella ribis* Marik.) and aphids, e.g., currant blister aphid (*Crytomyzus ribis* L.) could also be withdrawn from market, because of concerns about toxicity to honey bees (Mullin et al., 2010; Brandt et al., 2016).

Studies on the use of spirotetramat (lipid biosynthesis inhibition) for control of some important pests of blackcurrant, e.g., blackcurrant gall mite (*Cecidophyopsis ribis* Westw.), aphids (Aphididae), and two-spotted spider mite (*Tetranychus urticae* Koch) have already been done. The spirotetramat product Movento 100 SC at the dosage of 0.75 L ha⁻¹, once immediately after flowering of blackcurrants, reduced the number of buds damaged by *Cecidophyopsis ribis* by 76.9–79.6% (data not yet published). Movento 100 SC at the dosage of 0.7 or 1.0 L ha⁻¹ applied once just after blackcurrant flowering showed very high efficiency (after 3 weeks 98.7–100%) in controlling aphids (Łabanowska et al., 2013). Spirotetra-

mat (Movento 100 SC, 0.75 L ha⁻¹) applied after blackcurrant blossom provided also very good control of *T. urticae*, efficacy of control from 98.4 to 99.0% during a 2- and 3-weeks period of observations being achieved. On plants treated with spirotetramat, the population of *T. urticae* was very low even 5 weeks after spraying (Łabanowska et al., 2017).

Several chemicals can be effective against *D. tetensi*, but not all are approved for use on blackcurrant. Ideally, modern crop protection agents should be effective in the control of more than one pest species and be of low toxicity to beneficial predatory species in order to be used in IPM systems (Cuthbertson, 2004; Cuthbertson et al., 2014). On blackcurrant crops in Poland several species of phytoseiid predatory mites can occur: *Amblyseius andersoni* Chant., *Amblyseius bryophilus* Karg, *Typhlodromus pyri* Scheut., *Neoseiulus fallacis* Garman, *Euseius finlandicus* Oudemans, *Phytoseius macropilis* Banks, *Typhlodromus rhenanus* Oudemans and *Amblyseius huron* Chant et Chansel (Niemczyk, 2000a). However,

FIGURE 1. Damaged tips of the shoots with young (small transparent) larvae of *D. tetensi*.

Typhlodromus pyri is the most frequently occurring species exploited for biocontrol of phytophagous mites in northern and central Europe in Integrated Pest Management (IPM) programs (Sengonca et al., 1994; Solomon et al., 2000; Niemczyk, 2000b; Praslicka et al., 2011). The population of phytoseiid mites on blackcurrant in Poland is at a low level before flowering. During or after flowering populations increase and the highest occurrence of the predators is from the second half of July to the end of August (Niemczyk, 2000a; Łabanowska, 2013). The predator population is affected by pesticides used in spray programs to control pests, diseases and weeds (Fountain and Medd, 2015). Pesticides are commonly rated based on toxicity tests in accordance with the guidelines of the International Organization for Biological and Integrated Control (IOBC) Working Group on Pesticides and Beneficial Organisms (Hassan, 1985).

Considering the above concerns, here we report work which evaluated the efficacy of spirotetramat for control of *D. tetensi* in young blackcurrant plantations in Poland to identify more effective treatments which are less harmful to beneficial predatory species, with residues in blackcurrant fruits below maximum residue levels for use by growers in Integrated Pest Management (IPM) programs.

Materials and methods

Experimental plots

In the period 2012–2014 four field experiments were conducted by the Research Institute of Horticulture (RIH) in Skierniewice. Commercial plantations were rented from growers, and localized in central Poland in Zglinna Mała, 51°51'35.7"N, 20°11'31.7"E (2012); Zglinna Duża, 51°50'18.7"N, 20°11'44.5"E (2013); Kazimierzów, 51°51'23.4"N, 20°12'14.4"E (2013); and Stara Rawa, 51°53'21.3"N, 20°16'07.2"E (2014). Three to four year-old blackcurrant plantations of the quite strongly growing Polish cultivar 'Tisel' ('Titania' × self-pollinated) were chosen for this study. Randomized complete block experimental designs with five pesticide treatments, an untreated control and with four replicates were used. Each plot comprised one row of bushes 10.0 m in length, the middle 8.0 m being used for assessments leaving a 1.0 m guard at the end of each plot. In additional one guard row on each side was provided. The row spacing was approximately 4.0 m and the plants were spaced 0.5 m apart in the row. The bushes had a height of about 1.0 m. The plantations all received normal overall fungicide spray programs for diseases control, which were effective. The plantations had no irrigation or fertigation systems.

Treatments

The plantations were inspected visually twice per week to check for pests and diseases during the whole growing season. Spray treatments were applied when damage to the tips of the shoots was first observed (Figure 1) with young (small transparent) larvae of *D. tetensi* and the threshold level (10% damaged shoot tips) was exceeded. Spirotetramat as the insecticide Movento 100 SC at the rates 0.45 L and 0.75 L ha⁻¹ was used twice (against 1st and 2nd generation) in all years of the investigation. A treatment with spirotetramat applied only once against the 1st generation was included to check for length of action and effects of 1st generation applications on the 2nd generation. The insecticides thiacloprid (Calypso 480 SC, at a rate of 0.2 L product ha⁻¹) and lambda cyhalothrin (Karate Zeon 050 CS, at a rate of 0.15 L product ha⁻¹) were used twice as standard control products. All products used in the trials were

applied via a motorized knapsack sprayer (Stihl SR 430) with air-assistance at a spray volume of 500 L ha⁻¹. Sprays were applied to both sides of the row, to ensure uniformity of cover. On each assessment occasion, all of the bushes were carefully inspected for visual symptoms of phytotoxicity. The treatment data are shown in Tables 1–5.

Sampling

The counts were made of the numbers of galls per plot (100 shoots in each plot) in situ by RIH staff. Four plots were used for each treatment (400 shoots/treatment). The blackcurrant leaf midge population (larvae and egg) density was estimated in the lab before the first treatment. Treatment efficacy was assessed one week following each treatments, and three weeks after the second treatment. Samples of 25 of the shoots were taken randomly from each plot (100 shoots/treatment), on each sampling date to the lab. Larvae and eggs were viewed and counted under a stereo microscope. The upper and lower surface of each curled leaf were examined. The study was conducted in accordance with Good Experimental Practice according to EPP0 PP 2/26 (1) guidelines for *Ribes* and *Rubus* crops. In addition, on the same sampling dates, samples of 25 of the mature leaves were taken randomly from each plot (100 leaves/treatment) to the lab. Mobile forms of phytoseiids were viewed and counted using a stereo microscope. The upper and lower surface of each leaf was examined.

Furthermore, in each year of the study, when blackcurrant fruits reached collective maturity (just before harvest), fruits (1.0 kg) from each plot treated once by Movento 100 SC (0.75 L ha⁻¹) were collected randomly for testing residues (spirotetramat and its metabolites). Fruits were collected only from these plots due to limited financial resources and because the parent company, Bayer Ltd., intends to register spirotetramat in blackcurrant for use as a single application after blossom. The analysis was conducted at the Food Safety Laboratory, Research Institute of Horticulture, Skierniewice, Poland (Accreditation No. AB 757).

Statistical analysis

Data were analysed statistically by ANOVA in the Statistica 13.1 program. Multiple comparisons of means were performed with Newman-Keuls tests at $P \leq 0.05\%$. The numerical data were $\log_{10}(x+1)$ transformed, where x is number of galls/larvae/eggs/phytoseiids found in each sample of 100 or 25 shoots and 25 leaves. Means (in the Tables) that do not differ significantly are marked with the same letters. In addition, values of F , P and standard errors (SE) were calculated.

Efficacy

The efficacy of treatments was calculated according to Abbott's formula: $[(A-B)/A] \times 100\%$, where A = total number of galls/larvae/eggs/phytoseiids in untreated control and B = total number of galls/larvae/eggs/phytoseiids on treated plants (Abbott, 1925).

Results

The respective mean values from experiments I to IV for the numbers of *D. tetensi* one day before first sprays were 0.12, 0.13, 0.14, 0.13 galls per shoot, 7.2, 7.2, 6.9, 6.3 larvae per gall, and 1.6, 0.5, 0.6, 1.7 eggs per gall. However, in all experiments there was no significant difference between treatments for all these variates before the sprays were applied (data not shown). Furthermore, there were no phytoseiid mites on the leaves at that observation date (data also not shown).

TABLE 1. Results of blackcurrant leaf midge (*Dasineura tetensi*) control by insecticides. Trial 1, 2012 (Zglinna Mała).

Treatment	Product dose rate (L ha ⁻¹)	No. sprays	Observation dates									
			7 days after 1 st treatment (1 st gen.)					7 days after 2 nd treatment (2 nd gen.)				
			No. galls/shoot [Efficacy %]	No. larvae/gall [Efficacy %]	No. eggs/gall [Efficacy %]	No. galls/shoot [Efficacy %]	No. larvae/gall [Efficacy %]	No. eggs/gall [Efficacy %]	No. galls/shoot [Efficacy %]	No. larvae/gall [Efficacy %]	No. eggs/gall [Efficacy %]	21 days after 2 nd treatment (2 nd gen.) 29 June
Untreated	–	–	0.35 a ± 0.02 [0]	10.3 a ± 5.7 [0]	43.8 a ± 10.8 [0]	0.61 a ± 0.07 [0]	8.0 a ± 1.8 [0]	0 ± 0.0 [0]	0.77 a ± 0.14 [0]			
Calypso 480 SC (Thiacloprid)	0.2	2	0.18 b ± 0.01 [49.6]	3.8 b ± 3.3 [63.4]	4.3 b ± 2.2 [90.3]	0.20 b ± 0.03 [68.2]	5.3 a ± 3.6 [34.4]	0 ± 0.0 [–]	0.21 b ± 0.03 [73.4]			
#Movovento 100 SC (Spirotetramat)	0.45	2	0.14 c ± 0.01 [59.6]	0 c ± 0.0 [100]	0 c ± 0.0 [100]	0.14 c ± 0.02 [78.0]	0 b ± 0.0 [100]	0 ± 0.0 [–]	0.14 b ± 0.03 [81.8]			
#Movovento 100 SC (Spirotetramat)	0.75	2	0.12 d ± 0.03 [67.4]	0 c ± 0.0 [100]	0 c ± 0.0 [100]	0.12 c ± 0.02 [80.0]	0 b ± 0.0 [100]	0 ± 0.0 [–]	0.12 b ± 0.03 [84.4]			
#Movovento 100 SC (Spirotetramat)	0.75	1	0.11 d ± 0.01 [69.5]	0 c ± 0.0 [100]	0 c ± 0.0 [100]	0.11 c ± 0.03 [81.6]	0 b ± 0.0 [100]	0 ± 0.0 [–]	0.11 b ± 0.02 [85.7]			
Karate Zeon 050 CS (Lambda cyhalothrin)	0.15	2	0.15 c ± 0.02 [58.2]	0 c ± 0.0 [100]	0 c ± 0.0 [100]	0.15 c ± 0.01 [76.3]	1.0 b ± 0.8 [87.5]	0 ± 0.0 [–]	0.17 b ± 0.01 [78.2]			
[#] F _(5, 15)			89.406	18.418	247.552	119.147	37.654	–	78.511			
[#] P			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001			

#: Not approved on blackcurrant in Poland.

*: Means followed by the same letter in each column were not significantly different (Newman-Keuls' test, $p \leq 0.05$) ± standard errors.#: In ANOVA of $\log_{10}(x+1)$ transformed data.

Efficacy according to Abbott's formula.

Spray application dates: 1st: 18 May 2012; 2nd: 8 June 2012.

TABLE 2. Results of blackcurrant leaf midge (*Dasineura tetensi*) control by insecticides. Trial II, 2013 (Zglinna Duża).

Treatment	Product dose rate (L ha ⁻¹)	No. sprays	Observation dates									
			7 days after 1 st treatment (1 st gen.)					7 days after 2 nd treatment (2 nd gen.)				
			No. galls/shoot [Efficacy %]	No. larvae/gall [Efficacy %]	No. eggs/gall [Efficacy %]	No. galls/shoot [Efficacy %]	No. larvae/gall [Efficacy %]	No. eggs/gall [Efficacy %]	No. galls/shoot [Efficacy %]	No. larvae/gall [Efficacy %]	No. eggs/gall [Efficacy %]	21 days after 2 nd treatment (2 nd gen.) 5 July
Untreated	–	–	0.44 a ± 0.09 [0]	7.8 a ± 2.2 [0]	4.8 a ± 0.5 [0]	0.57 a ± 0.01 [0]	8.3 a ± 1.0 [0]	1.8 a ± 0.5 [0]	0.83 a ± 0.16 [0]			
Calypso 480 SC (Thiacloprid)	0.2	2	0.18 b ± 0.03 [58.8]	3.5 b ± 0.6 [54.8]	0 b ± 0.0 [100]	0.23 b ± 0.02 [60.5]	2.5 b ± 1.3 [69.7]	1.3 a ± 0.5 [28.6]	0.26 b ± 0.03 [68.2]			
#Movovento 100 SC (Spirotetramat)	0.45	2	0.17 b ± 0.02 [62.7]	1.0 c ± 0.0 [87.1]	0 b ± 0.0 [100]	0.18 c ± 0.01 [69.3]	0.8 c ± 0.5 [90.9]	0.3 b ± 0.5 [85.7]	0.18 bc ± 0.01 [77.6]			
#Movovento 100 SC (Spirotetramat)	0.75	2	0.11 b ± 0.01 [74.6]	0.3 c ± 0.5 [96.8]	0 b ± 0.0 [100]	0.11 d ± 0.01 [77.2]	0 c ± 0.0 [100]	0 b ± 0.0 [100]	0.11 c ± 0.01 [87.0]			
#Movovento 100 SC (Spirotetramat)	0.75	1	0.16 b ± 0.01 [65.0]	0.8 c ± 0.5 [90.3]	0 b ± 0.0 [100]	0.17 c ± 0.01 [70.6]	0.8 c ± 0.5 [90.9]	0 b ± 0.0 [100]	0.19 bc ± 0.02 [76.7]			
Karate Zeon 050 CS (Lambda cyhalothrin)	0.15	2	0.12 b ± 0.02 [72.9]	0.3 c ± 0.5 [96.8]	0 b ± 0.0 [100]	0.13 d ± 0.01 [77.2]	0.3 c ± 0.5 [97.0]	0 b ± 0.0 [100]	0.15 c ± 0.01 [81.5]			
#F _(5,15)			40.870	30.911	1467.647	419.422	30.994	24.683	86.745			
#P			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001			

#: Not approved on blackcurrant in Poland.

*: Means followed by the same letter in each column were not significantly different (Newman-Keuls' test, $p \leq 0.05$) ± standard errors.†: In ANOVA of $\log_{10}(x+1)$ transformed data.

Efficacy according to Abbott's formula.

Spray application dates: 1st: 25 May 2013; 2nd: 14 June 2013.

TABLE 3. Results of blackcurrant leaf midge (*Dasineura tetensi*) control by insecticides. Trial III, 2013 (Kazimierzów).

Treatment	Product dose rate (L ha ⁻¹)	No. sprays	Observation dates									
			7 days after 1 st treatment (1 st gen.)					7 days after 2 nd treatment (2 nd gen.)				
			No. galls/shoot [Efficacy %]	No. larvae/gall [Efficacy %]	No. eggs/gall [Efficacy %]	No. galls/shoot [Efficacy %]	No. larvae/gall [Efficacy %]	No. eggs/gall [Efficacy %]	No. galls/shoot [Efficacy %]	No. larvae/gall [Efficacy %]	No. eggs/gall [Efficacy %]	21 days after 2 nd treatment (2 nd gen.) 5 July
Untreated	–	–	0.36 a ± 0.06 [0]	6.3 a ± 3.3 [0]	0 ± 0.0 [0]	0.42 a ± 0.10 [0]	8.3 a ± 2.6 [0]	0 ± 0.0 [0]	0.06 a ± 0.02 [0]			
Calypso 480 SC (Thiacloprid)	0.2	2	0.20 b ± 0.03 [44.4]	1.0 b ± 0.8 [84.0]	0 ± 0.0 [–]	0.12 b ± 0.03 [71.6]	1.5 b ± 1.3 [81.8]	0 ± 0.0 [–]	0.02 b ± 0.01 [72.7]			
#Movovento 100 SC (Spirotetramat)	0.45	2	0.18 b ± 0.02 [50.0]	0 b ± 0.0 [100]	0 ± 0.0 [–]	0.06 bc ± 0.02 [85.8]	0 c ± 0.0 [100]	0 ± 0.0 [–]	0.01 b ± 0.01 [90.9]			
#Movovento 100 SC (Spirotetramat)	0.75	2	0.17 b ± 0.04 [52.8]	0 b ± 0.0 [100]	0 ± 0.0 [–]	0.04 c ± 0.03 [90.5]	0 c ± 0.0 [100]	0 ± 0.0 [–]	0 b ± 0.0 [100]			
#Movovento 100 SC (Spirotetramat)	0.75	1	0.17 b ± 0.02 [52.8]	0 b ± 0.0 [100]	0 ± 0.0 [–]	0.08 bc ± 0.03 [81.1]	0.3 c ± 0.5 [97.0]	0 ± 0.0 [–]	0.01 b ± 0.01 [90.9]			
Karate Zeon 050 CS (Lambda cyhalothrin)	0.15	2	0.21 b ± 0.02 [41.7]	0.8 b ± 1.5 [88.0]	0 ± 0.0 [–]	0.07 bc ± 0.02 [83.4]	0 c ± 0.0 [100]	0 ± 0.0 [–]	0.01 b ± 0.01 [90.9]			
#F _(5,15)			15.990	15.913	–	53.372	40.428	–	27.813			
#P			<0.001	<0.001	–	<0.001	<0.001	–	<0.001			

#: Not approved on blackcurrant in Poland.

*: Means followed by the same letter in each column were not significantly different (Newman-Keuls' test, $p \leq 0.05$) ± standard errors.†: In ANOVA of $\log_{10}(x+1)$ transformed data.

Efficacy according to Abbott's formula.

Spray application dates: 1st: 25 May 2013; 2nd: 14 June 2013.

TABLE 4. Results of blackcurrant leaf midge (*Dasineura tetensi*) control by insecticides. Trial IV, 2014 (Stara Rawa).

Treatment	Product dose rate (L ha ⁻¹)	No. sprays	Observation dates									
			7 days after 1 st treatment (1 st gen.)					7 days after 2 nd treatment (2 nd gen.)				
			No. galls/shoot [Efficacy %]	No. larvae/gall [Efficacy %]	No. eggs/gall [Efficacy %]	No. galls/shoot [Efficacy %]	No. larvae/gall [Efficacy %]	No. eggs/gall [Efficacy %]	No. galls/shoot [Efficacy %]	No. larvae/gall [Efficacy %]	No. eggs/gall [Efficacy %]	21 days after 2 nd treatment (2 nd gen.) 17 July
Untreated	–	–	0.39 a ± 0.06 [0]	6.8 a ± 1.7 [0]	1.5 a ± 2.4 [0]	0.61 a ± 0.10 [0]	9.8 a ± 3.3 [0]	0 ± 0.0 [0]	0.98 a ± 0.11 [0]			
Calypso 480 SC (Thiacloprid)	0.2	2	0.16 b ± 0.03 [60.0]	1.0 b ± 0.8 [85.2]	0 a ± 0.0 [100]	0.18 b ± 0.01 [70.2]	3.8 b ± 1.5 [61.5]	0 ± 0.0 [–]	0.24 b ± 0.02 [75.1]			
#Movovento 100 SC (Spirotetramat)	0.45	2	0.14 b ± 0.04 [64.5]	0 b ± 0.0 [100]	0 a ± 0.0 [100]	0.16 b ± 0.02 [73.5]	1.0 d ± 0.0 [89.7]	0 ± 0.0 [–]	0.16 c ± 0.01 [84.1]			
#Movovento 100 SC (Spirotetramat)	0.75	2	0.13 b ± 0.02 [66.5]	0 b ± 0.0 [100]	0 a ± 0.0 [100]	0.13 b ± 0.01 [78.8]	0 e ± 0.0 [100]	0 ± 0.0 [–]	0.13 c ± 0.01 [86.7]			
#Movovento 100 SC (Spirotetramat)	0.75	1	0.13 b ± 0.01 [65.8]	0 b ± 0.0 [100]	0 a ± 0.0 [100]	0.14 b ± 0.01 [78.0]	2.0 c ± 0.0 [79.5]	0 ± 0.0 [–]	0.15 c ± 0.02 [84.6]			
Karate Zeon 050 CS (Lambda cyhalothrin)	0.15	2	0.14 b ± 0.02 [64.5]	0.5 b ± 1.0 [92.6]	0 a ± 0.0 [100]	0.15 b ± 0.03 [75.9]	0.5 d ± 0.6 [94.9]	0 ± 0.0 [–]	0.16 c ± 0.02 [84.1]			
#F _(5,15)			36.135	28.753	2.156	90.846	50.441	–	264.319			
#P			<0.001	<0.001	0.114	<0.001	<0.001	–	<0.001			

#: Not approved on blackcurrant in Poland.

*: Means followed by the same letter in each column were not significantly different (Newman-Keuls' test, $p \leq 0.05$) ± standard errors.†: In ANOVA of $\log_{10}(x+1)$ transformed data.

Efficacy according to Abbott's formula.

Spray application dates: 1st: 9 May 2014; 2nd: 26 June 2014.

TABLE 5. Number of phytoseiid mites (Phytoseiidae) after insecticide applications (2012–2014).

Treatment	Product dose rate (L ha ⁻¹)	No. sprays	Number of phytoseiid mites per 1 blackcurrant leaf											
			7 days after 1 st treatment				7 days after 2 nd treatment				21 days after 2 nd treatment			
			Trial I 2012	Trial II 2013	Trial III 2013	Trial IV 2014	Trial I 2012	Trial II 2013	Trial III 2013	Trial IV 2014	Trial I 2012	Trial II 2013	Trial III 2013	Trial IV 2014
Untreated	–	–	1.2 a ± 0.6	0.6 a ± 0.8	0.3 a ± 0.3	1.0 a ± 0.7	1.7 a ± 0.7	2.6 a ± 1.3	2.4 a ± 0.2	2.8 a ± 0.3	4.7 a ± 0.5	6.3 a ± 1.0	6.2 a ± 0.3	7.1 a ± 0.4
Calypso 480 SC (Thiacloprid)	0.2	2	0.5 ab ± 0.2	0.2 a ± 0.2	0.1 a ± 0.2	0.2 a ± 0.2	0.1 b ± 0.2	0.4 b ± 0.5	0.4 e ± 0.2	0.4 c ± 0.5	1.8 c ± 0.9	2.1 c ± 0.9	2.0 c ± 0.8	2.2 d ± 0.6
#Movovento 100 SC (Spirotetramat)	0.45	2	0.6 ab ± 0.2	0.3 a ± 0.5	0.2 a ± 0.2	0.3 a ± 0.3	0.9 ab ± 0.7	1.4 ab ± 0.9	1.1 c ± 0.2	1.6 b ± 0.3	3.0 b ± 0.3	4.2 b ± 0.4	4.0 b ± 0.7	4.8 b ± 0.4
#Movovento 100 SC (Spirotetramat)	0.75	2	0.4 ab ± 0.2	0.2 a ± 0.2	0.1 a ± 0.2	0.3 a ± 0.4	0.6 ab ± 0.4	0.6 b ± 0.7	0.8 d ± 0.2	1.2 b ± 0.3	2.4 b ± 0.5	3.8 b ± 0.5	4.1 b ± 0.4	3.8 c ± 0.2
#Movovento 100 SC (Spirotetramat)	0.75	1	0.5 ab ± 0.2	0.2 a ± 0.2	0.1 a ± 0.2	0.3 a ± 0.4	1.1 ab ± 0.7	1.9 ab ± 0.6	1.7 b ± 0.3	2.1 ab ± 0.6	5.4 a ± 0.9	6.8 a ± 1.4	5.9 a ± 0.4	7.8 a ± 0.9
Karate Zeon 050 CS (Lambda cyhalothrin)	0.15	2	0.3 b ± 0.2	0.1 a ± 0.2	0.0 a ± 0.0	0.1 a ± 0.2	0.3 b ± 0.3	0.6 b ± 0.8	0.4 e ± 0.2	0.1 c ± 0.2	0.7 d ± 0.4	0.8 d ± 0.3	0.8 d ± 0.2	0.5 e ± 0.2
#F _(5,15)			3.841	0.567	0.760	1.949	0.760	1.949	58.287	24.441	58.287	24.441	63.702	139.682
#P			0.015	0.723	0.589	0.135	0.589	0.135	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

#: Not approved on blackcurrant in Poland.

*: Means followed by the same letter in each column were not significantly different (Newman-Keuls' test, $p \leq 0.05$), ± standard errors.‡: In ANOVA of $\log_{10}(x+1)$ transformed data.Spray application dates, trial I: 1st: 18 May 2012; 2nd: 8 June 2012. Spray application dates, trial II: 1st: 25 May 2013; 2nd: 14 June 2013. Spray application dates, trial III: 1st: 25 May 2013; 2nd: 14 June 2013. Spray application dates, trial IV: 1st: 9 May 2014; 2nd: 26 June 2014.

Efficacy of spirotetramat for blackcurrant leaf midge control

Seven days after the first spray application, there were many significant differences between the treatments and the untreated control for the numbers of galls per shoot and larvae/eggs per gall, except at the Kazimierzów site where there were no eggs present in the galls or differences between the treatments for the number of eggs (Stara Rawa). Spirotetramat at the rate of 0.45 L ha⁻¹ reduced the numbers of galls on the shoots significantly, the thiacloprid and lambda cyhalothrin treatment giving similar results at three of four sites. Spirotetramat used at the higher dose (0.75 L ha⁻¹) reduced the numbers of galls more effectively than thiacloprid, lambda cyhalothrin and spirotetramat at the lower rate (0.45 L ha⁻¹) only at one site – Zglinna Mała. At the other three locations, significant differences between treatments did not occur. The effectiveness was similar and amounted to 50.0–64.5% for spirotetramat used at the lower rate (0.45 L ha⁻¹), 52.8–74.6% for spirotetramat used at the higher rate (0.75 L ha⁻¹), 44.4–60.0% for thiacloprid, and 41.7–72.9% for lambda cyhalothrin in reduction of the numbers of galls per shoot. Spirotetramat at three of the four sites reduced the number of larvae in the galls to zero. At the first two sites (Zglinna Mała and Zglinna Duża) this active ingredient (irrespective of the doses used) and lambda cyhalothrin were equally effective, and were more effective than thiacloprid, which only reduced the number of larvae in galls (Tables 1 and 2). At next to sites (Kazimierzów and Stara Rawa) all three active ingredients were equally effective in reducing the number of larvae per gall (Tables 3 and 4). The effectiveness of spirotetramat (irrespective of the doses used) was very high and reached the level from 87.7 to 100%, and it was similar to this achieved with lambda cyhalothrin (88.0–100%), and higher than obtained with thiacloprid (54.8–85.2%) in reducing the number of larvae per gall. In case of eggs there was a significant difference in their number between treated and untreated plots only in two experiments (Zglinna Mała and Zglinna Duża). Spirotetramat and lambda cyhalothrin were more effective than thiacloprid in the Zglinna Mała site and all active ingredients were equally effective in the Zglinna Duża site in reducing the number of eggs per gall (Tables 1–4).

Seven days after the second spray application, spirotetramat at the lower rate of 0.45 L ha⁻¹ was more effective than thiacloprid in the two trials (Zglinna Mała and Zglinna Duża), and similar to the spirotetramat (0.75 L ha⁻¹) treatment (one application against the 1st generation) in all trials, and similar to lambda cyhalothrin treatment in reducing the numbers of galls in the shoots in the three trials (Zglinna Mała, Kazimierzów and Stara Rawa). Spirotetramat at the rate of 0.75 L ha⁻¹ (two application treatments) reduced the numbers of galls on the shoots significantly. It was more effective than thiacloprid in the three trials (except in Stara Rawa), and similar to spirotetramat (one application treatment) in the three trials (except in Zglinna Duża), and also similar to lambda cyhalothrin in all trials. The effectiveness was 69.3–85.5% for spirotetramat used twice at the lower rate (0.45 L ha⁻¹), 77.2–90.5% for spirotetramat used twice at the higher rate (0.75 L ha⁻¹), 70.6–81.6% for spirotetramat used once, 60.5–71.6% for thiacloprid, and 75.9–83.4% for lambda cyhalothrin in reduction the numbers of galls per shoot. In the first three trials spirotetramat (irrespective of the doses used and number of treatments) and lambda cyhalothrin were equally effective, and were more effective than thiacloprid in reducing the number of larvae in galls. In the trial

number four spirotetramat at the rate 0.45 L ha⁻¹ and lambda cyhalothrin were equally effective, and more effective than thiacloprid and single treatment with spirotetramat, and were less effective than double treatments of spirotetramat (0.75 L ha⁻¹) in reducing the number of larvae in galls. However, only spirotetramat applied twice at the rate 0.75 L ha⁻¹ reduced the number of larvae in the galls to zero in all trials. The effectiveness of spirotetramat (irrespective of the doses used and the number of applications) was very high and reached the level from 79.5 to 100%, and it was similar to this obtained with lambda cyhalothrin (87.5–100%), and higher than achieved with thiacloprid (34.4–81.8%) in reducing the number of larvae per gall. On that date, no *D. tetensi* eggs were found irrespective of treatment in the three of four trials (except in Zglinna Duża). However, there were no significant differences in the number of eggs in galls in spirotetramat (irrespective of the doses used and number of treatments) and lambda cyhalothrin treatments, but such significant differences occurred between them and thiacloprid treatments (Tables 1–4).

Twenty-one days after the second spray application, spirotetramat used at the lower rate (0.45 L ha⁻¹) was more effective than thiacloprid only in one trial located in Stara Rawa, and similar to the lambda cyhalothrin treatment in all trials, in reducing the numbers of galls. Spirotetramat (two sprays had been applied before this assessment date) at the higher dose (0.75 L ha⁻¹) reduced the numbers of galls more effectively than thiacloprid in the two trials (Zglinna Duża and Stara Rawa) and similar to lambda cyhalothrin or spirotetramat at the lower rate (0.45 L ha⁻¹) in all trials. Spirotetramat used once (only against 1st pest generation) was more effective than thiacloprid only in Stara Rawa trial and was similar to the spirotetramat (two application treatments) at the lower dose (0.45 L ha⁻¹) and was also similar to the lambda cyhalothrin treatments in all trials in reducing the numbers of galls on the shoots. The effectiveness was 77.6–90.9% for spirotetramat used twice at the lower rate (0.45 L ha⁻¹), 84.4–100% for spirotetramat used twice at the higher rate (0.75 L ha⁻¹), 76.7–90.9% for spirotetramat used once, 68.2–75.1% for thiacloprid, and 78.2–90.9% for lambda cyhalothrin in reduction of the numbers of galls per shoot. On that observation date, the effects of the treatments (including the untreated control) on the number of larvae and eggs in the galls could not be determined (data not shown) because the larvae had completed development and left the galls and because the leaves had become tough and necrotic they were not attractive for *D. tetensi* females and in any case the assessment coincided with the end of 2nd generation of the pest (Tables 1–4).

All the active ingredients used at the experiments do not control the pest eggs directly, and the low number of eggs or lack of eggs in the galls is a result of control of adults or female reproductive disorders because of these substances (Tables 1–4).

No visual symptoms of phytotoxicity were observed on any of the bushes at either assessment.

Effects on phytoseiid predatory mites

Seven days after the first spray application, populations of phytoseiid mites were low at all sites for all treatments, including the untreated plots. A significant difference between all chemical treatments and the untreated control for the number of phytoseiid mites only occurred between lambda cyhalothrin and the untreated control in trial I (Table 5). Spirotetramat at the rates of 0.45 and 0.75 L ha⁻¹ reduced

FIGURE 2. Effects of insecticides on reduction of phytoseiid mites [Trial I, Zglinna Mała, 2012].

FIGURE 3. Effects of insecticides on reduction of phytoseiid mites [Trial II, Zglinna Duża, 2013].

FIGURE 4. Effects of insecticides on reduction of phytoseiid mites [Trial III, Kazimierzów, 2013].

FIGURE 5. Effects of insecticides on reduction of phytoseiid mites [Trial IV, Stara Rawa, 2014].

TABLE 6. Spirotetramat residues in blackcurrant fruits (2012–2014).

Substance	Result	MRL
	(mg kg ⁻¹)	
BYI08330-Enol	0.0029 ± 0.0004	none*
BYI08330-Ketohydroxy	0.0081 ± 0.0003	none*
BYI08330-Monohydroxy	0.0000 ± 0.0000	none*
BYI08330 Enol-glucoside	0.0029 ± 0.0003	none*
Spirotetramat	0.0037 ± 0.0008	none*
Spirotetramat (with metabolites)	0.019	0.1

* No MRL has been set for these substances.

the numbers of phytoseiid mites by 33.3–66.7% and 57.1–71.4%, respectively, in comparison to the untreated controls. A greater reduction in predatory mites (57.1–83.3%) was obtained with thiacloprid (0.2 L ha⁻¹), and the reduction was still greater with lambda cyhalothrin (78.6–100%) used at the rate of 0.15 L ha⁻¹ (Figures 2–5).

Seven days after the second spray application, there were no significant differences between spirotetramat used at the rates 0.45 and 0.75 L ha⁻¹ (single and double treatments) and untreated plots, but a significant difference occurred between thiacloprid and lambda cyhalothrin, and untreated plots in reducing the numbers of phytoseiid mites (Trial I). In trial II, where spirotetramat was applied twice at the lower rate and once at the higher rate, the numbers of phytoseiid mites were similar to the control plots, but on the plots where this active ingredient was used twice at the higher rate and on the plots treated by thiacloprid and lambda cyhalothrin the numbers of phytoseiid mites were lower than on the control plots. In trial III on the plots treated with spirotetramat, the numbers of phytoseiid mites depended on the application numbers and the dosage. Higher numbers of phytoseiid mites were found on the plots treated once than treated twice by this active ingredient. More phytoseiid mites were found on the plots treated by spirotetramat than thiacloprid and lambda cyhalothrin. In trial IV, the numbers of phytoseiid mites found on plots treated once by spirotetramat were similar to untreated plots. On the plots treated twice by spirotetramat (irrespective of the dose) the numbers of phytoseiid mites were similar, and higher than obtained with the reference substances (Table 5). Spirotetramat used twice at the dose 0.45 and 0.75 L ha⁻¹ reduced the numbers of phytoseiid mites to 42.4–55.2% and 57.6–44.4% of the untreated control, respectively. The effect of that active ingredient used once at the dose 0.75 L ha⁻¹ was lower (24.2–35.0%) in reducing the numbers of phytoseiids, depending on the trials. Regardless of the trial, the most toxic to the phytoseiid mites were thiacloprid or lambda cyhalothrin. They reduced the population of phytoseiids to 82.8–95.0% and 77.4–97.0% of the untreated control, respectively (Figures 2–5).

Twenty-one days after the second spray application, populations of the phytoseiid mites were high (4.7–7.1 individuals/leaf). The numbers of phytoseiid mites on the plots treated by spirotetramat used twice at the dosages 0.45 and 0.75 L ha⁻¹ were lower than untreated plots, but higher than on the plots treated by thiacloprid or lambda cyhalothrin. However, on the plots treated once by spirotetramat the numbers of phytoseiid mites were similar like on the untreated plots and higher than in other treatments (Table 5). Spirotetramat used twice at the doses 0.45 and 0.75 L ha⁻¹ reduced phytoseiid populations by 31.8–37.7% and 33.8–48.0%, respectively. The effect of that tested substance used once at the dose 0.75 L ha⁻¹ was lower (0.0–4.1%) in reducing

the numbers of phytoseiids, depending on the trial. Lambda cyhalothrin was most harmful to the phytoseiid mites. It reduced the population of mites by 85.7–92.9%. Thiacloprid was little less harmful reducing numbers by 62.5–69.4% (Figures 2–5).

Residues of spirotetramat in blackcurrant fruits

The study was conducted for three consecutive years (2012, 2013, and 2014). The intervals between the last application of the sprays to harvest of the fruits were 55, 51, 63 days for the three years, respectively. Spirotetramat was measured along with its four metabolites: BYI08330-enol, BYI08330-ketohydroxy, BYI08330-monohydroxy, and BYI08330 enol-glucoside, expressed as spirotetramat (R), according to Reg. 396/2005 EU. The obtained results were below the maximum residue level (MRL) for spirotetramat. No MRLs have been set for its metabolites, but these were also well below the MRL for spirotetramat (Table 6).

Discussion

Spirotetramat (group: tetrone and tetramic acid derivatives) as Movento 100 SC, a new product for use on blackcurrant in Poland, is a phloem and xylem mobile insecticide introduced as a suspension concentrate (SC) formulation to the market by Bayer Ltd.. The efficacy of spirotetramat is known to be much higher against immature stages than against adult insects for a range of species (aphids, whiteflies, psyllids, mites and scales) (Nauen et al., 1998, 2008; Bruck et al., 2009; Bangels et al., 2011; Schoevaerts et al., 2011; Jaworska et al., 2012; Francesena et al., 2012; Łabanowska et al., 2013, 2015, 2017; McKenna et al., 2013). In the current study, Movento 100 SC (spirotetramat) in three programs (different dosages and application numbers) was used, but no studies have been done to evaluate the effect of spirotetramat for the control of blackcurrant leaf midge. It was evaluated in the UK in a series of three replicated field experiments in SE England, UK in 2010, 2011 and 2012, respectively, where it was found to be highly efficacious in controlling the pest, including controlling larvae in semi-mature and mature galls highly effectively in comparison with lambda cyhalothrin, which gave little control of larvae in galls (J. Cross, NIAB EMR, East Malling, Kent, UK, pers. commun.). In our current study, spirotetramat was also very effective in leaf midge larvae control. Since 2013, thiacloprid (group: neonicotinoids) as Calypso 480 SC has been registered for controlling the blackcurrant leaf midge (*D. tetensi*) and other midges and pests (moths, aphids and flies) on blackcurrant in Poland (Plant Protection Program, 2019). Thiacloprid selectively acts on the insect nervous system as an agonist of the nicotinic acetylcholine receptor, thus disrupting signal transmission in the insect's nervous system, leading to the death of the treated insect (Elbert et al., 2002; Pavela et al., 2007). The efficacy

of thiacloprid for control of blackcurrant leaf midge was also evaluated in a series of field experiments in SE England, UK in 2002, 2006 and 2009 (A.L. Harris, NIAB EMR, East Malling, Kent UK, pers. commun.). However, these earlier studies differed for the studies reported here because different dosages of thiacloprid (0.125 L ha⁻¹ Calypso 480 SC) and different spray volumes (from 500 to 1,000 L ha⁻¹) were used. In 2002, they found that foliar sprays of thiacloprid (0.125 L ha⁻¹ Calypso 480 SC) at a volume rate of 1,000 L ha⁻¹ controlled existing larval infestations of *Dasineura tetensi* on blackcurrant only partially (effectiveness 84%). In the 2006 trial, sprays at the same dose in a volume of 500 L ha⁻¹ applied in the middle stages of the first generation of larval attack when semi-mature and some mature larvae were present in galls gave no significant control. The results highlight the importance of treatment application at the early stages of oviposition and larval attack. In 2009, they obtained similar results where a spray at the same dose and volume failed to control existing infestations of larvae. In the current study, it was found that Calypso 480 SC (used at dosage 0.2 L ha⁻¹, higher than in the experiments done in the UK) efficacy in controlling larvae varied between experiments, either being ineffective or just giving partial control, similarly to the UK studies.

From 2001 to 2014 lambda cyhalothrin (SP) as Karate Zeon 05 CS was registered for controlling the blackcurrant leaf midge and other pests (midges, moths) on blackcurrant in Poland (R. Lalik, Polish Ministry of Agriculture and Rural Development, pers. commun.). This active ingredient has broad-spectrum action against pests at all stages of development. It kills as contact and feeding poison (Pavela et al., 2007). The synthetic pyrethroid (SP) insecticide lambda cyhalothrin (Hallmark 100 CS (0.1 L ha⁻¹)) with a maximum of two applications per season and at spray volumes of 200–500 L ha⁻¹ has been registered for controlling the blackcurrant leaf midge on blackcurrant plantations in the UK. This product was effective in control of the midge, reduced numbers of *D. tetensi* adult caught in sex pheromone traps by 72% and reduction of galling damage by 75% (Cross et al., 2016). In the current study, similar results were obtained using lambda cyhalothrin (Karate Zeon 050 CS) at a slightly lower rate of 0.15 L ha⁻¹. It was found that the efficacy of lambda cyhalothrin in controlling the larvae was very high (88.0–100%), after one or two treatments.

Knowledge of the effectiveness of individual pesticides for pest control and their impact on beneficial organisms are important to their use in IPM programs (Salman et al., 2015). Generally, selective pesticides are more harmful to the pest than the predator (Fountain and Medd, 2015). Such evidence of selectivity was also observed in the current study on the blackcurrant bushes treated with spirotetramat. Its effects on phytoseiid mite populations varied depending on the year, number of applications and the product dosage. According to the toxicity rating maintained by IOBC, spirotetramat has a range from one to three. The same toxicity level of spirotetramat to predatory mites was shown by Schnorrbach et al. (2008) in apple orchards. However, comparison of the results obtained in the current studies with other pesticides is not possible, because a search of the available literature did not reveal any other field research on blackcurrant or other bush plants where this active ingredient was evaluated for its effects on phytoseiid mites. On the other hand, there is a limited number of papers where the toxicity of spirotetramat to phytoseiid mites was tested in the laboratory, e.g., Kuk and Kim (2018) and Lefebvre et al. (2012). However, results from laboratory tests usually overestimate harmful effects

because of high exposure of phytoseiid mites to pesticides, whereas in the field (plantations, orchards) predators have various shelters and can be more dispersed to untreated plant surfaces (Bonafos et al., 2007).

Lower numbers of phytoseiids were found on bushes sprayed with thiacloprid than spirotetramat in the current study. However, there is lack of available literature on any other field research on blackcurrant where thiacloprid was assessed for toxicity to phytoseiid mites on blackcurrant bushes. In the Koppert, IPM impact and Biobest web site databases (September 2018) it is possible to find data about influence of thiacloprid on some phytoseiid mites, but not the species found on blackcurrant in Poland. According to the web site, thiacloprid toxicity is ranked from one to three. Such a level shows that this active ingredient is less toxic to Phytoseiidae than recorded in the current study (range 3 and 4). However, there is supporting evidence in the literature that this active ingredient is not safe to beneficials such as the parasitoid *Platygaster demades* Walker and anthorid predatory bugs, which are natural enemies of the blackcurrant leaf midge (Cross et al., 2016).

Lambda cyhalothrin is stated not to be suitable for integration with beneficial fauna within integrated pest management programs. In the current study, >75% reduction in numbers of phytoseiid mites were noted on the bushes treated by this active ingredient. A similar result was found earlier in the web site databases (Koppert and Biobest) and by Cross et al. (2016), where SP insecticides with a broad spectrum of activity were considered likely to be harmful to the midge's key natural enemies and other beneficial insects.

Conclusions

1. Spirotetramat as Movento 100 SC at rates 0.45 and 0.75 L ha⁻¹ reduced the number of the blackcurrant leaf midge, *Dasineura tetensi* larvae (after two sprays) in blackcurrant plantations by 87.1–100% and 96.8–100%, respectively.
2. Spirotetramat as Movento 100 SC at the rate of 0.75 L ha⁻¹ (one spray for 1st generation), had 90.3–100% efficacy in controlling of larvae of the blackcurrant leaf midge, and gave long lasting reduction for 2nd generation larvae by 79.5–100%.
3. Thiacloprid as Calypso 480 SC at the rate 0.2 L ha⁻¹ used twice gave only partial efficacy 54.8–85.2% against the 1st larvae generation, and 34.4–81.8% against the 2nd generation larvae.
4. The control of *D. tetensi* obtained with spirotetramat and lambda cyhalothrin 0.15 L ha⁻¹ (88.0–100%) were similar and better than those obtained with thiacloprid.
5. Spirotetramat as Movento 100 SC at rates 0.45 and 0.75 L ha⁻¹ reduced the numbers of phytoseiid mites (after two sprays) in blackcurrant plantations by 33.3–66.7% (range 2 and 3) and 57.6–77.4% (range 3 and 4), respectively, one week after each treatment, and by 31.8–37.7% (range 2) and 33.8–48.0% (range 2), respectively, three weeks after a second treatment.
6. Thiacloprid or lambda cyhalothrin were less selective than spirotetramat and reduced the population of phytoseiid mites by 62.5–69.4% (range 3) and 85.7–92.9% (range 4), respectively, three weeks after second treatment.
7. Spirotetramat as Movento 100 SC at the rate of 0.75 L ha⁻¹ (one application), reduced the population of phytoseiid mites by 24.2–35.0% (range 2) approximately three weeks after treatment, but about six weeks after treatment the phytoseiid mites population recovered completely.

8. Spirotetramat gave residues well below maximum residue levels (MRLs).

The blackcurrant leaf midge has to be controlled in nurseries and young blackcurrant plantations, and we have shown spirotetramat to be useful and highly effective. It has a broad spectrum of activity against pests because one application can control midges, eriophyids, aphids and mites and we have shown it doesn't have persistent adverse effects on phytoseiid mites. However, future work should concentrate on developing non-pesticidal control methods for blackcurrant pests such as new biocontrol approaches, exploiting sex pheromones to disrupt *D. tetensi* mating or developing new resistant cultivars.

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