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Original scientific paper

Comparative toxicity of spinetoram to *Trialeurodes vaporariorum* Westwood and its parasitoid *Encarsia formosa* Gahan

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SUMMARY

The role of selective new generation bioisecticides, beside their effectiveness against key pests, relies on their safety to beneficial arthropods. Spinetoram, a semi-synthetic analogue of the microbial-derived bioinsecticide spinosad is registered worldwide for application in numerous crops, but assessment of its ecotoxicological risk to beneficial arthropods has scarcely been documented. Moreover, this is the first report on toxic effects of spinetoram on a pest, the greenhouse whitefly *Trialeurodes vaporariorum* Westwood (Hemiptera: Aleyrodidae), and/or its successful biocontrol agent, the parasitoid *Encarsia formosa* Gahan (Hymenoptera: Aphelinidae). Under laboratory conditions, we assessed the acute toxicity of spinetoram insecticide (25% a.i.) to adults, nymphs and eggs of the greenhouse whitefly, as well as to parasitoid adults and pupae. In all concentration-response bioassays, the spinetoram insecticide was applied to tobacco leaves settled onto 1% agar layer in ventilated Petri dishes using a Potter spray tower. The parameters of spinetoram acute toxicity to adults of both the pest and the parasitoid were evaluated in residual contact bioassays, while whitefly eggs and nymphs, and parasitoid pupae were topically treated with a series of spinetoram concentrations, covering a range of 10-90% mortality. Lethal spinetoram effects on the parasitoid *E. formosa* were assessed through selectivity ratio (SR) estimations, showing the ratios beetween median lethal concentrations (LC_{50s}) estimated for the parasitoid, and LC_{50s} estimated for the pest. The following LC_{50} values were obtained: 4.593, 15.027 and 11.73 mg a.i./l for whitefly adults, nymphs and eggs, respectively, and 0.686 and 1.715 mg a.i./l for parasitoid adults and pupae, respectively. The calculated SR estimations were below 1, indicating that spinetoram insecticide is non-selective to both tested stages of the parasitoid *E. formosa.* A more detailed understanding of spinetoram impact on *E. formosa* in whitefly integrated management requires further evaluation of sublethal effects and greenhouse trials, with an emphasis on population-level responses.

Keywords: bioinsecticide, *Encarsia formosa*, IPM, selectivity ratio, whitefly

INTRODUCTION

Insecticide resistance in whiteflies, caused by overused synthetic chemicals and the associated side effects on the environment and non-target organisms, urgently promotes the use of alternative and environment-friendly control strategies (Kapantaidaki et al., 2018; Patra & Kumar Hath, 2022; Mota-Sanchez & Wise, 2023). In the concept of Integrated Pest Management (IPM), which is considered a more ecologically sound and sustainable strategy for whitefly control, biological control with parasitoids plays an essential role (van Lenteren & Martin, 1999; Gerling et al., 2001). The dominant parasitoid species *Encarsia formosa* Gahan (Hymenoptera: Aphelinidae) has been utilized for biological control of two most harmful whitefly species, the greenhouse whitefly *Trialeurodes vaporariorum* Westwood (Hemiptera: Aleyrodidae) and the tobacco whitefly *Bemisia tabaci* (Gennadius). For many decades, it has been considered one of the most successful biological control agents in greenhouse crops in many world regions (Hoddle et al., 2001; Bacci et al., 2007; Li et al., 2011; Sugiyama et al., 2011). Due to unfavorable ecological conditions for the parasitoid and/or high pest population density, insecticide treatments are necessary when *E. formosa* fails to keep a whitefly population below the economic threshold (Hoddle et al., 1998; Albajes et al., 1999). Biopesticides, i.e. commercial pest control agents manufactured from living organisms and/or their products (Chandler et al., 2011; Kumar et al., 2021), have been marked as potentially compatible for use with biocontrol agents in IPM or organic production. Low mammalian toxicity, looser harvest and re-entry restrictions and higher safety towards non-target organisms and the environment are some of the most frequently mentioned advantages of biopesticides over synthetic chemical compounds (Copping & Menn, 2000; Villaverde et al., 2014; Kumar et al., 2021).

Spinetoram, a semi-synthetic analogue of the microbial-derived bioinsecticide spinosad, has been classified by the US Environmental Protection Agency (EPA) as a "reduced risk pesticide" (Chloridis et al., 2007), which could be used as an alternative choice for controlling homopteran insect pests, such as whiteflies. Currently, spinetoram-based biopesticides are registered worldwide for application in many crops. It has been shown that they are highly effective against thrips, leafminer flies, some lepidopteran pest and whiteflies, among others (Dripps et al., 2011; Shimokawatoko et al., 2012; Abd-Ella, 2015). Although spinetoram has shown a reduced-risk profile in preliminary risk assessments, having toxicological properties similar to spinosad (Chloridis et al., 2007), the role of this potentially selective new generation bioinsecticide, besides its effectiveness against key pests, depends on its safety to non-target organisms. An increasing number of studies assessing the risk of spinosad to beneficial arthropods have been published in recent decades, suggesting that spinosad is non-selective to natural enemies of insects, especially parasitoids (Williams et al., 2003, Biondi et al., 2012). On the other hand, ecotoxicological assessment of spinetoram risk to beneficials has hardly been documented. There have been only a few reports from laboratory or field studies dealing with lethal and/or sublethal effects of spinetoram on predatory insects (Srivastava et al., 2008; Lefebvre et al., 2011; Ricupero et al., 2020) and parasitoids (Hernández et al., 2011; Abbes et al., 2015; Abd-Ella, 2015). Furthermore, to the best of our knowledge, no previous studies have quantified the effects of spinetoram on the greenhouse whitefly or its parasitoid *E. formosa*. Since many bioinsecticides that are effective against target pests are also harmful to parasitoids, causing lethal and/or sublethal effects and reducing the effectiveness of biological control agents (Desneux et al., 2007; Biondi et al., 2013; Drobnjaković et al., 2018, 2019; Giunti et al., 2022; Shankarganesh et al., 2022), integration of spinetoram and *E. formosa* in IPM programs requires to understand the toxicology of spinetoram regarding both the pest and its parasitoid.

Within that framework, this study aimed to evaluate the acute toxicity of spinetoram to the greenhouse whitefly and its parasitoid under laboratory conditions. The results of this study should serve as a starting point for further research of its effects, contributing to the optimization of integrated whitefly control strategies.

MATERIALS AND METHODS

Biological materials

A laboratory colony of *T. vaporariorum* was initiated from infested tomato plants collected from a commercial greenhouse in Padinska Skela, Serbia (N44°56'56.35"; E020°25'41.41") in the autumn of 2018. After the laboratory colony was established, the whitefly population in the greenhouse had no further contact with insecticides and did not experience any further selection pressure. A commercial strain of *E. formosa* with normal sensitivity to pesticides was successfully bred, starting from the pupal stage of the parasitoid obtained from Koppert Biological Systems Inc (The Netherlands). The parasitoid wasp population was grown together with its host pest at 27±1°C and 60±10% R.H. under a 16L:8D photoperiod.

Both the pest and the parasitoid were maintaned on four weeks old *Nicotiana tabacum* L. plants (with 6-8 fully developed leaves) of "Samsun" variety in ventilated muslin cages (Bug Dorm, Megaview Science Co., Ltd., Taiwan) in accordance with the recommended methodology of the European Plant Protection Organisation (EPPO, 2004).

Insecticide

The commercial insecticide Delegate™ 250 (manufactured by Corteva Agriscience) is formulated as water dispersible granules (WG). Its content of spinetoram as the active ingredient was 250 g/l.

Acute toxicity bioassays

All concentration-response bioassays for both the pest and its parasitoid were performed in five replicates in a climate chamber under the same controlled laboratory conditions as described for insect rearing. Bioassays were conducted in Petri dishes (14 cm diameter), each with a lid opening (10 cm diameter) and covered with muslin on top to ensure ventilation and prevent condensation inside. Whiteflies at different stages of development (adult, nymph and egg), and adults and pupae of the parasitoid wasp were added to Petri dishes as needed. Dilutions of the insecticide spinetoram were prepared with distilled water to obtain final concentrations (at least 6) of the active ingredient (a.i.). Since products based on spinetoram are not yet authorized for whitefly control in protected crops, preliminary trials were conducted to determine the range of insecticide concentrations by exposing each test stage to a concentration equivalent to a higher application rate recommended for the control of some other pests of greenhouse solanaceous vegetables (tomato, eggplant, cucumber, pepper and lettuce - 132 g/ha; 33 mg a.i/l)), until the observed mortality was < 100 %. A Potter Precision Spray Tower (Burkard Scientific, UK) was used to spray 2 ml of liquid under 100 kPa air pressure to create a water deposit of 2.6±0.2 mg/cm^2 in each dish. Control treatments for each acute toxicity bioassay were sprayed with distilled water only.

A) ***Acute toxicity bioassays with T. vaporariorum.*** Ten couples of two-day-old adult whiteflies (per replicate) were anaesthetised with CO_2 for 2 seconds and then carefully transferred into each muslin bag placed over fully developed tobacco leaves (4-week-old plants) to lay eggs for 24 hours. Adult whiteflies were then removed from each bag, while tobacco plants remained in the cages for additional 48 hours. After that period, the tobacco leaves were cut from the plants and observed under a stereomicroscope to record the number of eggs laid. Each leaf containing 40 eggs was considered an experimental unit. Tobacco leaves were then treated with a range of spinetoram concentrations (37.5, 18.75, 9.37, 4.69, 2.34, and 1.17 mg a.i./l) and, after complete air drying, transferred individually to clean Petri dishes containing agar layers. Tobacco leaves remained in Petri dishes until the L_1 crawling stage (crawler) hatched from the treated eggs; hatching was observed and recorded under a stereomicroscope. Mortality was calculated using the number of crawlers emerged in relation to the number of treated eggs, 7 days after treatment.

Similar to the egg bioassay, adult pests were anaesthetised in a concentration-response bioassay with whitefly nymphs and transferred to muslin bags for a period of 24 hours to lay eggs. After that period, adult whiteflies were removed from the bags, while tobacco plants remained in the cages for a period of about 18 days until the laid eggs have developed into fourth-instar nymphs. Tobacco leaves were then cut from the plants to count the number of fourth-instar whitefly nymphs under a stereomicroscope. Tobacco leaves with nymphs were then treated with a range of spinetoram concentrations (37.5, 18.75, 9.37, 4.69, 2.34, and 1.17 mg a.i./l) and, after air drying, transferred individually to clean Petri dishes on agar layers where they remained until adults emergence. Mortality was calculated from the number of emerged adults against the number of treated whitefly nymphs, 7 days after treatment.

Acute toxicity of the insecticide spinetoram to the adult stage of the whitefly was assessed in a residual contact test in which a range of spinetoram concentrations was sprayed: 37.5, 18.75, 9.37, 4.69, 2.34 and 1.17 mg a.i./l. The insecticide (or pure water in control dishes) was applied to the entire surface of each Petri dish (i.e. the lid and the lower dish with a tobacco leaf on agar medium). After the treated surfaces dried for 2 hours at room temperature, 40 (0-2 day old) adult whiteflies were anaesthetised with CO_2 for two seconds and then carefully transferred to each Petri dish. Mortality was recorded 48 hours after exposure, and adults were considered dead if they remained immobile after a light touch with a fine brush.

B) Acute toxicity bioassays with E. formosa. The baseline toxicity of the insecticide spinetoram to parasitoid adults was assessed by a residual contact test in the same way as described for the adult stage of the pest. Briefly, forty newly hatched (12-24 h old) adult wasps were exposed to dry spinetoram residues (3.75, 1.87, 0.94, 0.47, 0.23 and 1.15 mg a.i./l) in each Petri dish with a few drops of honey on a piece of aluminium foil (0.5 × 0.5 mm) attached to the lid of each dish.

Honey was applied after the insecticide has dried to avoid possible contamination of honey drops and ingestion of insecticide residues by parasitic wasps. As with the adult stage of the pest, mortality was calculated based on the number of live wasps relative to the number of wasps exposed for 48 hours (EPPO, 2004; Drobnjaković et al., 2018, 2019, 2021).

For the concentration-mortality response of the parasitoid pupal stage, tobacco leaves with parasitised whitefly nymphs (parasitoid pupae, 3 days old, i.e. 11 days after parasitoid oviposition in host nymphs) were fixed on aluminium foil with the natural, non-toxic adhesive Traganth-kit. After drying, the leaves were cut into pieces to adjust the number of pupae to about 40 per piece and placed on clean filter papers in Petri dishes. Petri dishes containing these tobacco leaves with pupae were treated with serially diluted solutions (7.5, 3.75, 1.87, 0.94, 0.47 and 0.23 mg a.i./l). After air drying for 2 hours, the treated leaves with pupae were transferred to clean Petri dishes to observe the emergence of adult parasitoids. Mortality was calculated using the ratio of emerged adults to treated pupae 9 days after treatment (EPPO, 2004; Drobnjaković et al., 2018, 2019, 2021).

Selectivity ratio. Direct lethal effects of the insecticide spinetoram on the tested life stages of *E. formosa* were assessed through the selectivity ratio (SR) as an Environmental Risk Assessment (ERA) parameter. In our study, selectivity ratios showed the relation beetween LC_{50} values estimated for the adult and pupal stages of the parasitoid, compared to LC_{50} values estimated for all tested stages of the pest (adult, nymph and egg). The selectivity ratio (SR) was calculated using the formula of Şengonca & Liu (2001):

$$SR = \frac{LC_{50} \text{ of the parasitoid}}{LC_{50} \text{ of the pest}}$$

$SR < 1$ indicates that the chemical is more toxic to the parasitoid than to the greenhouse whitefly (non-selective); $SR > 1$ indicates that the chemical is less toxic to the parasitoid.

Statistical analysis

The baseline toxicity of spinetoram to all life stages of the pest and parasitoid tested was estimated using a log-probit regression model (Finney, 1971) in Polo Plus software (LeOra Software, Berkeley, USA), estimating lethal concentrations (LC_{10}, LC_{50}, LC_{90}) and slopes of the regression lines. The concentration-mortality relationships were considered valid (i.e. they fitted the observed data) if there was no significant difference between the observed and expected data at $p < 0.05$ level. A pairwise comparison of the estimated LC_{50} values was performed using the lethal concentration ratio test: when 95% confidence interval between two LC values included 1, these values were considered nonsignificantly different (Robertson et al., 2007).

RESULTS

Acute toxicity bioassays

Log-probit regression analyses of concentration-mortality data showed that the spinetoram insecticide demonstrated significiant acute toxicity both to *T. vaporariorum* and *E. formosa*, but toxicity to the tested development stages of the parasitoid was significantly higher, compared to the pest.

Table 1. Baseline toxicity of spinetoram to life stages of the greenhouse whitefly and parasitoid *Encarsia formosa*, after topical or residual exposure

Insects	Life stages	*n*	LC_{50} (mg/l) (95% CLs)	LC_{90} (mg/l) (95% CLs)	LC_{10} (mg/l) (95% CLs)	Slope (± SE)	χ^2	*df*
Trialeurodes vaporariorum	Adult	1248	4.59 (2.76 - 6.84)	51.92 (27.91 - 164.95)	0.41 (0.09 - 0.91)	1.22 (± 0.13)	5.33	4
	Nymph	1156	15.28 (9.39 - 22.20)	179.89 (105.93 - 428.15)	1.30 (0.34 - 2.79)	1.20 (± 0.10)	6.04	4
	Egg	1402	11.73 (8.73 -1 5.35)	123.99 (81.80 - 221.10)	1.11 (0.54 - 1.84)	1.25 (± 0.06)	5.60	4
Encarsia formosa	Adult	1215	0.69 (0.57 - 0.81)	5.10 (3.91 - 7.22)	0.09 (0.06 - 0.13)	1.47 (± 0.12)	1.78	4
	Pupa	1400	1.72 (1.42 - 2.05)	15.60 (11.47 - 23.24)	0.19 (0.12 - 0.27)	1.34 (± 0.10)	3.79	4

n = number of individuals ; CLs = confidence limits; SE = standard error, $\chi 2$ = chi-square testing goodness of fit of concentration-mortality response; *df* = degrees of freedom

In the case of *T. vaporariorum*, significantly different median lethal concentrations of spinetoram were determined for the tested developmental stages. A LC_{50} ratio test showed that the adult stage of the pest was the most sensitive to the toxic effect of spinetoram, while the response of the nymphal stage to spinetoram showed the lowest lethal effect in acute toxicity bioassays. The LC_{50} values determined for the tested whitefly development stages were significantly lower (7.2, 2.2 and 2.8 times lower for adults, nymphs and eggs, respectively) (Table 1), compared to the application rate of the spinetoram insecticide recommended for use in protected solanaceus vegetable crops (33 mg a.i./l).

In the case of *E. formosa*, the parasitoid pupae showed 2.5-fold higher LC_{50}s than adults, but the ratio test did not indicate a significantly higher toxicity of spinetoram to the parasitoid adult stage. The label concentration of spinetoram insecticide was 47.8- and 19.2-fold (for adults and pupae, respectively) the estimated LC_{50} values for the parasitoid (Table 1).

Selectivity ratio estimations, showing ratios between median lethal concentrations estimated for the parasitoid, compared to LC_{50}s estimated for the greenhouse whitefly, are summarized in Figure 1. The calculated selectivity ratio values in all comparisons were less than 1, showing that the spinetoram insecticide is much more toxic to the parasitoid than to the pest.

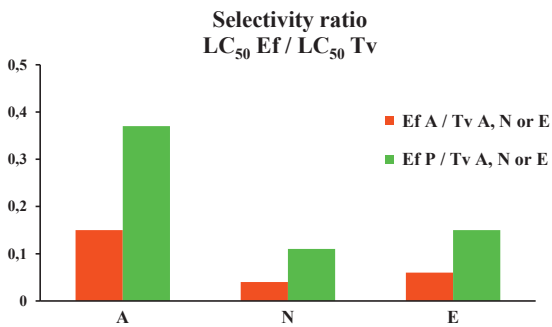

Figure 1. Selectivity ratios of spinetoram for the adult and pupal stages of *Encarsia formosa*

DISCUSSION

The current study showed that the insecticide spinetoram has high acute toxicity both to *T. vaporariorum* and *E. formosa* under the conditions described. However, the toxicity found for the tested parasitoid stages was significantly higher than for the pest. Acute toxicity parameters showed that spinetoram strongly affected the viability of eggs, nymphs and adults of the greenhouse whitefly pest, and the adult stage was the most sensitive to its toxic effect, while the nymphal stage was the least sensitive. In the case of *E. formosa*, adults and pupae were equally sensitive to spinetoram. Analysis of the obtained results based on the selectivity ratio, i.e. values below 1, indicated a non-selective nature of the spinetoram insecticide to both tested stages of the parasitoid.

Side effects of spinetoram on agricultural arthropod pests, as well as their arthropod natural enemies, have been scarcely documented (Srivastava et al., 2008; Hernández et al., 2011; Lefebvre et al., 2011; Abbes et al., 2015; Abd-Ella, 2015; Ricupero et al., 2020). To the best of our knowledge, this is the first report on toxic effects of spinetoram on the greenhouse whitefly, and its important biocontrol agent, the parasitoid *E. formosa*. Only one other study quantified the toxicity of spinetoram to whitefly and/or to *Encarsia* spp. species. Abd-Ella (2015) assessed the susceptibility of the pomegranate whitefly, *Siphoninus phillyreae* (Haliday) (Hemiptera: Aleyrodidae), a pest of numerous ornamental and fruit crops, and its major parasitoid species *Encarsia inaron* (Walker) (Hymenoptera: Aphelinidae) to spinetoram insecticide (Radiant SC; 0.021 ml a.i./l), using the leaf-dipping technique. Of five tested neurotoxic insecticides (imidacloprid, spinetoram, emamectin benzoate, abamectin and teflubenzuron), representing five insecticide chemical classes, spinetoram had the highest acute toxicity to pomegranate whitefly nymphs and adults. Although selectivity ratios between the LC_{50}s of the parasitoid and the pest were > 1, indicating a potentially selective nature of spinetoram, a risk quotient analysis, used to assess the risk to non-target arthropods (Hassan et al., 1998; Peterson, 2006) showed that spinetoram was slightly - moderately toxic (Preetha et al., 2010) to the *E. inaron* adult stage, 24 and 48 h post-treatment.

Similar to our findings, other studies quantifying toxic effects of spinetoram to parasitoids also suggested that spinetoram's toxicological profile regarding parasitoids is not promising. In a study that evaluated the lethal effects of insecticides on adults of *Ganaspidium nigrimanus* (Kieffer) (Hymenoptera: Figitidae) and *Neochrysocharis formosa* (Westwood) (Hymenoptera: Eulophidae), two important parasitoid species of the dipteran pest *Liriomyza trifolii* (Burgess), spinetoram proved to be the most harmful insecticide tested, suggesting

that it should be cautiously used in pest management systems. The field recommended rate of spinetoram (Radiant SC; 164 mg a.i./l) significantly decreased the cumulative survival of adult parasitoids when they were exposed to spinetoram either topically in leaf residue bioassays, or through feeding on a spinoteram contaminated food source (Hernández et al., 2011). Adverse effects of spinetoram have also been recorded in a study with another hymenopteran parasitoid wasp - *Bracon nigricans* (Braconidae), a natural enemy of the invasive tomato pest *Tuta absoluta* (Lepidoptera: Gelechiidae). Three days after residual contact with dry spinetoram insecticide residue (insecticide solutions were applied at maximum label rate, Radiant SC; 0.09 ml a.i./l), very high mortality of newly emerged parasitoid adults was recorded at three tested constant temperatures (77% mortality at 25°C, and total mortality at higher temperatures, 30 and 40°C) (Abbes et al., 2015).

The 'reduced risk' alternatives are not always of lower risk to arthropods, particularly natural enemies, and may have variable effects (Lefebvre et al., 2011; Biondi et al., 2012; Parsaeyan et al., 2020). The results of our study indicate that spinetoram may be a good choice in chemical management of greenhouse whitefly, while greenhouse populations of *E. formosa* parasitoid may be eliminated in the IPM system if sprayed with the recommended field rate of the spinetoram insecticide. Although toxic effects of an insecticide on an arthropod may be estimated by the mortality of adult females at the median lethal concentration (Robertson & Worner, 1990; Stark et al., 1997), such assessment provides only a partial measure of toxic effects (Stark & Banken, 1999; Desneux et al., 2007). A more precise assessment of risks for *E. formosa* involved in integrated use of spinetoram in whitefly management requires a further assessment of sublethal effects and greenhouse trials, highlighting the population-level response. For the most realistic scenario, spinetoram toxicity should be validated under greenhouse conditions, taking into account different application rates, routes of exposure, along with the ecology of the parasitoid during the growing season.

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Komparativna toksičnost spinetorama za *Trialeurodes vaporariorum* Westwood i parazitoida *Encarsia formosa* Gahan

REZIME

Uloga potencijalno selektivnih bioinsekticida u okviru integralnog koncepta zaštite biljaka, pored efikasnosti u suzbijanju štetočina, umnogome zavisi i od njihove bezbednosti po neciljane organizme. Spinetoram je polu-sintetski analog mikrobiološki dobijenog bioinsekticida spinosada koji se koristi širom sveta u suzbijanju raznih poljoprivrednih štetočina, ali je procena rizika primene spinetorama po korisne artropode veoma slabo istražena. Štaviše, toksičnost spinetorama prema štetočini - beloj leptirastoj vaši *Trialeurodes vaporariorum* Westwood (Hemiptera: Aleyrodidae), kao i/ili prema njenom efikasnom biološkom agensu, parazitoidu *Encarsia formosa* Gahan (Hymenoptera: Aphelinidae), nikada nije dokumentovana. U laboratorijskim uslovima, utvrđivana je akutna toksičnost (letalni efekti) insekticida na bazi spinetorama (25% a.s.) po razvojne životne stadijume (adulte, nimfe i jaja) bele leptiraste vaši, kao i po adulte i lutke parazitoida. Svi ogledi su izvedeni na temperaturi 27±1°C i relativnoj vlažnosti vazduha od 60±10%, uz fotoperiod 16:8 h, u pet ponavljanja. U svim doza-odgovor biotestovima, insekticid na bazi spinetorama primenjen je pomoću Potter Spray Tower aparata na lišće duvana, smešteno na sloju 1% agara, u ventiliranim Petri šoljama. Adulti štetočine i parazitoida izlagani su dejstvu svežih rezidua spinetorama u period od 48 sati, dok su jaja i nimfe štetočine, kao i lutke parazitoida, direktno tretirani serijom koncentracija spinetorama, pokrivajući odgovore od 10-90% smrtnosti. Akutna toksičnost spinetorama prema *E. formosa* procenjena je kroz indekse selektivnosti, koji predstavljaju odnos između srednjih letalnih koncentracija dobijenih za parazitoida i štetočinu. U biotestovima akutne toksičnosti dobijene su sledeće srednje letalne koncentracije spinetorama: 4,593, 15,027 i 11,73 mg a.s./l za adulte, nimfe i jaja bele leptiraste vaši, respektivno, kao i 0,686 i 1,715 mg a.s./l za adulte i lutke parazitoida, respektivno. Analiza dobijenih rezultata kroz indekse selektivnosti koji su bili niži od 1, nagoveštava neselektivnu prirodu insekticida na bazi spinetorama, prema oba testirana životna stadijuma parazitoida. Sveobuhvatna determinacija rizika zajedničke primene spinetorama i *E. formosa* u okviru integralnog koncepta zaštite biljaka od bele leptiraste vaši zahteva i procenu subletalnih efekata, kao i dalje testiranje spinetorama u poljskim uslovima, sa naglaskom na populacione parametre parazitoida.

Ključne reči: bioinsekticid, *Encarsia formosa*, integralni koncept zaštite biljaka, indeks selektivnosti, bela leptirasta vaš