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Original article (Orijinal araştırma)

Non-target effects of insecticides commonly used against lepidopteran pests on the predator, *Nesidiocoris tenuis* (Reuter, 1895) (Hemiptera: Miridae), under greenhouse conditions[1]

Lepidopter zararlılara karşı kullanılan bazı insektisitlerin sera koşullarında *Nesidiocoris tenuis* (Reuter, 1895) (Hemiptera: Miridae)'e yan etkileri

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Abstract

Nesidiocoris tenuis (Reuter, 1895) (Hemiptera: Miridae) is the most widely used biological control agent of tomato pests, particularly tomato leafminer. Five treatments, spinetoram, chlorantraniliprole + abamectin, chlorantraniliprole + thiamethoxam, emamectin benzoate and dimethoate were tested on *N. tenuis* under greenhouse conditions in summer and autumn of 2018 in Malatya Province, Turkey. After insecticide application, *N. tenuis* were counted on days 1, 4, 7, 14, 21 and 28. The non-target effects of insecticides are classified according to IOBC toxicity categories. Spinetoram caused 24 and 52% mortality in summer and autumn experiments, respectively and is compatible with *N. tenuis* considering mortality in both seasons. Therefore, it is recommended for IPM. Chlorantraniliprole + abamectin was classified as slightly harmful in the summer experiment as it resulted in 45% mortality, however, in autumn conditions, it was resulted in 79% mortality and classified as harmful. This effect seen under cooler conditions should be consider in planning IPM. Chlorantraniliprole + thiamethoxam caused 62 and 63% mortality which was increasing up to the final day of autumn assessment, whereas emamectin benzoate caused high mortality of 86 and 87% in summer and autumn, respectively. Thus, it is concluded that these latter two insecticides are not compatible with *N. tenuis*.

Keywords: Biological control, inoculative releasing, insecticides, protected cultivation, side effects, tomato

Öz

Nesidiocoris tenuis (Reuter, 1895) (Hemiptera: Miridae), başta Domates güvesi olmak üzere domates zararlılarına karşı en yaygın kullanılan biyolojik mücadele etmenidir. Bu çalışmada, 2018 yılı yaz ve sonbahar dönemlerinde Malatya İli sera koşullarında spinetoram, chlorantraniliprole + abamectin, chlorantraniliprole + thiamethoxam, emamectin benzoate ve dimethoate etken maddeli 5 farklı pestisitin *N. tenuis*'e yan etkilerinin belirlenmesi amaçlanmıştır. İnsektisit uygulamaları yapıldıktan sonra 1, 4, 7, 14, 21 ve 28. günlerde *N. tenuis* sayımları yapılmıştır. İnsektisitlerin yan etkileri IOBC toksisite kategorisine göre sınıflandırılmıştır. İki sezonun ortalaması dikkate alındığında, spinetoram, sırasıyla yaz ve sonbahar denemelerinde %24 ve 52 ölüme neden olmuş ve aynı zamanda *N. tenuis* ile de uyumlu olduğu saptanmıştır. Böylece IPM programlarında önerilebilir. Chlorantraniliprole + abamectin yaz denemesinde %45 ölüm oranı ile zararsız veya az zararlı sınıfında yer alırken, sonbahar denemesinde ise %79 ölüme neden olmuş ve zararlı olarak sınıflandırılmıştır. Serin şartlarda görülen bu etki IPM programları hazırlanırken dikkate alınmalıdır. Chlorantraniliprole + thiamethoxam yaz ve sonbahar denemelerinde, özellikle sonbahar denemesinde son sayım gününe kadar artmaya devam eden %62 ve 63 ölüme neden olmuşken, emamectin benzoate ise %86 ve 87 oranında yüksek ölüme neden olmuştur. Bu yüzden, bu iki insektisitin de *N. tenuis* ile uyumlu olmadığı düşünülmektedir.

Anahtar sözcükler: Biyolojik mücadele, aşılama salımı, insektisitler, örtüaltı yetiştiriciliği, yan etki, domates

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Introduction

Turkey, with over 12 Mt of tomato production, ranks as the fourth highest producer after China, India and the USA (FAO, 2018). There are biotic factors that limit tomato production in Turkey including the pest invertebrates, tomato leafminer [*Tuta absoluta* (Meyrick, 1917) (Lepidoptera: Gelechiidae)], whitefly [*Bemisia tabaci* (Gennadius, 1889) (Hemiptera: Aleyrodidae)], vegetable leafminer [*Liriomyza trifolii* (Burgess in Comstock, 1880) (Diptera: Agromyzidae)], western flower thrips [*Frankliniella occidentalis* (Pergande, 1895), onion thrips [*Thrips tabaci* Lindeman, 1889 (Thysanoptera: Thripidae)] and two-spotted spidermite [*Tetranychus urticae* Koch, 1836 (Acarina: Tetranychidae)] (Ulubilir & Yabaş, 1996; Yasarakıncı & Hıncal, 1999; Bulut & Göçmen, 2000; Keçeci et al., 2007; Kılıç, 2010).

The common use of chemical pest control leads to negative consequences including destruction of natural pest predators and the development of insecticide resistance in pests (Devonshire & Field, 1991). Integrated pest management (IPM) has become important in pest control and alternative methods have been developed (Desneux et al., 2007; van Lenteren, 2009; Bueno & van Lenteren, 2010; Yücel et al., 2013). Although chemical pest control is mostly preferred by producers, there is also an increase in the use of biological control of greenhouse vegetable pests. Before *T. absoluta* was introduced to European tomato crops, the primary pests were whiteflies with biological control achieved by a combination of *Macrolophus pygmaeus* (Rambur, 1839) (Hemiptera: Miridae), *Encarsia formosa* Gahan, 1924 (Hymenoptera: Aphelinidae) and *Eretmocerus mundus* Mercet, 1931 (Hymenoptera: Aphelinidae). However, the arrival of *T. absoluta*, which in now found in almost all tomato production areas in the Mediterranean basin and Europe (Biondi et al., 2018), especially in greenhouse tomato cultivation between 2006 and 2010, led to changes in biological control approaches. The current biological control is now based on *Nesidiocoris tenuis* (Reuter, 1895) (Hemiptera: Miridae), which feeds on preadult stages of whiteflies as well as the eggs and larvae of *T. absoluta* (Yucel et al., 2013; Pérez-Hedo & Urbaneja, 2016; Topakcı & Keçeci, 2017).

The following insecticides, used in tomato production, could potentially impact on *N. tenuis* and its effectiveness as a biocontrol agent. Chlorantraniliprole is a ryanodine receptor modulator. Insect ryanodine receptors activated by chlorantraniliprole stimulate the release of calcium from muscles, causing impaired muscle regulation, paralysis and ultimately death. Abamectin is a glutamate-gated chloride channel allosteric modulator and activates this channel stimulating the release of γ-aminobutyric acid from presynaptic inhibitory membranes and resulting in an increased flow of chloride ions into the cell blocking nerve signals. Another insecticide applied with chlorantraniliprole is thiamethoxam which belongs to neonicotinoids group (MoA group 4A). This group of insecticides bind to the acetylcholine sites on nicotinic acetylcholine receptors causing some symptoms such as hyperexcitation, lethargy and paralysis. Emamectin benzoate is an activator of the chloride channel (MoA group 6) causing neuronal and muscular system malfunctions. Spinetoram is nicotinic acetylcholine receptor allosteric activator (MoA group 5) causing hyperexcitation of neurons in the central nervous system (IRAC, 2020).

Non-target effects pesticides are mostly assessed under laboratory and semi field conditions given that field studies can be time-consuming and expensive. However, field tests should provide more reliable results (Thomson & Hoffmann, 2006; Pozzebon et al., 2015). The non-target effects of insecticides on *N. tenuis* have mostly been assessed under laboratory conditions. Thus, it is important to also conduct assessments under standard tomato production conditions. Only a single published study has been conduction on the effects of chlorantraniliprole on *N. tenuis* under greenhouse conditions (Dáder et al., 2020). However, there are no studies investigating the impact of newer products containing abamectin or thiamethoxam. Similarly, although there are a number of studies on spinosad, a spinosyns group agent, there are no studies on the new active ingredient spinetoram.

For successful IPM, the compatibility of pesticides with biological control agents is vital when applied in combination with biological control. This study aimed to determine the potential non-target effects of the some commonly-used insecticides on the predator insect, *N. tenuis*, under greenhouse conditions. The insecticides assessed, dimethoate and the 4 larvicides, spinetoram, chlorantraniliprole + abamectin, chlorantraniliprole + thiamethoxam and emamectin benzoate are commonly used to control cotton bollworm and tomato leafminer in tomato production.

Materials and Methods

Nesidiocoris tenuis rearing

A population of *N. tenuis* was obtained from Biobest Corporation, Antalya, Turkey and was subsequently reared on tomato seedlings in cages covered with fine netting. The cages were placed in a controlled environment room at 25 ± 1ºC, 60 ± 10% RH and 16:8 h L:D photoperiod. *Ephestia kuehniella* Zeller, 1879 (Lepidoptera: Pyralidae) eggs were used as the food source for these cultures (Sanchez et al., 2009; De Puysseleyr et al., 2013; Keçeci & Öztop, 2017).

Insecticides and their applications

The effect of the insecticides (Table 1) spinetoram, chlorantraniliprole + abamectin, chlorantraniliprole + thiamethoxam and emamectin benzoate were compared to the highly-toxic insecticide, dimethoate, under greenhouse conditions. These insecticides are known to be effective on larval stages, and are widely used for cotton bollworm, *Helicoverpa armigera* (Hübner, 1808) (Lepidoptera: Noctuidae) and tomato leafminer, *T. absoluta* (IRAC, 2017; Anonymous, 2020; Kandil et al., 2020).

Table 1. Active ingredients, trade names, chemical groups, target pests and application rate of the tested insecticides

Treatment (active ingredient and formulation*)	Trade name (company)	Chemical group	Target pest	Recommended field rates of products in Turkey
Spinetoram (120 g/L, SC)	Radiant (Dow AgroSciences)	Spinosyns	tomato leafminer	500 mL/kL water
Chlorantraniliprole and thiamethoxam (100 and 200 g/L, SC)	Durivo (Sygenta)	Diamides and neonicotinoids	tomato leafminer	800 mL/ha
Chlorantraniliprole and abamectin (45 and 18 g/L, SC)	Voliam Targo (Sygenta)	Diamides and Avermectins	cotton bollworm	900 mL/kL water
Emamectin benzoate (5%, SG)	Surrender (Agrobest)	Avermectins	cotton bollworm	300 g/kL water
Dimethoate (400 g/L, EC)	Poligor (Hektaş)	Organophosphates	various**	1 L/kL water

* EC, emulsion concentrate; SC, suspension concentrate; SG, soluble granules;
** Dimethoate is broad-spectrum, highly-toxic insecticide included as a positive control.

The experiments were conducted in the summer and autumn of 2018 under greenhouse conditions in the Department of Crop Protection, Faculty of Agriculture, Malatya Turgut Özal University. Net (50 mesh) cages (2 x 2.5 x 2 m, width x length x height) were used with 10 tomato cv. Bigmek F1 plants per cage planted as seedlings. The experiments were laid out in a randomized complete block design with three replicate cages per treatment, and included three untreated controls.

In the summer, tomato seedlings were planted on 16 April. *N. tenuis* were released (2 adults/m^2) (Calvo & Urbaneja, 2004) in all cages on 21 June. After predator release, 0.14 g *E. kuehniella* eggs were placed six times on each of the 10 tomato plants at 7-9-d intervals as a food source and to enable establishment of the *N. tenuis*. On 5 August, the plants were sprayed with the insecticide treatments at the maximum recommended concentration for field use (Table 1). Spinetoram, chlorantraniliprole + abamectin, emamectin benzoate and dimethoate were applied as a foliar application in 1.15 L of water/cage with a backpack sprayer. Chlorantraniliprole + thiamethoxam was applied to the tomato plant roots with 0.5 L of water/plant. Control plants was only sprayed with water. Supplementary food was provided only once, 3 d after application of the treatments. No other organisms that could potentially be a food source for the predators were observed on plants during the experiment.

In the autumn, tomato seedlings were planted on 13 September, and *N. tenuis* released on 28 September with four *E. kuehniella* egg applications as in the summer experiment. Insecticides were applied on 30 October.

Sampling

Adults and nymphs of *N. tenuis* on all parts of three plant in each cage were counted using a magnifying glass 1 d before the insecticide application and 1, 4, 7, 14, 21 and 28 d after insecticide application.

Data analyses

Counts adults plus nymphs of *N. tenuis* per plant were converted to percentage mortality for each assessment time using Henderson-Tilton formula (Henderson & Tilton, 1955) based on the numbers in the untreated control for each experimental block. The data was examined using exploratory statistics (Tukey, 1997) and assumptions tests for least squares hypothesis testing, and found to contain significant non-normality (Shapiro-Wilk test, $p < 0.001$ and by examining Q-Q plots) and lack of homogeneity of variance (Levene's test $p < 0.001$). So, the assumption required for a least square repeated measures ANOVA were not met. Therefore, the data was initially analyzed by fitting linear mixed-effects models using restricted maximum likelihood with R function “lmer" in the “lme4” package (Bates et al., 2015). The model formula used include blocks and assessment times as random effects to account for the nesting and repeated measures in the experimental design. Main effects (treatment and time) were significant for both seasons and response variates (counts and mortalities), but no interactions were found to be significant. Therefore, nonlinear least squares asymptotic fits were made with the R function “nls" and model, Response ~ SSasymp (Cycle, Asym, R0, lrc), where SSasymp function is a self-start model to evaluate the asymptotic regression and its gradient in the R package "lme4" (Bates et al., 2015). For the mortality data, where the parameter Asym was statistically significant the estimate obtains represented the equilibrium mortality as there was no evidence of population increase in the untreated controls over the 28-d assessment period. The logarithmic rate constant (lrc) indicates the rate of response to the treatments but these rate changes are evident in the plotted regressions, so only Asym values are presented here. These mortality estimates are also used to classify insecticide treatments based on International Organization for Biological and Integrated Control toxicity categories for semi field and field conditions: N, harmless or slightly harmful for 0-50% mortality; M, moderately harmful for 51-75% mortality; and T, harmful for >75% mortality (Boller et al., 2006).

Results

In the summer experiment, on the day before insecticide application, the mean predator population ranged between 15 and 24 individuals/plant. In the autumn experiment, predator population in all plot were 7 to 10 individuals/plant before treatment. During the summer and autumn experiments, the mean daily temperatures (and range) the duration of the experiments were 25.2ºC (22.7-27.0ºC) and 16.7ºC (10.7-18.9ºC), respectively. Due to the low temperatures during the autumn experiment, the predator population did not reach levels as high as those observed in the summer period. Therefore, each experiment was analyzed separately.

Summer experiment

The results for the summer experiment are presented in Figure 1. During the summer experiment, there was a slight decrease in the number of *N. tenuis* in the control plots. However, except for spinetoram, predator population declined rapidly with insecticide treatment. Spinetoram reduced the number of *N. tenuis* more slowly from 1 to 7 d after treatment, then the population stabilized. Chlorantraniliprole + abamectin effect quickly reduced the number of *N. tenuis* rapidly 1 to 4 d after treatment. In contrast, number of *N.*

tenuis with chlorantraniliprole + thiamethoxam treatment, applied as a soil drench, did not decrease up to 4 d after treatment but rapidly decreased by 7 d after treatment before stabilizing. Given this disjuncture in the rate of decline, the asymptotic fit for this treatment was not as tight as the other treatments, but the equilibrium morality appeared to be reliably estimated (Figure 1d, i & Table 2). With emamectin benzoate the population decrease was complete by 7 d after treatment. The control insecticide, dimethoate, caused almost complete mortality a 1 d and 100% by day 4.

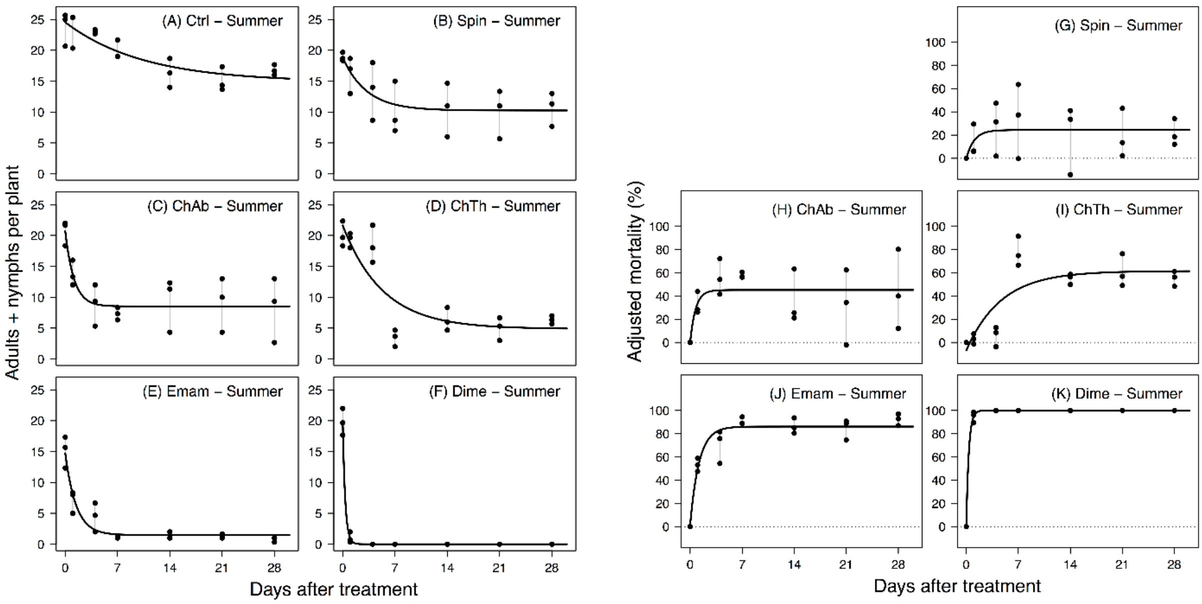

Figure 1. A-F, Numbers of *Nesidiocoris tenuis* for an untreated control and five insecticide treatments applied in summer 2018; and G-K, adjusted mortalities (%) for the insecticide treatments. Mortalities were adjusted using the Henderson-Tilton formula (Henderson & Tilton, 1955). Points represent the values for each of the replicates and the regression lines are for a nonlinear least squares fits of the model, Response ~ SSasymp(Day, Asym, R0, lrc), where SSasymp is a self-start model to evaluate the asymptotic regression and its gradient in the R package "lme4" (Bates et al., 2015). See Table 2 for the values and significance of the Asym parameters. Treatment codes: Ctrl, control; ChAb, chlorantraniliprole + abamectin; ChTh, chlorantraniliprole + thiamethoxam; Dime, dimethoate; Emam, Emamectin benzoate; and Spin, spinetoram. Treatments are displayed from lowest to highest equilibrium mortality.

Autumn experiment

The results for the summer experiment are presented in Figure 2. In the autumn experiment, the initial *N. tenuis* population was lower than that in the summer. The population only decreased slightly in control cages, probably because of cooler conditions. In contrast to summer experiment there was a significant decrease in predator numbers with spinetoram application and nearly half of the population was affected. With chlorantraniliprole + abamectin, a rapid decline was evident on day 1 and had stabilized by day 4. Emamectin benzoate had caused a significant reduction in population 1 d after treatment. The asymptotic fits were relatively tight for the population changes in all treatments, however, changes the less uniform decline in the control population compared to the summer experiment (Figures 1a vs 2a) feed some variability in the mortalities adjusted by the Henderson-Tilton formula. Nevertheless, the equilibrium toxicities were reliably estimated (Table 2) excepted with chlorantraniliprole + thiamethoxam treatment. For that treatment no statistically, significant asymptote was estimated because the mortality progress over 28 d of the experiment. So, for classification of that treatment, the 28 d toxicity (62%, Table 2) was used.

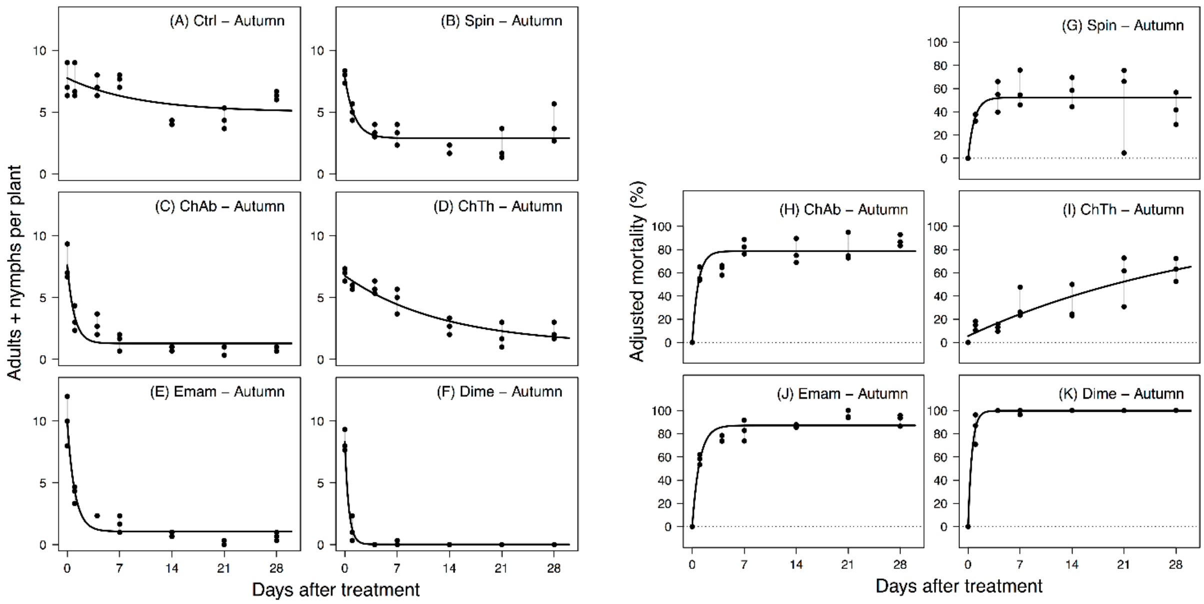

Figure 2. A-F, Numbers of *Nesidiocoris tenuis* for an untreated control and five insecticide treatments applied in autumn 2018; and G-K, adjusted mortalities (%) for the insecticide treatments. Mortalities were adjusted using the Henderson-Tilton formula (Henderson & Tilton, 1955). Points represent the values for each of the replicates and the regression lines are for a nonlinear least square fits of the model, Response ~ SSasymp (Day, Asym, R0, lrc), where SSasymp is a self-start model to evaluate the asymptotic regression and its gradient in the R package "lme4" (Bates et al., 2015). See Table 2 for the values and significance of the Asym parameters. Treatment codes: Ctrl, control; ChAb, chlorantraniliprole + abamectin; ChTh, chlorantraniliprole + thiamethoxam; Dime, dimethoate; Emam, Emamectin benzoate; and Spin, spinetoram. Treatments are displayed from lowest to highest equilibrium mortality for the summer data presented in Figure 1.

Table 2. Values and significance of the Asym parameters (estimated equilibrium mortality) for regression lines for nonlinear least squares fits of the model, Response ~ SSasymp(Day, Asym, R0, lrc), where SSasymp is a self-start model to evaluate the asymptotic regression and its gradient in the R package "lme4" (Bates et al., 2015) shown in Figures 1 and 2. Mortalities were adjusted using the Henderson-Tilton formula (Henderson & Tilton, 1955) and classified according to Organization for Biological and Integrated Control (IOBC) toxicity categories

Treatment	Season	Estimated equilibrium mortality (%)	Standard error	T value	P value	IOBC toxicity category*
Spinetoram	summer	24.3	5.25	4.6	<0.001	N
	autumn	52.3	4.42	11.8	<0.001	M
Chlorantraniliprole +abamectin	summer	45.1	5.44	8.3	<0.001	N
	autumn	78.6	2.60	30.2	<0.001	T
Chlorantraniliprole + thiamethoxam	summer	61.5	7.53	8.2	<0.001	M
	autumn	108.0**	88.60	1.2	ns	M
Emamectin benzoate	summer	86.1	2.50	34.5	<0.001	T
	autumn	87.1	1.98	43.9	<0.001	T
Dimethoate	summer	100.0	0.39	253.5	<0.001	T
	autumn	99.8	1.13	88.3	<0.001	T

* N: Harmless or slightly harmful; M: Moderately harmful; and T: Harmful;

** An estimated of the equilibrium mortality for the chlorantraniliprole + thiamethoxam treatment in autumn could not be reliably obtained by this nonlinear regression method, so it means final adjusted morality (62.7%) was used for determining its IOBC toxicity category.

The estimated equilibrium mortality and insecticide toxicity categories for *N. tenuis*, determined in the summer and autumn experiments, are shown in Table 2. Spinetoram caused only 24% mortality in the summer experiment and is classified harmless or only slightly harmful. Chlorantraniliprole + abamectin caused mortality of nearly half of the predator population, but is also categorized as harmless or slightly harmful. However, spinetoram and chlorantraniliprole + abamectin caused significant reduction in *N. tenuis* population and is classified as moderately harmful and harmful, respectively, under cooler conditions. Chlorantraniliprole + thiamethoxam is classified as moderately harmful in both experiments, while emamectin benzoate and dimethoate were classed as harmful (Table 2).

Discussion

Biological control has increased in importance as an alternative pest control method in IPM. However, the effectiveness of a biological control agent can be compromised, particularly if pesticides are used when against unexpected secondary pest outbreaks. Therefore, it is essential to determine the non-target effects of pesticides to ensure successful and sustainable IPM. Consequently, in the present study, the non-target effects of 5 insecticides, namely spinetoram (a spinosyn), chlorantraniliprole + thiamethoxam (diamide and neonicotinoid), chlorantraniliprole + abamectin (diamide and avermectin), emamectin benzoate (avermectin) and dimethoate (organophosphate), on the predator insect, *N. tenuis,* were determined.

Spinetoram caused 24 and 52% mortality of *N. tenuis* in summer and autumn, respectively. Despite in high mortality under cooler conditions, based mean mortality of two season, spinetoram can be classified as harmless or less harmful (category N). Similarly, it was reported that spinetoram did not cause mortality of the adults and nymphs of a mirin bug, *Macrolphus basicornis* (Stal, 1860) (Soares et al., 2019). Martinou et al. (2014) reported that the active ingredient of spinosad another insecticide classified in the same group as spinetoram (spinosyns) was harmless or slightly harmful (category N) to *M. pygmaeus*. This is consistent with the findings of Arnó & Gabarra (2011), who found less than 13% mortality on predatory insects *M. pygmaeus* and *N. tenuis* in response to spinosad application. However, they also reported that spinosad exposure of females of *M. pygmaeus* and *N. tenuis* caused a significant decrease in number of progenies. Thus, they concluded that the sublethal effects of spinosad on predator reproduction should not be overlooked. In contrast, in other research, spinosad was reported as moderately harmful (category M) or harmful (category T) to *N. tenuis* (Sukhoruchenko et al., 2015; Portakaldalı & Satar, 2015a). Although, those studies reported high mortality from spinosad, this might have been due to the different insecticide formulation or conditions.

Chlorantraniliprole + thiamethoxam and chlorantraniliprole + abamectin gave differing results indicating the secondary insecticide was influential. Chlorantraniliprole + thiamethoxam was categorized as moderately harmful (category M) in both experiments. However, in the autumn experiment, its mortality effect did not stabilize, but it is unlikely that further unestimated decline in the population would push it into the next category. The low initial mortality of this insecticide was due to it being applied as a drench taking time for it to reach the upper canopy of the plant where the predator mainly resided.

Chlorantraniliprole + abamectin was classified as harmless or less harmful (category N) under warmer summer conditions, but was classed as harmful (category T) in autumn. This could be due to the slow breakdown of the insecticide under cooler conditions (Op de Beeck et al., 2017). In an experiment conducted under greenhouse conditions, Dáder et al. (2020) reported that chlorantraniliprole was harmless to *N. tenuis*. Another study also reported that chlorantraniliprole was harmless or less harmful with a mortality of less than 25% to the mirid, *M. pygmaeus* (Martinou et al., 2014). Therefore, it is suspected that the addition of abamectin may have a synergistic effect on the chlorantraniliprole against *N. tenuis* under greenhouse conditions.

Emamectin benzoate was classified as harmful (category T) in both experiments. These findings are consistent with a study conducted under laboratory conditions by Portakaldalı & Satar (2015b) who reported 74-79% mortality to *N. tenuis*. These findings are also consistent with those of some previous studies on *Pilophorus typicus* (Distant, 1909) (Heteroptera: Miridae) (Nakahira et al., 2010) and *Orius laevigatus* (Fieber) (Hemiptera: Anthocoridae) (Biondi et al., 2012). In contrast, Martinou et al. (2014) found that emamectin benzoate was harmless to another mirid, *M. pygmaeus* adults, under laboratory experiments. In addition, Amor et al. (2012) reported similar findings under semifield conditions for *M. pygmaeus*. Dáder et al. (2020) also determined that emamectin benzoate was only slightly harmful in a study conducted under greenhouse conditions with natural prey, including *T. absoluta* and *B. tabaci*. It is probable that different insecticide application rates, more than double used in the present study, and the insufficiency of the artificial diet provided led to increased movement of the predators on the plant and higher exposure to the insecticide, and thereby higher mortality. Also, emamectin benzoate is a systemic insecticide with a translaminar property; it is possible that omnivorous insects, such as *N. tenuis*, could ingest more toxic substances due to feeding directly the plant rather than just insecticide-contaminated prey.

One of the most important goals of IPM is the inclusion of insecticides that not harmful to the natural enemies of target pests. In the present study, it was revealed that spinetoram could be employed safely in IPM programs. Chlorantraniliprole + abamectin could potentially be used taking into consideration a possible effect on the predator population, which could be reduced by around 50%. Chlorantraniliprole + thiamethoxam has long lasting negative effects on the predator, so cannot be recommended. Caution should also be exercised in the use of emamectin benzoate, particularly at the application rates used in the present study, due to its harmful effects on *N. tenuis*.

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