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Residual Contact Toxic Effects of Spinosyn Insecticide, Spinetoram Against German Cockroach (*Blatella germanica*) Adults

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ABSTRACT

The study investigated the residual contact toxicity of spinetoram suspension, which is spinosyn (semi-synthetic) insecticide, against *Blatella germanica* (L.) adults on the surfaces of concrete, ceramic floor tile and parquet. On three different surfaces, *B. germanica* adults were exposed with spinetoram suspension at the rates of 2.5, 5, 7.5, 10, 15, 25, 50, 75, 100 mg^{-m2} and mortality of *B. germanica* adults were recorded at the day of 1, 3, 5, 7 and 9. In all surface applications of spinetoram, exposure times and concentrations caused significant effect on mortality rates of *B.germanica* adults. Lower concentrations of spinetoram (2.5 and 5 mg^{-m2}) on the all-applied surfaces caused low mortality of adults of *B. germanica*. However, 75 and 100 mg/m^2 concentrations caused 100% mortality of *B. germanica* adults after 5 day of exposure time. In general, while mortality rate of *B. germanica* adults increased with exposure time, 100% mortality was not achieved for the concentrations of spinetoram (7.5, 10, 15, 25 and 50 mg^{-m2}). There were significant differences in the efficacy of spinetoram concentrations against *B. germanica* adults on all three applied surfaces. At 100 mg^{-m2} concentration of spinetoram, mortality of *B. germanica* adults was higher on concrete surface than the other surfaces. However, other concentrations of spinetoram, mortality of adults was generally similar on all three surfaces. As a result, spinetoram has potential to control of house pest, *B. germanica,* and decreases using of dangerous conventional synthetic insecticides.

Research Article

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Yarı Sentetik Spinosin Insektisidi Spinetoram' ın Alman Hamam Böceği (*Blatella Germanica* (L.))' Ergin Dönemine Karşı Rezidual Kontak Toksik Etkisi

ÖZET

Mevcut çalışmada laboratuar koşullarında yarı-sentetik spinosin insektisidi Spinetoram' ın solüsyon halinde üç farklı uygulama yüzeyinde (beton, fayans ve parke) Alman Hamam böceği 'nin ergin dönemine karşı kontak toksisitesi araştırılmıştır. Üç farklı yüzeyde *B. germanica*' erginlerine karşı 1, 3, 5, 7, 9 gün süreyle Spinetoram' ın 2.5, 5, 7.5, 10, 15, 25, 50, 75, 100 (mg aktif madde^{-m2}) konsantrasyon-larında biyolojik testler yapılmıştır. *B.germanica* erginlerinin ölüm oranları üzerinde spinetoram' ın tüm uygulama yüzeylerinde spinetoram konsantrasyonu ve maruz bırakma süresi önemli etkiye sahip olmuştur. Spinetoram' ın düşük konsantrasyonları (2.5 ve 5 mg^{-m2}) tüm uygulama yüzeylerinde *B.germanica* nimf ve erginlerini düşük oranlarda öldürmüştür. Diğer yandan Spinetoram' ın 75 ve 100 mg^{-m2} konsantrasyonları her üç uygulama yüzeyinde uygulamanın 5. gününde *B.germanica* erginlerinde %100 ölüme sebep olmuştur. Genel olarak, *B. germanica* erginlerinin ölüm oranı maruziyet süresi ile artarken, spinetoram konsantrasyonları için (7.5, 10, 15, 25 ve 50 mg^{-m2})% 100 ölüm sağlanamamıştır. Uygulanan üç yüzeyin hepsinde *B. germanica* erginlerine karşı spinetoram konsantrasyonlarının etkililiğin de önemli farklılıklar olusmuştur. 100 mg / m^2 spinetoram konsantrasyonunda *B. germanica* erginlerinin ölüm oranı beton

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yüzeyde diğer yüzeylere göre daha yüksek gerçekleşmiştir. Bununla birlikte, diğer spinetoram konsantrasyonlarda, erginlerin ölüm oranı genellikle üç yüzeyde de benzer olmuştur. Bu çalışmadan çıkan sonuç Spinetoram' ın ev ve diğer binalarda sorun olan *B.germanica* mücadelesinde kullanılabilme potansiyeline sahip olduğu ve Spinetoram' ın bu zararlıya karşı kullanılan çevreye zararlı kimyasalların oranını azaltacağı düşünülebilir.

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INTRODUCTION

Cockroaches are widely distributed in the World (Demirsoy, 1990) and are found in hot and humid places and generally in places with common living areas such as houses, restaurants, bakeries, hotels. Besides causing harmful effect to people, they also contaminate food stuffs. They also transmit infectious diseases such as cholera, plague, childhood paralysis (Bitter and Williams, 1949; Öden, 1962; Burgess et al., 1973; Çetin et al., 1973). They also cause allergies in humans, as they carry pathogens (Waldvogel et al., 1999). In addition to continuing their life activities in this way, they are vectoring various diseases, especially by carrying a variety of pathogenic microorganisms on the countertops due to wandering around. Most food poisoning occurs when humans consume foodstuffs that cockroaches leave their saliva, feces and eggs. They infect bacteria and protozoans when they get stuck and then they get on the food. Therefore, they are harmful, medical and economical pests (Roberts, 1996). Synthetic pesticides are applied intensively for managements of pest insects in homes and in food-producing areas. Cockroaches are commonly controlled by synthetic insecticides (Rust et al., 1993). Long-term use of broad-spectrum synthetic insecticides is known to be a very harmful effect on the environment, human health and beneficial organisms (Pimentel et al., 1992; Mansouri et al., 2004). However, cockroaches have improved resistance to a wide range of insecticides (Rust and Reierson, 1991; Dong et al., 1998; Holbrook et al., 1999; Zhang et al., 2007). In addition, the cost of production required to develop a new insecticide is high (Thacker, 1999). Therefore, as German cockroaches threaten human and animal health, damage to natural biological equilibrium, resistance to insecticides, it is necessary to develop alternative control methods against cockroaches in order to minimize their damage or to reduce their populations. In recent years, increasing consciousness of people towards the environment and natural pesticides have been searched for alternatives that have less impact on the environment and non-target organism. It can be also broken down more quickly and easily than synthetic pesticides which is negative effects on human health (Arnason et al., 1989; Feng and Isman, 1995; Wewetzer, 1995; Hedin et al., 1997; Momen et al., 2004).

The semi-synthetic spinosin insecticide spinetoram that are both protective and contact active has lower toxicity to the environment, mammals and birds. Spinetoram needs to be investigated in the control of German cockroaches for the reason that it is not done up to now with the spinetoram against German cockroaches. Spinosad, derived from the fermentation product of the *Saccharopolyspora spinosa* bacterium from the Actinomycete class, naturally found in the soil, is a commercially available insecticide (Mertz & Yao 1990). Spinosad is active on the insect nervous system in an uncertain location on nicotinic acetylcholine receptors, and it is contact and stomach effects (Dripps et al., 2011). Spinosad has a low toxicity to mammals (acute oral oral LD50 > 5000 mg / kg) and a rapid decrease in activity when exposed to sunlight (Thompson et al., 2000; Dow AgroSciences, 2006). Spinetoram is a new member of semi-synthetic spinosin insecticides. Spinetoram is a low-risk insecticide (DeAmicis et al., 2011; Dow AgroSciences, 2006; EPA, 2009; FAO, 2010) resulting from the chemical modification of Spinosine (spinosin L and J) resulting from the fermentation of the *Saccharopolyspora spinosa* bacterium from the Actinomycete class. Spinetoram is a new spinosin insecticide with faster and higher potency compared to spinosad (Dripps et al., 2008; Sparks et al., 2008). Spinetoram is a broad-spectrum insecticide against many pest insects including Lepidoptera, Thysanoptera and Diptera in many plants. Low doses of spinetoram (10 µg / ml) show low toxicity against the pretadors such as Chrysopidae and Hemiptera (Copping et al., 2001; DeAmicis et al., 1997; Gamal et al., 2007; Kirst et al., 1992; Mahmoud et al., 2007; Williams et al., 2003). This active substance has also low toxicity to birds and mammals (Bret et al., 1997). It has been shown by the US Environmental Protection Agency as one of the insecticides with low toxicity to the environment (Dow AgroSciences, 2008). The spinetoram acts quickly when taken by the stomach and stops feeding within 24 hours and death occurs. When the mechanism of action of the spinetoram is examined, it is effective on nicotinic acetylcholine and gamma amino butyric acid (GABA) receptors (Williams et al., 2003).

Because of the low negative effect of the semisynthetic spinosin insecticide spinetoram on the environment and lack of studies on German cockroaches with this insecticide, this study investigates to determine the residual contact toxicity of spinetoram against adult stages of German cockroaches using spraying technique on three different application surfaces (concrete, ceramic floor tile and parquet).

MATERIALS and METHODS

Insect

Blatella germanica colonies were grown in plastic cups (60 liters) and kept at room temperature. The habitat of *B. germanica* (L.) was provided with egg containers placed in plastic boxes. We supplied water in glass tubes with cotton stoppers and dry dog food to the insects. For biological tests, the adult stages of *B. germanica* (L.) were used.

Surfaces Used in Biological Tests

Parquet Surface

Laminated parquet, which is produced in accordance with HDR and 717 E-1 standards, is 8 × 195 × 1200 mm in dimensions and is cut to dimensions of 100 × 100 mm and dimensioned for use in the tests.

Tile Surface

The tile surfaces used in the study are 150 × 150 × 5.5 mm in size, according to TS202 standards, from the mixture of clay, kaolin, quartz, feldspar and limestone materials and they are reduced to 100 × 100 mm dimensions.

Concrete Surface

Concrete surface used in biological tests The mortar obtained from a mixture of 200 g cement + 50 ml water was poured into plastic boxes (100 × 100 × 60 mm) and then the plastic boxes which were poured with mortar were left to dry to form the concrete surface.

Pressure Adjustable Machine for Surface Spraying

The Airbrush compressor is used in surface spraying for biological tests. HSENG Airbrush AS18 (Ningbo Haosheng Pneumatic Machinery Co., Zhejiong China). On the pressure gauge, pressure regulator, air filter and airbrush (paint gun), start at 30 psi, adjustable pressure, stop at 60 psi (available special pressure). Airbrush compressor, power: 1/5 HP, voltage: 220-240 V, frequency: 50 HZ, size: 25.5 × 13.5 × 17 cm, net weight: 3.6 kg. Paint gun, nozzle: 0.2 mm, working pressure: 15 - 50 psi, reservoir capacity: 2 ml.

Spinetoram Surface Applications in Laboratory Conditions against German cockroach

Biological tests were conducted in a completely dark climate room of 25 ± 1 °C temperature and 65 ± 5% relative humidity. In the biological tests, adult German cockroach was used, spinetoram, commercial preparation Delegate 250 WG, was used on concrete, tile, parquet surfaces in plastic boxes. In the biological tests, the control and experiments were conducted in 5 replications and 10 insects were used for each replicate. The amount of active substance corresponding to the concentrations of 2.5, 5, 7.5, 10, 15, 25, 50, 75, 100 mg/m^2 (mg active substance /m^2 surface area) was weighed with a precision scale (0.0001 g). Ten ml of pure water was added to the glass beaker (50 ml) with glass cylinder (10 ml) and the weighed amount of insecticide was transferred into a glass beaker and mixed with magnetic stirrer for 10 min. One ml of spinetoram was used for each repetition of each concentration application in surface spraying. In each concentration application, the spinetoram suspension, which was used for each concentration, was sprayed homogeneously on the application surfaces with the spraying pump by putting the micropipette (1000 µl) into the reservoir of the pressurized spraying pump. After the surfaces were dried and holes were opened to provide air inlet and outlet to the lids of the plastic box, 10 adult insects were placed in plastic boxes for each replication. Experiments were kept in a dark climate room of 25 ± 1 °C temperature and 65 ± 5% relative humidity. In the experiment daily motility rates were recorded. Compared to control insects, insects with no antennas and legs movements were considered dead (Toews et al., 2003).

Evaluation of Data and Statistical Analysis

The mortality rates (%) of *B. germanica* were calculated for each surface application and subjected to Arcsine transformations and bi-directional (factors, exposure duration and application concentration) variance analysis (ANOVA) (Proc GLM; SAS Ins., 2009) was applied. The differences between the means were determined according to the 5% significance level LSD (SAS Ins., 2009).

RESULTS

Mortality Rates of *Blatella germanica* Adults Exposed to Different Concentrations of Spinetoram on Concrete Surface

The mortality rate (%) of *B. germanica* exposed to different concentrations of spinetoram on the concrete surface for 9 days is given in Table 1. Significant differences were found among mortality rates of all concentrations of spinetoram in all exposures (Table 1, $P < 0.0001$). There was no statistically significant difference between the mortality rates of the controls and low concentrations of spinetoram (2.5, 5 mg/m^2) (Table 1) at day 1 and the lowest mortality rates were obtained at day 1 at all the concentrations of spinetoram. Mortality rates for 75 and 100 mg/m² concentrations on the 7th and 9th day were statistically similar. Mortality rates for spinetoram 75 and 100 mg/m² concentrations were significantly higher than those of spinetoram 2.5, 5, 7.5, 10, 15, 25, 50 mg/m² concentrations at the exposure times (days 3, 5, 7 and 9) except first day of exposure time. Overall, there was a significant increase in mortality rates at subsequent concentrations of 25 mg/m² of spinetoram in all other exposure times except day 1. Although the slowing of movement in insects was observed from day 3, 100% mortality of *B. germanica* adults was obtained at day 7 with concentrations of 75 and 100 mg/m². Tested all the concentrations of spinetoram caused very low mortality of the *B. germanica* adults after one day exposure. On the other hand, at the end of 7th and 9th day, high concentrations of spineoram (50, 75, 100 mg/m²) resulted in 100% and nearly 100% of deaths of the adults.

Horizontally, there was a statistically significant difference in the mortality rates of *B. germanica* adults exposed to all concentrations of spinetoram at the concrete surface (Table 1, P < 0.0001). The highest mortality rate at all concentrations was obtained on day 9 while the lowest mortality was obtained on day 1 (Table 1). The mortality rates at 3, 5, 7 and 9 days at all concentrations were significantly higher than those obtained at day 1. When the table is examined horizontally, it is found that the mortality rates at day 9 are significantly higher than those at day 7 at 2.5, 5 and 25 mg/m² concentrations Table 1). In general, the mortality rates at 9th day and 7th day in the concentrations of spinetoram 75 and 100 mg/m² were statistically similar while mortality rates at 9th day in the concentrations 2.5 and 5 mg/m² were higher than at 7th day (Table 1).

Mortality Rates of *Blatella germanica* Adults Exposed to Different Concentrations of Spinetoram on Tile Surface

The mortality rate (%) of *B. germanica* exposed for 9 days to different concentrations of spinetoram on the tile surface is given in Table 2. Statistically significant differences between mortality rates for all concentrations of spinetoram in a majority of exposures, if not all, when examined vertically (Table 2, P < 0.0001). In general, an increase in the mortality rate was observed with increasing concentrations of spinetoram during all exposure periods (Table 2).

Horizontally, there was a statistically significant difference in the mortality rates of *B. germanica* adults exposed to all concentrations of spinetoram on the tile surface (Table 2, P < 0.0001). At all concentrations, the highest mortality rate was obtained on day 9 while the lowest mortality rate was obtained on day 1 (Table 2). As a result, the mortality rates of the adults of *B. germanica* at 3rd, 5th, 7th, and 9th day were higher than the mortality rates in 1st day at all concentrations except 7.5 and 50 mg/m².

Mortality Rates of *Blatella germanica* Adults Exposed to Different Concentrations of Spinetoram on Parquet Surface

The mortality rate (%) of the adults of *B. germanica* exposed to different concentrations of spinetoram on the parquet surface for 9 days is given in Table 3. Statistically significant differences were found between mortality rates for all concentrations of spinetoram in all exposure times (Table 3, P < 0.0001). The lowest mortality rates of the adults of *B. germanica* were obtained on day 1 at all concentrations applied. On day 9, concentrations of 75 and 100 mg/m² were statistically similar. Mortality rates at concentrations of 75 and 100 mg/m² at day 9 were statistically significantly higher than the mortality rates at concentrations of 2.5, 5, 7.5, 10, 15, 25 and 50 mg/m².

When examined Table 3. horizontally, there was a statistically significant difference in the mortality rates of *B. germanica* adults from all concentrations of spinetoram on the parquet surface (Table 3, P < 0.0001). The highest mortality rate at all concentrations was obtained on day 9 while the lowest mortality was obtained on day 1 (Table 3). Adult mortality rates at all concentrations other than 50 and 75 mg/m² on day 9 were statistically similar to adult mortality on day 7.

The Effect of the Applied Surface on *Blatella germanica* Mortality

Horizontally, it was observed that there was no statistically significant difference between the mortality rates of *B. germanica* adults on all application surfaces at all concentrations except 75 and 100 mg/m² on the 3rd day. In all concentrations (2.5, 5, 10, 15, 25 and, 50 mg/m²) of spinetoram except 75 and 100 mg/m², the mortality rates on concrete, tile and parquet surfaces were found to be statistically similar (Table 4). In general, it was observed that spinetoram was more effective against *B. germanica* adults on concrete surface and especially at high concentrations (75 and 100 mg/m²) than on tile and parquet surfaces.

Mortality rates on the 5th day of *B. germanica* adults exposed to different concentrations of spinetoram on concrete, tile and parquet surfaces are given in Table 5. It was observed that there was no statistically significant difference between the mortality rates of *B. germanica* adults on all application surfaces at all concentrations except 100 mg/m² on the 5th day. It was observed that Spinetoram was more effective against *B. germanica* adults on concrete surface than on tile and parquet surfaces at concentration of 100 mg/m².

Table 1. Mortality rate of *Blatella germanica* adults exposed to different concentrations of spinetoram on concrete surface for 9 days

Çizelge 1. Beton yüzey üzerinde Spinetoram' ın farklı konsantrasyonlarına 9 gün süreyle maruz bırakılan Blatella germanica erginlerinin ölüm oranı

Concentration (mg / m²)	Mortality rate (%) * ± S.E					F and P value	LSD value
	1.day	3.day	5.day	7.day	9.day		
2.5	0 ± 0^{Cd}	8 ± 2^{EFc}	16 ± 2.44^{DEc}	32 ± 2^{Eb}	56 ± 2.44^{Da}	$F_{4,20} = 81.45$; $P < 0.0001$	6.0466
5	2 ± 2^{Cd}	12 ± 2^{DEFc}	22 ± 2^{Dc}	40 ± 3.16^{DEb}	60 ± 3.16^{CDa}	$F_{4,20} = 65.08$; $P < 0.0001$	6.5905
7.5	4 ± 2.44^{BCc}	16 ± 2.44^{CDEb}	30 ± 3.16^{CDb}	52 ± 3.74^{CDEa}	60 ± 3.16^{CDa}	$F_{4,20} = 3649$; $P < 0.0001$	7.9713
10	4 ± 2.44^{BCc}	28 ± 3.74^{BCDb}	48 ± 2^{BCa}	54 ± 2.44^{CDa}	66 ± 4^{CDa}	$F_{4,20} = 47.70$; $P < 0.0001$	7.8893
15	8 ± 3.74^{BCc}	30 ± 4.47^{BCDb}	50 ± 3.16^{BCab}	60 ± 3.16^{CDa}	70 ± 3.16^{CDa}	$F_{4,20} = 31.94$; $P < 0.0001$	9.1284
25	8 ± 2^{BCd}	32 ± 6.63^{BCc}	58 ± 3.74^{Bb}	66 ± 2.44^{Cab}	80 ± 4.47^{BCa}	$F_{4,20} = 36.63$; $P < 0.0001$	9.4334
50	12 ± 2^{ABd}	38 ± 2^{Bc}	68 ± 3.74^{Bb}	88 ± 3.74^{Ba}	92 ± 3.74^{ABa}	$F_{4,20} = 45.56$; $P < 0.0001$	10.406
75	16 ± 4^{ABd}	74 ± 4^{Ac}	90 ± 4.47^{Ab}	100 ± 0^{Aa}	100 ± 0^{Aa}	$F_{4,20} = 75.28$; $P < 0.0001$	9.4972
100	28 ± 2^{Ac}	72 ± 2^{Ab}	98 ± 2^{Aa}	100 ± 0^{Aa}	100 ± 0^{Aa}	$F_{4,20} = 193.58$; $P < 0.0001$	5.4598
Control	0 ± 0^{Ca}	4 ± 2.44^{Fa}	6 ± 2.44^{Ea}	8 ± 3.74^{Fa}	8 ± 3.74^{Ea}	$F_{4,20} = 1.45$; $P = 0.2540$	-
F and P value	$F_{9,40} = 9.73$ $P < 0.0001$	$F_{9,40} = 34.61$ $P < 0.0001$	$F_{9,40} = 56.57$ $P < 0.0001$	$F_{9,40} = 85.01$ $P < 0.0001$	$F_{9,40} = 59.06$ $P < 0.0001$		
LSD value	9.4962	8.2654	8.8151	7.5522	8.4936		

*Two-way analysis of variance (ANAVO) was applied to the data and the differences between the averages were determined according to LSD test at 5% significance level. Different upper-case letters in the same column and different lower-case letters in the same line are statistically different from each other.

Table 2. Mortality rate of *Blatella germanica* adults exposed to different concentrations of spinetoram on tile surface for 9 days

Çizelge 2. Fayans yüzey üzerinde Spinetoram' ın farklı konsantrasyonlarına 9 gün süreyle maruz bırakılan Blatella germanica erginlerinin ölüm oranı

Concentration (mg/m²)	Mortality rate (%)* ± S.E					F and P value	LSD value
	1.day	3.day	5.day	7.day	9.day		
2.5	2 ± 2^{DEd}	12 ± 2^{Ec}	20 ± 0^{Ebc}	32 ± 3.74^{Fb}	50 ± 3.16^{Ea}	$F_{4,20} = 47.95$; $P < 0.0001$	6.6105
5	4 ± 2.44^{CDEd}	14 ± 2.44^{DEc}	32 ± 3.74^{DEb}	46 ± 2.44^{EFab}	52 ± 2^{Ea}	$F_{4,20} = 38.39$; $P < 0.0001$	7.6046
7.5	10 ± 3.16^{BCDc}	20 ± 3.16^{CDEc}	38 ± 3.74^{CDb}	54 ± 2.44^{DEab}	60 ± 3.16^{DEa}	$F_{4,20} = 29.60$; $P < 0.0001$	7.8154
10	12 ± 2^{ABCd}	28 ± 3.74^{BCDc}	46 ± 4^{BCDb}	62 ± 2^{CDEa}	72 ± 3.74^{CDEa}	$F_{4,20} = 56.71$; $P < 0.0001$	6.0195
15	14 ± 2.44^{ABd}	30 ± 3.16^{BCDc}	50 ± 3.16^{BCDb}	64 ± 4^{CDEb}	80 ± 3.16^{BCDa}	$F_{4,20} = 60.87$; $P < 0.0001$	6.2428
25	18 ± 3.74^{ABe}	36 ± 4^{BCd}	54 ± 2.44^{BCc}	70 ± 3.16^{BCDb}	86 ± 2.44^{BCa}	$F_{4,20} = 61.63$; $P < 0.0001$	6.3904
50	18 ± 3.74^{ABd}	36 ± 5.09^{BCcd}	60 ± 3.16^{Bbc}	74 ± 4^{BCb}	90 ± 4.47^{BAa}	$F_{4,20} = 30.68$; $P < 0.0001$	10.558
75	22 ± 3.74^{ABe}	40 ± 3.16^{BAd}	60 ± 3.16^{Bc}	82 ± 3.74^{Bb}	100 ± 0^{Aa}	$F_{4,20} = 131.73$; $P < 0.0001$	6.2301
100	28 ± 3.74^{Ad}	56 ± 4^{Ac}	84 ± 4^{Ab}	100 ± 0^{Aa}	100 ± 0^{Aa}	$F_{4,20} = 162.70$; $P < 0.0001$	5.9302
Control	0 ± 0^{Eb}	2 ± 2^{Fab}	5 ± 2.44^{Fab}	12 ± 3.74^{Ga}	12 ± 3.74^{Fa}	$F_{4,20} = 4.14$; $P = 0.0132$	11.88
F and P value	$F_{9,40} = 12.91$ $P < 0.0001$	$F_{9,40} = 26.06$ $P < 0.0001$	$F_{9,40} = 40.34$ $P < 0.0001$	$F_{9,40} = 62.32$ $P < 0.0001$	$F_{9,40} = 58.68$ $P < 0.0001$		
LSD value	8.5161	6.9917	6.8479	6.9156	8.2441		

*Two-way analysis of variance (ANAVO) was applied to the data and the differences between the averages were determined according to LSD test at 5% significance level. Different upper-case letters in the same column and different lower-case letters in the same line are statistically different from each other.

Table 3. Mortality rate of *Blatella germanica* adults exposed to different concentrations of spinetoram on parquet surface for 9 days
Çizelge 3. Parke yüzey üzerinde Spinetoram' ın farklı konsantrasyonlarına 9 gün süreyle maruz bırakılan Blatella germanica erginlerinin ölüm oranı

Concentration (mg / m²)	Mortality rate (%)* ± S.E					F and P value	LSD value
	1.day	3.day	5.day	7.day	9.day		
2.5	4 ± 2.44 CDd	10 ± 3.16 EFcd	18 ± 2 Dbc	28 ± 3.74 FGab	46 ± 4 Ea	$F_{4,20}$ = 17.43; P < 0.0001	9.6312
5	4 ± 2.44 CDd	14 ± 2.44 DEc	26 ± 2.44 CDbc	40 ± 3.16 EFab	48 ± 2 Ea	$F_{4,20}$ = 33.26; P < 0.0001	7.4412
7.5	8 ± 3.74 BCDd	16 ± 2.44 DEcd	32 ± 3.74 CDbc	46 ± 2.44 DEab	56 ± 2.44 DEa	$F_{4,20}$ = 24.65; P < 0.0001	8.6038
10	12 ± 3.74 ABCDc	24 ± 2.44 CDc	44 ± 4 BCb	58 ± 3.74 CDEab	72 ± 2 CDa	$F_{4,20}$ = 33.31; P < 0.0001	8.1686
15	16 ± 509 ABCDd	30 ± 3.16 BCDcd	44 ± 2.44 BCbc	62 ± 3.74 CDab	78 ± 3.74 CBa	$F_{4,20}$ = 25.33; P < 0.0001	9.4487
25	18 ± 3.74 ABCd	36 ± 2.44 ABCc	54 ± 2.44 Bbc	68 ± 3.74 Cab	82 ± 3.74 CBa	$F_{4,20}$ = 45.35; P < 0.0001	6.83
50	24 ± 2.44 ABd	40 ± 3.16 ABCcd	56 ± 5.09 Bbc	70 ± 3.16 Cb	88 ± 3.74 Ba	$F_{4,20}$ = 31.70; P < 0.0001	8.6062
75	26 ± 5.09 ABd	44 ± 2.44 ABc	60 ± 4.47 ABc	86 ± 2.44 Bb	100 ± 0 Aa	$F_{4,20}$ = 108.53; P < 0.0001	6.6591
100	30 ± 3.16 Ad	54 ± 4 Ac	76 ± 4 Ab	98 ± 2 Aa	100 ± 0 Aa	$F_{4,20}$ = 61.90; P < 0.0001	8.8563
Control	2 ± 2 Db	4 ± 2.44 Fab	6 ± 2.44 Eab	14 ± 2.44 Ga	14 ± 2.44 Fa	$F_{4,20}$ = 5.48; P = 0.0038	10.414
F and P value	$F_{9,40}$ = 6.70 P < 0.0001	$F_{9,40}$ = 22.88 P < 0.0001	$F_{9,40}$ = 31.95 P < 0.0001	$F_{9,40}$ = 65.01 P < 0.0001	$F_{9,40}$ = 65.25 P < 0.0001		
LSD value	11.681	7.4092	7.2923	6.517	7.3919		

*Two-way analysis of variance (ANAVO) was applied to the data and the differences between the averages were determined according to LSD test at 5% significance level. Different upper-case letters in the same column and different lower-case letters in the same line are statistically different from each other

Table 4. Mortality rates of *Blatella germanica* adults on day 3 exposed to different concentrations of spinetoram on different surfaces
Çizelge 4. Farklı yüzeyler üzerinde Spinetoram' ın farklı konsantrasyonlarına maruz bırakılan Blatella germanica erginlerinin 3. gündeki ölüm oranları

Concentration (mg / m²)	Mortality rate (%)* ± S.E			F and P value	LSD value
	Concrete surface	Tiles surface	Parquet surface		
2.5	8 ± 2 FEa	12 ± 2 Ea	10 ± 3.16 EFa	$F_{2,12}$ = 0.63; P = 0.5509	-
5	12 ± 2 FEDa	14 ± 2.44 EDa	14 ± 2.44 EDa	$F_{2,12}$ = 0.26; P = 0.7828	-
7.5	16 ± 2.44 CEDa	20 ± 3.16 ECDa	16 ± 2.44 EDa	$F_{2,12}$ = 0.65; P = 0.5392	-
10	28 ± 3.74 CBDa	28 ± 3.74 BCDa	24 ± 2.44 DCa	$F_{2,12}$ = 0.46; P = 0.6439	-
15	30 ± 4.47 CBDa	30 ± 3.16 BCDa	30 ± 3.16 BDCa	$F_{2,12}$ = 0.00; P = 0.9990	-
25	32 ± 6.63 CBa	36 ± 4 BCa	36 ± 2.44 BACa	$F_{2,12}$ = 0.32; P = 0.7288	-
50	38 ± 2 Ba	36 ± 5.09 BCa	40 ± 3.16 BACa	$F_{2,12}$ = 0.33; P = 0.7273	-
75	74 ± 4 Aa	40 ± 3.16 BAb	44 ± 2.44 BAb	$F_{2,12}$ = 31.18; P < 0.0001	6.1556
100	72 ± 2 Aa	56 ± 4 Ab	54 ± 4 Ab	$F_{2,12}$ = 8.34; P = 0.0054	-
Control	4 ± 2.44 Fa	2 ± 2 Fa	4 ± 2.44 Fa	$F_{2,12}$ = 0.25; P = 0.7828	-
F and P value	$F_{9,40}$ = 34.61 P < 0.0001	$F_{9,40}$ = 26.06 P < 0.0001	$F_{9,40}$ = 22.88 P < 0.0001		
LSD value	8.2654	6.9917	7.4092		

*Two-way analysis of variance (ANAVO) was applied to the data and the differences between the averages were determined according to LSD test at 5% significance level. Different upper-case letters in the same column and different lower-case letters in the same line are statistically different from each other.

Table 5. Mortality rates of *Blatella germanica* adults on day 5 exposed to different concentrations of spinetoram on different surfaces
Çizelge 5. Farklı yüzeyler üzerinde Spinetoram' ın farklı konsantrasyonlarına maruz bırakılan Blatella germanica erginlerinin 5. gündeki ölüm oranları

Concentration (mg / m^2)	**Mortality rate (%)* ± S.E**			**F and P value**	**LSD value**
	Concrete surface	**Tiles surface**	**Parquet surface**		
2.5	16 ± 2.44 ^{EDa}	20 ± 0 ^{Ea}	18 ± 2 ^{Da}	$F_{2,12}$ = 1.20; P = 0.3349	-
5	22 ± 2 ^{Da}	32 ± 3.74 ^{EDa}	26 ± 2.44 ^{DCa}	$F_{2,12}$ = 3.11; P = 0.816	-
7.5	30 ± 3.16 ^{CDa}	38 ± 3.74 ^{CDa}	32 ± 3.74 ^{DCa}	$F_{2,12}$ = 1.35; P = 0.2964	-
10	48 ± 2 ^{CBa}	46 ± 4 ^{CBDa}	44 ± 4 ^{BCa}	$F_{2,12}$ = 0.34; P = 0.7169	-
15	50 ± 3.16 ^{CBa}	50 ± 3.16 ^{CBDa}	44 ± 2.44 ^{BCa}	$F_{2,12}$ = 1.38; P = 0.2877	-
25	58 ± 3.74 ^{Ba}	54 ± 2.44 ^{CBa}	54 ± 2.44 ^{Ba}	$F_{2,12}$ = 0.63; P = 0.5495	-
50	68 ± 3.74 ^{Ba}	60 ± 3.16 ^{Ba}	56 ± 5.09 ^{Ba}	$F_{2,12}$ = 2.27; P = 0.1461	-
75	90 ± 4.47 ^{Aa}	60 ± 3.16 ^{Ba}	60 ± 4.47 ^{BAa}	$F_{2,12}$ = 13.20; P = 0.0009	12.167
100	98 ± 2 ^{Aa}	84 ± 4 ^{Ab}	76 ± 4 ^{Ab}	$F_{2,12}$ = 16.81; P = 0.0003	9.9217
Control	6 ± 2.44 ^{Ea}	5 ± 2.44 ^{Fa}	6 ± 2.44 ^{Ea}	$F_{2,12}$ = 0.00; P = 1.0000	-
F ve P value	$F_{9,40}$ = 56.57 P < .0001	$F_{9,40}$ = 40.34 P < .0001	$F_{9,40}$ = 31.95 P < .0001		
LSD value	8.8151	6.8479	7.2923		

*Two-way analysis of variance (ANAVO) was applied to the data and the differences between the averages were determined according to LSD test at 5% significance level. Different upper-case letters in the same column and different lower-case letters in the same line are statistically different from each other

DISCUSSION

This laboratory study has investigated residual contact toxicity for spinetoram to adults of *B. germanica* on three different application surfaces (concrete, tiles and parquet). Different concentrations of spinetoram and exposure times have had significant impact on the mortality rates of adults of *B. germanica*. In general, at the end of day 1, all the tested concentrations of spinetoram showed that adults of *B. germanica* hardly ever died, and that at all concentrations the mortality of adults of *B. germanica* increased significantly after day 1. Similar to these results, Çelik (2013) investigated residual contact toxicity of spinetoram against *Acanthoscelides obtectus* adults on solution concrete, tile and parquet surface in solution and determined that the duration and concentration of spinetoram as a result of the study had a significant effect on the insect mortality rate. Rişvanlı (2015) also investigated the residual contact toxicity of spinetoram against *P. americana* adults on concrete, tile and parquet surface and it was determined that spinetoram had a significant effect on the mortality rate of *P. americana* adults. Low concentrations of Spinetoram (0.001 and 0.002 mg/cm^2) on all application surfaces caused a low mortality rate in *P. americana* adults. In addition, concentrations of Spinetoram 0.005 mg/cm^2 and above on all application surfaces caused 100% mortality in *P. americana* adults. All of these results indicate that the effectiveness of spinetoram may vary depending on the insect species tested and application concentration. In addition, in the present study, as in these studies, it was found that spinetoram exposure time and concentration had a significant effect on mortality. In the present study, it was seen that with the tested low concentrations of spinetoram on all application surfaces (concrete, tiles and parquet) caused very low mortality of *B. germanica* adults, but the majority of them died especially at high concentrations (75 and 100 mg/m^2). In general, low concentrations of Spinetoram (2.5, 5, 7.5, 10, 15, 25 and 50 mg/m^2) on all application surfaces caused very low mortality of *B. germanica* adults. All these results showed that spinetoram concentrations of 75 mg/m^2 and above could successfully control *B. germanica* adults on all application surfaces.

The application surface of spinetoram had a significant effect on the mortality rates of *B. germanica* adults. The efficacy of spinetoram on application surfaces against *B. germanica* adults showed significant differences in application concentrations. According to the mortality rates on the third and 5th days, the effectiveness of spinetoram against *B. germanica* adults was found to be the same in lower concentrations on concrete, tile and parquet surfaces. However, it has been determined that the effectiveness of spinetoram against *B. germanica* adults is significantly higher on the concrete surfaces at higher (75 and 100 mg/m^2) concentrations than the tile and parquet surfaces. Similarly, several studies have shown that the application surface, the insect species tested and the insecticide formulation against the stored product pests have significant effects on different contact and residual insecticides (Williams et al., 1983; Jain and Yadav, 1989; Samson and Hall, 1989; Arthur, 1997 and 2007). In addition, Toews et al. (2003) reported that the effect of spinosad against some stored grain pests, especially on concrete surfaces, was higher than that of galvanized steel, waxed and wax-free tile surfaces. Similar to these results, in the present study, it was found that spinetoram had higher activity against *B. germanica* adults on the surface of the concrete at higher concentrations than the tiles and parquet surfaces. This difference is thought to be due to the insect species tested, the formulation of the insecticides or the active substance tested. It can also be said that differences in the physical structure of concrete, tile and parquet surfaces cause differences in the effectiveness of spinetoram. In many studies (Chadwick, 1985; Hodges and Dales, 1991; Hodges, 1993), the residual activity of insecticides is higher on non-porous surfaces (glass, iron, ceramic tiles, etc.) than porous surfaces (such as concrete, burlap and mud).

As a result, concentrations of spinetoram solution 75 mg/m^2 and above showed high residual toxicity against *B. germanica* adults on all application surfaces (concrete, tiles and parquet) under laboratory conditions. Based on the data obtained, it is thought that the solution application of spinetoram can be used for the controlling of *B. germanica*, which is a problem in home and other buildings, and may be a potential alternative to synthetic insecticides. However, in order for spinetoram to be used commercially in the control of *B. germanica*, it is necessary to investigate the insecticide properties of spinetoram on real habitats of German cockroaches beside the laboratory and to investigate the applicability of spinetoram under natural conditions and to determine long-term residual contact toxicity.

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Author Contributions

The authors declare that they have contributed equally to the article. The authors declare that they have contributed equally to the article..

Conflicts of Interest

The authors declare no conflict of interest.

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