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Comparative evaluation of some commercial spray-applied insecticides as control method against Blatta orientalis

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Abstract: Cockroaches are globally distributed pests with high epidemic importance. Their role as spreaders of many infectious and parasitic diseases in animals and humans determines disinsection as the main anti-epidemic measure. The present study compared the effectiveness of spray application of different commercial insecticides against a field population of oriental cockroaches (B. orientalis) under laboratory conditions. A very high efficiency of fipronil (100% mortality) was found as early as 37-48 hours after treatment and a high efficiency of synthetic pyrethroids - 95-97% mortality at 49-60 hours. With the organophosphate derivatives (Dichlorvos) low mortality (37%) and unsatisfactory efficiency was achieved. The obtained results confirm the insecticides from the phenylpyrazole group and the synthetic pyrethroids, in spray-applied forms, as an effective method of fighting the oriental cockroach.

Keywords: Oriental cockroach; insecticides; spray method; pyrethroids; phenylpyrazoles; organophosphates

INTRODUCTION

Cockroaches are globally distributed insects, exhibiting rapidly adaptive behavior across a wide range of habitats. They are one of the common pests in anthropogenic biotopes (residential and public buildings, restaurants, food industry enterprises, livestock farms, etc. (Siddiqui et al., 2023). Their presence in these sites is associated with a high risk for the health of animals and humans due to their proven significant role as transmitters of many infectious pathogens, including those with zoonotic potential (Odinets et al., 1993; Donets, 2004; Vatev et al., 2006; Piper and Antonelli, 2012; Esty and Phipatanakul, 2018; Nasirian, 2019; Schapheer et al., 2018; Sookrung et al., 2018; Davari et al., 2023). Cockroaches also play an essential role in the spread of various parasites, being intermediate hosts for some of them (Varadinova et al., 2015; Nasirian, 2016; Atiokeng Tatang et al., 2017). Their health importance is also complemented by the release of various allergenic substances (Tachbele et al., 2006; Salehzadeh et al., 2007; Fakoorziba et al., 2010; Kassiri and Kazemi, 2012; Page , 2012; Pai, 2013; Motevali Haghi et al., 2014; Menasria et al., 2015; Davari et al., 2017; Martinez-Giron et al., 2017; Nasirian, 2017).

The control of cockroach infestations is often difficult and unsuccessful, due to their great adaptability and high fertility, year-round reproduction, wide food range, long endurance of starvation. In addition, the resistance of cockroaches to the insecticides widely used to control them is progressively increasing (Odinec, 1993; Lee et al., 2022; Scharf et al., 2022; Gits, M. P. et al., 2023).

The most widely used means to control cockroaches are insecticides (Lee et al., 2021). They are available in different formulations and ways of application – food-based insecticidal baits, contact sprays, powders, etc. Insecticides have a damage impact on the target pest by various mechanisms, some of which are aimed at a

precisely defined specific system - blocking of the enzyme cholinesterase, blocking of sodium channels in the neuronal membrane, antagonism of gamma-aminobutyric acid, etc. (Ghosal, A., 2018). In 2011 Shahraki et al., carried out a comparative assessment of the advantages and disadvantages of the most widely used insecticide agents in the fight against the German cockroach:

1. Organophosphate compounds (dichlorphos, etc.). Over the years, more than 100 insecticidal compounds of this group have been registered in use worldwide (Ishaaya and Horowitz, 1998; Salgado, 2013). Their mechanism of action is based on disrupting the function of the insect's nervous system by blocking the enzyme cholinesterase, which plays a major role in hydrolyzing acetylcholine. This results in irreversible paresis and paralysis (Ishaaya and Horowitz, 1998; Ware and Whitacre, 2004).

2. Synthetic pyrethroids (Lambda-cyhalothrin, cypermethrin, deltamethrin, tetramethrin, etc.). Pyrethroids affect the peripheral and central nervous systems of insects by causing blockade of sodium channels in neuronal membranes and are considered as axonal poisons (Radcliffe et al., 2009; Gour and Sridevi**,** 2012). They are distinguished by a rapid paralytic effect on insects, referred to as the „Knockdown effect".

3. Phenylpyrazole chemical family, such as Fipronil. It is a second-generation phenilpirazol insecticide that blocks Gamma-aminobutyric acid (GABA)-gated chloride channels in the central nervous system. Disruption of the GABA receptors by fipronil prevents the uptake of chloride ions resulting in excess neuronal stimulation and death of the target insect (Cole et al., 1993; Kreiger, 2001).

One of the approved and commonly used methods of insecticide application is by spray. The results of experiments with cockroaches show that spray application is an effective insecticidal method, enabling the use of a diverse spectrum of insecticides (Miller and Meek, 2004; Rahayu et al., 2016; Paramasivam and Selvi, 2017). However, almost all the studies were carried out with populations of *Blatella germanica*, which raises the question of the effectiveness of insecticides in other synanthropic species, such as *Blatta orientalis, Periplaneta americana*, etc.

The aim of the present study is to attempt to shed light on this question by comparing the effectiveness of some of the most commonly used commercial insecticides applied by spray to Oriental cockroaches (*Blatta orientalis*) captured in livestock facilities. We hope that the presented results will be helpful for optimization of the effectiveness of insecticide treatments against the Oriental cockroach, which has been established as a dominant synanthropic species in pig farms in the Republic of Bulgaria (Boneva et al., 2023).

MATERIALS AND METHODS

Using the spray method, the effectiveness of some of the most commonly used insecticides (Table 1) against a field population of black cockroaches (*B. orientalis*) caught in a pig farm was evaluated. To conduct the research, experimental and control groups of 6 cockroaches each (5th

Table 1. Insecticides used.

Insecticide (manufacturer) - concentration	Active ingredients (concentration)
Nuvan (Nuvan Pharma, Bulgaria) - 0.5%	Dichlorvos (35g/100ml)
Icon (Syngenta, Switzerland) - 0.5%	Lambda cyhalothrin (10g/100ml)
Ectomin (Pharma Vet, Bulgaria) - 0.2%	Cypermetrin (10g/100ml)
Neostomosan (CEVA, France) - 0.1%	Tetramethrin (5g/5ml)
Butox (MSD, Netherland) - 0.1%	Deltamethrin (5g/100ml)
Fiprist (KRKA, Slovenia) - 0.02%	Fipronil (2.5mg/1ml)

stage nymphs randomly selected) were formed. For easier handling, the cockroaches were previously immobilized by the cooling method by a 12-minute stay at t = 4-6°C, with a subsequent period of acclimatization before the treatment, in accordance with Mellanby (1939). The cockroaches were placed in petri dishes (9 cm diameter), the edges of which were pre-treated with a 1:1 mixture of baby oil and mineral oil to prevent their escape. The Petri dishes were placed in plastic boxes (30x30x60 cm), where they were subjected to the subsequent insecticide treatment by spraying with an insecticide solution from a distance of 15 cm at a dose of 40.7 ml/sq.m. (Gaire and Romero., 2020). The maximal concentrations of insecticide solutions recommended by the manufacturer were used. The solutions were prepared with distilled water and placed in identical single-use plastic vials with a volume of 30 ml, providing a dose of 0.095 ml for 1 injection. Each experiment was threefold repeated, and the average knockdown effect and mortality were measured at equal time intervals until the 72nd hour (Syed et al., 2014) or until reaching 100% mortality (Rahayu et al., 2016).

The data obtained have been processed with the statistical software IBM® SPSS® Statistics 26.0 (NY, USA). Statistical processing was performed by UNIANOVA analysis, applying Tamhane and Tukey test. The standard deviation and coefficient of determination were determined based on the observed means.

RESULTS AND DISCUSSION

In the tests for the effectiveness of the insecticides applied by the spray method, no knockdown effect was reported for any of the insecticides used (Table 2). The highest mortality rate (100%) was found after Fiprist treatment at 37-48 hours followed by Ectomin where 97.17% mortality was reported between 49-60 hours after treatment. High insecticidal efficiency (96.83 – 95.83% mortality) was also found after Icon, Neostomosan and Butox, in the same period after treatment. The lowest insecticidal efficiency

Table 2. Effectiveness of the spray application of insecticides against the field population of *Blatta orientalis*.

Monitoring period	Test groups					
	1. Icon	2. Butox	3. Ectomin	4. Fiprist	5. Neostomosan	6. Nuvan
	Mortality % ($\bar{x}$ ± SD)					
A: 01-12 h	$15.33\pm1.16^{a}_{2,3,4,5,6}$	$0.00\pm0.00^{a}_{1}$	$0.00\pm0.00^{a}_{1}$	$0.0\pm0.00^{a}_{1}$	$0.0\pm0.00^{a}_{1}$	$0.00\pm0.00^{a}_{1}$
B: 13-24 h	$76.00\pm1.30^{b}_{2,3,4,5,6}$	$34.67\pm2.26^{b}_{1,5,6}$	$32.33\pm1.55^{b}_{1,6}$	$44.0\pm2.07^{b}_{1,5,6}$	$19.83\pm2.08^{e}_{5}$	$6.50\pm1.05^{b}_{1,2,3,4,6}$
C: 25-36 h	$94.50\pm0.48^{e}_{2,3,5,6}$	$80.17\pm1.01^{c}_{1,4,5,6}$	$83.83\pm0.6^{c}_{1,4,5,6}$	$98.17\pm0.32^{c}_{2,3,5,6}$	$72.17\pm1.35^{c}_{1,3,4,6}$	$26.33\pm2.29^{c}_{1,2,3,4,5}$
D: 37-48 h	$94.50\pm0.48^{d}_{5,6}$	$88.83\pm0.93^{d}_{4,6}$	$89.33\pm0.49^{d}_{4,5,6}$	**$100.00\pm0.00^{d}_{2,3,5,6}$**	$79.67\pm0.93^{d}_{1,3,4,6}$	$29.17\pm2.52^{d}_{1,2,3,4,5}$
E: 49-60 h	**$96.83\pm0.40^{e}_{6}$**	**$95.83\pm0.44^{e}_{6}$**	**$97.17\pm0.38^{e}_{6}$**	$100.00\pm0.00^{e}_{6}$	**$96.33\pm0.49^{e}_{6}$**	**$38.83\pm2.97^{e}_{1,2,3,4,5}$**
F: 61-72 h	$96.83\pm0.40^{e}_{6}$	$95.83\pm0.44^{e}_{6}$	$97.17\pm0.38^{e}_{6}$	$100.00\pm0.00^{e}_{6}$	$96.33\pm0.49^{e}_{6}$	$38.83\pm2.97^{e}_{1,2,3,4,5}$
	$R^2 = 0.830$	$R^2 = 0.777$	$R^2 = 0.894$	$R^2 = 0.873$	$R^2 = 0.778$	$R^2 = 0.155$

SD – *Standard Deviation;* **R^2** *- coefficient of determination based on observed mean values;* ^{a,b,c,d,e,f} *Superscripts indicating statistical significance ($p < 0.05$) of differences found between the respective groups according Tamhane or Tukey test (IBM® SPSS® Statistics 26.0)*

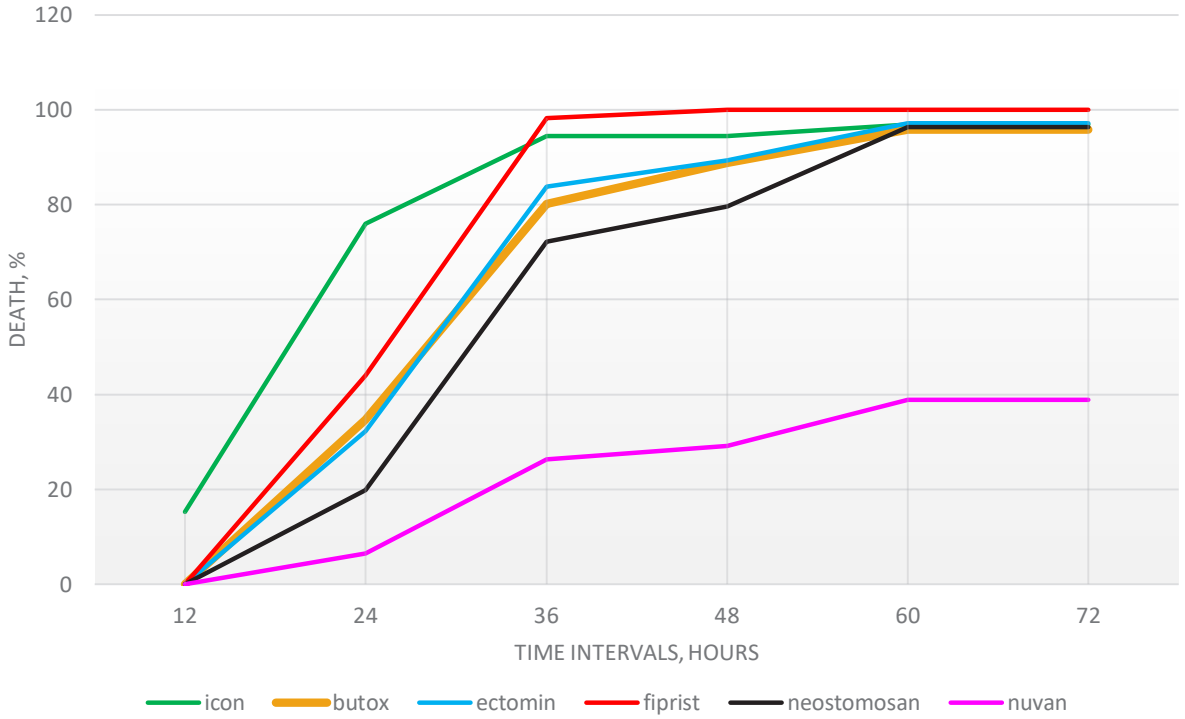

Fig. 1. Dynamics of mortality after spray application of insecticides to a field population of *Blatta orientalis.*

was recorded in the treatment with Nuvan, where only 38.83% mortality was found by the end of the monitoring period. The dynamic of mortality rate is represented in Fig. 1. The coefficients of determination for all insecticides, except Nuvan, ranged from 0.777 to 0.894, indicating a moderate effect of the type of insecticide used on mortality.

The high efficiency of fipronil and the rapid results achieved in insecticidal treatments against cockroach infestations were described more than 25 years ago in a study by Valles et al. (1997), whose experiments used standard strains of insecticide-susceptible and resistant German cockroaches. Mortality was reported 24 hours after topical administration of fipronil at 10.2 to 16.8 ng/individual. In 2004, Wang et al. conducted a similar study with topical application of fipronil, and at the end of the monitoring period (72nd hour) found up to 99% mortality at the different concentrations, which fully corresponds with our results. In 2002, Tilak et al. confirm the high efficiency of fipronil also in practical conditions during oral treatment with food baits containing 0.05% AI. They found a high reduction in the number of German cockroaches in the infested sites - 89% by the 7th day after treatment and 100% on the 30th day. Similar are the results of a study by Ahmad and Suliyat (2011), who applied fipronil in a low concentration (0.03%) in the form of gel baits against German cockroaches in laboratory conditions. They found a greater than 90% reduction in insects within 2 weeks. These results confirm the high toxicity and effectiveness of fipronil in cockroach control. Similar results were obtained by Holbrook et al. (2003), whose studies used ten concentrations of fipronil ranging from 1.5 to 3.2 ng per insect, with reported mortality ranging from 3 to 97% in 72 h. In 2006, Nasirian et al. found that even when administered in minimal amounts (up to 3.00 ng/individual), fipronil exerted its toxic effect within 72 hours.

Despite the proven high efficiency of fipronil and synthetic pyrethroids in the control of cockroaches, their use in various formulations and methods of insecticide treatment, there is also

evidence of the emergence of resistance to them (Chai and Lee, 2010; Gondhalekar et al., 2011). Thus, in topical treatments with pyrethroid insecticides, Valles and Yu (1996) and Wei et al. (2001) found high levels of resistance among field strains of German cockroach. In 2006, Limoee et al., found cross-resistance in 3 synthetic pyrethroids - permethrin, cypermethrin and cyfluthrin. In the experimental set-up, 7 field strains of the German cockroach were treated by topical application of each of the insecticides. Similar is the study by Chai and Lee (2010), who tested insecticides from different groups and found the presence of resistance and high resistance of German cockroaches when treated with pyrethroids. In our studies, no data indicating resistance to fipronil and priretroides were found in the studied field population of oriental cockroach. After application of these insecticides, a high mortality rate of over 95% was achieved. In contrast to our results, Cochran (1987) obtained significantly lower mortality when treating two field strains of German cockroaches with permethrin at 1.5 nl/cm², at a 24 hour monitoring period. The observed differences in the effectiveness of pyrethroid insecticides could be explaned by the different cockroach species used in our study (field population of Oriental cockroach) as well as the different experimental setup. Similar to ours results were obtained by Scharf et al. (1997) in laboratory and field tests on the effectiveness of pyrethroid insecticides. They applied lambda cyhalothrin with a concentration of 0.03% in the form of spray treatments and cypermethrin with a concentration of 92.3% in the form of topical application. Mortality was recorded at 72 h posttreatment and population density was monitored over 12 months. The results showed a high mortality of the treated individuals and up to 80% reduction of the German cockroach population when treated with lambda cyhalothrin.

The results of treatment by Nuvan in our experiments showed the lowest degree of effectiveness. At the beginning of the 70s of the last century, Wright (1971), established a high efficiency of this preparation, but in populations of German cockroaches. In laboratory conditions, using dichlorphos-soaked strips, a mortality of 90% was reported within a 48-hour monitoring period. We suppose that the differences in our results could bedue to the different experimental setup, as well as the use of a different species of cockroaches, but the presence of resistance can also be assumed. As is known, this type of insecticides has a long history of application, which probably helped the development of adaptive mechanisms and sensitivity reduction in insects, which could explain the results obtained.

CONCLUSIONS

The spray application of fipronil and synthetic pyrethroids to a field population of oriental cockroaches has high insecticidal efficacy in contrast to Dichlorvos (an organophosphate insecticide). The found variations highlight the need of performing periodic tests on the effectiveness of insecticides against field populations of cockroaches. The obtained data should serve as a basis for the correct selection of insecticides in practice and will contribute to the optimization of disinfection treatments. In order to minimaze the risk of development of resistance to insecticides, we could recommend the introduction of the principles of integrated pest control (IPM strategy), applying a complex approach by combiningdifferent insecticide methods and means, as well as the introduction of the rotation principle in the use of widely used insecticides.

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