

Efficacy of different insecticide treatments in controlling brown marmorated stink bug (*Halyomorpha halys*, Stål, 1855)

Učinkovitost različitih insekticidnih tretmana u suzbijanju smeđe mramoraste stjenice (*Halyomorpha halys*, Stål, 1855)

Vesna Tomaš, Ines Mihaljević, Marija Viljevac-Vuletić, Dominik Vuković, Zvonimir Zdunić

Agricultural institute Osijek, Južno predgrađe 17, 31000 Osijek

* Autor za korespondenciju/Corresponding author: E-mail adresa: vesna.tomas@poljin.hr (V. Tomaš)

Abstract

The brown marmorated stink bug (*Halyomorpha halys*, Stål, 1855) is an invasive polyphagous pest native to eastern Asia. In recent years, it has been causing more and more damage to a large number of agricultural crops. Among the fruit species in Croatia, the greatest damage was recorded on pears. The aim of this study was to evaluate the efficacy of the topical application of eight active substances in the control of adult forms of the brown marmorated stinky bugs, considering that the adult forms are much more resistant to insecticidal action compared to the nymphs. Active substances used in treatments were acetamiprid, spinetoram, deltamethrin, spirotetramat, azadirachtin, nettle and willow oil extract, kaoline, and silicone polymers. Adult forms of the pest were collected with an entomological catcher in the pear orchard of Agricultural Institute Osijek and placed in plastic containers. Each treatment had three replicates. Treatments with the highest mortality rate (100% after 48 h), were statistically significant regarding spinetoram and silicone polymers. The high mortality rate of treatment with silicone polymers was not expected. The research on insecticides with the highest efficacy will continue in field experiments to determine the reproducibility of the results under uncontrolled conditions. It is important to make the best choice of preparation according to knowledge of its efficacy.

Keywords: *Halyomorpha halys*, adult forms, mortality rate, pesticides, biopesticides

Sažetak

Smeđa mramorasta stjenica (*Halyomorpha halys*, Stål, 1855) invazivni je polifagni štetnik porijeklom iz istočne Azije. Posljednjih godina nanosi sve veće štete na velikom broju poljoprivrednih kultura. Među voćnim vrstama u Republici Hrvatskoj najveće štete zabilježene su na kruškama. Cilj istraživanja bio je procijeniti učinkovitost lokalne primjene osam djelatnih tvari u suzbijanju odraslih oblika smeđe mramoraste stjenice, s obzirom da su odrasli oblici znatno otporniji na insekticidno djelovanje u odnosu na ličinke. Aktivne tvari korištene u tretmanima bile su: acetamiprid, spinetoram, deltametrin, spirotetramat, azadiraktin, uljni ekstrakt koprive i vrbe, kaolin i silikonski polimeri. Odrasli oblici štetnika sakupljeni su entomološkom mrežom u

nasadu kruške Poljoprivrednog instituta Osijek i stavljeni u plastične posude. Svaki tretman imao je tri ponavljanja. Tretmani s najvećom stopom smrtnosti (100% nakon 48 h) i statistički značajnom razlikom u odnosu na ostale tretmane bili su spinetoram i silikonski polimeri. Visoka stopa smrtnosti u tretmanu sa silikonskim polimerima, nije bila očekivana. Istraživanje insekticida s najvećom učinkovitosti će se nastaviti u poljskim pokusima kako bi se utvrdila ponovljivost rezultata u nekontroliranim uvjetima. Uspješnost je suzbijanja u odabiru preparata najveće učinkovitosti prema ciljanom štetniku, kao i u saznanjima o pozitivnom učinku na okoliš.

Ključne riječi: *Halyomorpha halys*, odrasli oblici, stopa smrtnosti, pesticidi, biopesticidi

Introduction - Uvod

The brown marmorated stink bug, *Halyomorpha halys* (Stål, 1855), is an invasive pest native to East Asia (Zhu et al. 2012). In Croatia, it was discovered in 2017 in the district of Rijeka (Šapina and Šerić-Jelaska 2018). It is a polyphagous pest and abounds in a large number of hosts, over 170 different plant species (Lee et al. 2013, Rice et al. 2014, Hamilton et al. 2017). It has become an economic threat to Croatian agricultural producers due to its rapid spread (Pajač-Živković et al. 2021). The reason for that is the reduced use of broad-spectrum insecticides as well as the insufficient efficiency of biological control (Biddinger et al. 2012, Iacorone et al. 2022). It has from 1 to 3 generations per year and always occurs in large numbers (Lee et al. 2013, Haye et al. 2015, Hamilton et al. 2017, Saulich and Musolin 2017). In agricultural production, it causes direct and indirect damage. Intensive feeding of adult forms on plant organs such as buds, fruits, and stems caused direct damage. During feeding, it introduces digestive enzymes into plant tissue, resulting in various deformations of the same tissue (Haye et al. 2014). Indirect damage also occurs during the feeding as a vector for plant pathogens or as an intermediary because it opens the way for present pathogenic microorganisms through a newly formed entry wound (Rice et al. 2014). Chemical control has proven to be the most effective method for reducing the present harmful population and preventing economic damage, but it is also frequently ineffective due to pest-marked mobility and polyphagy (Candian et al. 2018). Frequent use of chemical insecticide treatments is reflected in the reduction of the natural entomophagic population (Bariselli et al. 2016, Candian et al. 2018). The best control method would be a synergy of chemical, biological, and biotechnical methods based on monitoring and critical abundance thresholds of the pest.

The aim of this study was to evaluate the efficacy of chemical and botanical insecticides on adult forms of *Halyomorpha halys* under controlled conditions. The mortality rates of individuals over 24 and 48 hours establish the relative efficacy of all tested insecticides. These results will enable us to better predict the efficacy of insecticides against *Halyomorpha halys* in the field.

Material and Methods – Materijal i Metode

Adults of *Halyomorpha halys* were collected in the pear orchard of Agricultural Institute Osijek at the beginning of September, and placed in plastic containers (22x17x7 cm) with the filter paper, which was well moistened as a source of water and air moisture, and fed with pieces of pear fruit.

In the trial, tested insecticides were registered for use on pears, and some of them are

used in organic production. The active substances with the concentration used are listed in Table 1. To determine the applied volume of each insecticide product used in the trial, the applicator handle on each spray bottle was fully compressed 30 times, and the liquid was collected in a graduated cylinder. The volume of insecticide was measured to the nearest ml, and the average volume delivered at each compression was calculated by dividing the total volume by 30. Each topical application consisted of three compressions, and the exact volume of each product was applied (4 ml). Insecticides were mixed with water in accordance by the label recommendations for fruit production in Croatia. 108 adults were randomly assigned to one of nine treatments in plastic containers (4 adults per container). Each treatment was repeated three times. Twelve holes were drilled in every container to allow ventilation and the drying of liquid sprays. To determine the effects of topical applications, adults were observed 24 and 48 hours after treatment (Bergmann and Raupp, 2014). In each container, each adult was evaluated and placed in one of two categories: alive (an adult capable of moving) or dead (an adult showing no movement and no response). The mortality rate as an analyzed variable of dead and alive insects was expressed as a percent calculated by Abbott's formula (1925).

The factors of significance and their interactions were calculated using the analysis of variance within software package R (R core team, 2019), and the significance of the differences between the mean values was tested using the LSD test.

Table 1. List of active substances of the tested insecticides with their concentrations in the trial treatments

Tablica 1. Popis aktivnih tvari i koncentracija ispitivanih insekticidnih preparata uključenih u istraživačke tretmane

	Trade Name <i>Trgovački naziv</i>	Active substances <i>Aktivna tvar</i>	Concentration <i>Koncentracija</i>
1.	Mospilan 20 SG	Acetamiprid	0,05%
2.	Delegate 250 WG	Spinetoram	0,03%
3.	Scatto	Deltametrin	0,05%
4.	Movento SC	Spirotetramat	0,15%
5.	Neemazal	Azadiractin	0,15%
6.	Bioprotect	Nettle and willow oil extract	0,40%
7.	Surround	Kaoline	3%
8.	Silmax EC	Silicone polymers	0,15%

Result and Discussion – *Rezultati i Rasprava*

Chemical control of brown marmorated stink bugs has proven to be an effective measure of protection that successfully prevents fruit damage (Nielsen et al. 2008, Lee et al. 2012, Leskey et al. 2012, Kuhar et al. 2017). The results of this study have shown that the preparation of adjuvant action based on silicone polymers has achieved the same good results as the preparation of insecticidal action based on spinetoram. Statistical significance was confirmed compared to all other treatments in the trial (Figure 1,2). The mortality rate was 100% after 48 hours (Figure 3). According to Kuhar et al. (2017), some insecticides from the neonicotinoid group have a toxic effect on *Halyomorpha halys* nymphs and have provided good control of *Haliomorpha halys* in laboratory and field experiments, but their performance varied depending on the

formulation, rate, and timing of application. It has further been proven that active substances such as imidacloprid and thiamethoxam have an initial toxic effect, followed by insect recovery. In our study, the preparation based on acetamiprid showed a toxic effect that followed the mortality rate of 67% after 24 hours, and the mortality increased with the duration of 48 hours by 8% (Figure 3). An increased mortality rate was also recorded by spinetoram and silicone polymer after 48 hours as well as a statistically significant difference between them and acetamiprid (Figure 2).

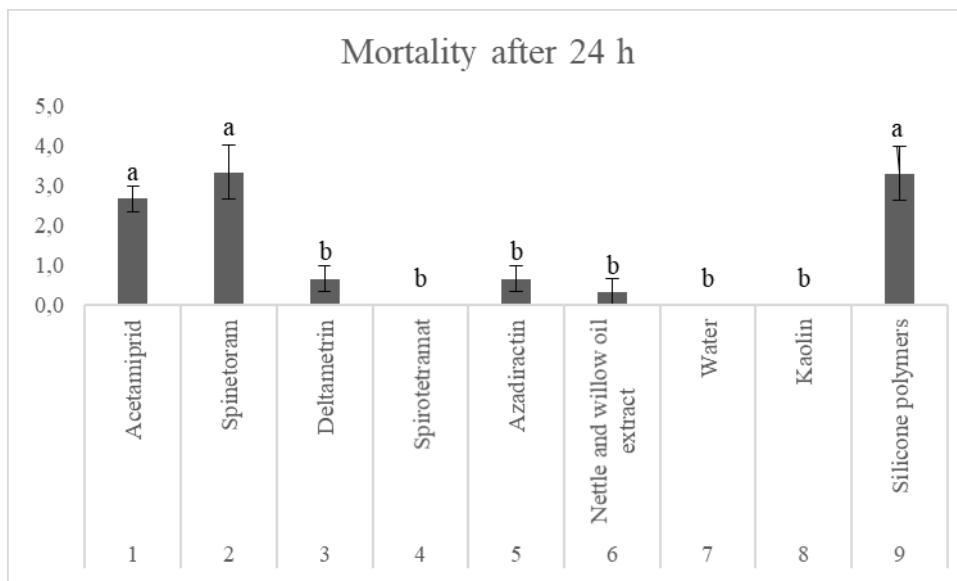


Figure 1 The impact of treatment on mortality of adult forms of *Halyomorpha halys*. The data are the mean values of three replicates. The letters represent a statistically significant difference $P \leq 0,05$ between the treatments according to LSD test.

Slika 1. Utjecaj tretmana na smrtnost odraslih oblika *Halyomorpha halys*. Podaci su srednje vrijednosti tri ponavljanja. Slova predstavljaju statistički značajnu razliku na razini $P \leq 0,05$ između tretmana prema LSD testu

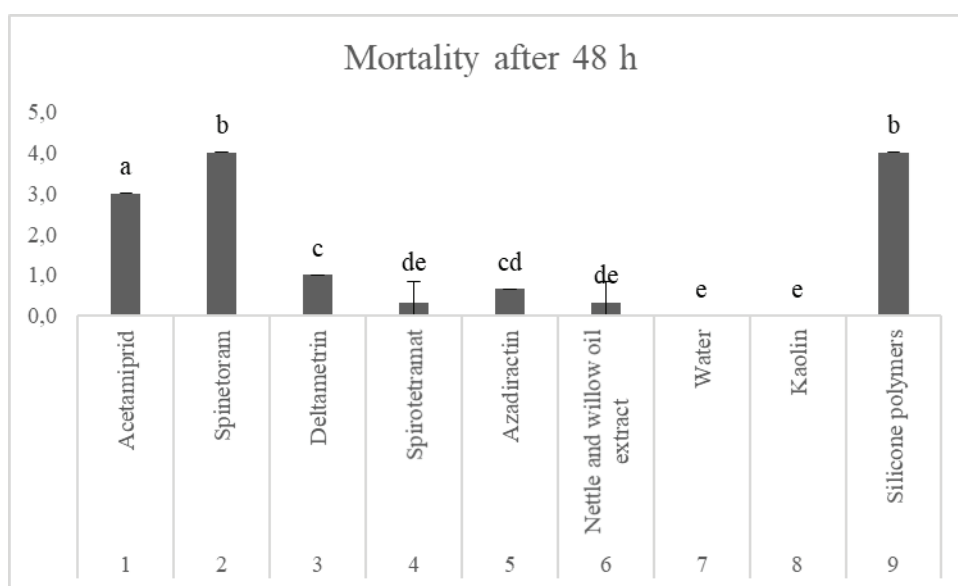


Figure 2 The impact of treatment on mortality of adult forms of *Halyomorpha halys*. The data are the mean values of three replicates. The letters represent a statistically significant difference $P \leq 0,05$ between the treatments according to LSD test.

Slika 2. Utjecaj tretmana na smrtnost odraslih oblika *Halyomorpha halys*. Podaci su srednje vrijednosti tri ponavljanja. Slova predstavljaju statistički značajnu razliku na razini $P \leq 0,05$ između tretmana prema LSD testu.

The active substance deltamethrin has contact and gastric action, it is effective in very low doses and has a long residual action. Hypothetically, higher efficiency was expected in the mortality rate of adult forms, but the final result of topical application showed a low efficiency of 16.7% after 24 hours and a small increase in mortality of 8% after 48 hours (Figure 3). According to Leskey et al. (2012), the most tested insecticides from the pyrethroid group (bifenthrin, fenpropathrin, permethrin, gamma-cyhalothrin, beta-cyfluthrin, lambda-cyhalothrin, and zeta-cypermethrin) had a high initial lethality index on adult forms of *Halyomorpha halys* which was not confirmed with the active substance of deltamethrin. Statistical significance of deltamethrin was confirmed after 48 hours compared to the control treatment (Figure 2).

The preparation based on the active substance spirotetramate has a highly systemic action, so no efficacy was expected during topical application. It showed minimal effectiveness after 48 hours, of 8.3%. Leskey et al. (2012) also confirmed a very low initial lethality index of 9.8% with an increasing tendency for pests to recover from a moribund condition after seven or more days of exposure.

Botanical pesticides are the result of the growing need to find alternative solutions for the replacement of some chemical insecticides. Plants with bioactive compounds have been used to manage different crop pests with notable success (Velázquez-Fernández et al. 2012, Gakuubi et al. 2016, Ahmed et al. 2017, Lengai et al. 2020, Wulf et al. 2023).

Many studies have proven the satisfactory efficacy of azadirachtin on various pests and their developmental stages (Marčić et al. 2009, Khan 2020, Kilani-Morakchi et al. 2021). In this study, topical applications of azadirachtin on adult forms of *Halyomorpha halys* did not show satisfactory efficacy. The mortality rate was 16.6% (Figure 3), and there was no difference in mortality after 48 hours of exposure. Sarajlić et al. (2022) obtained a similar result with a mortality rate of 7.5%.

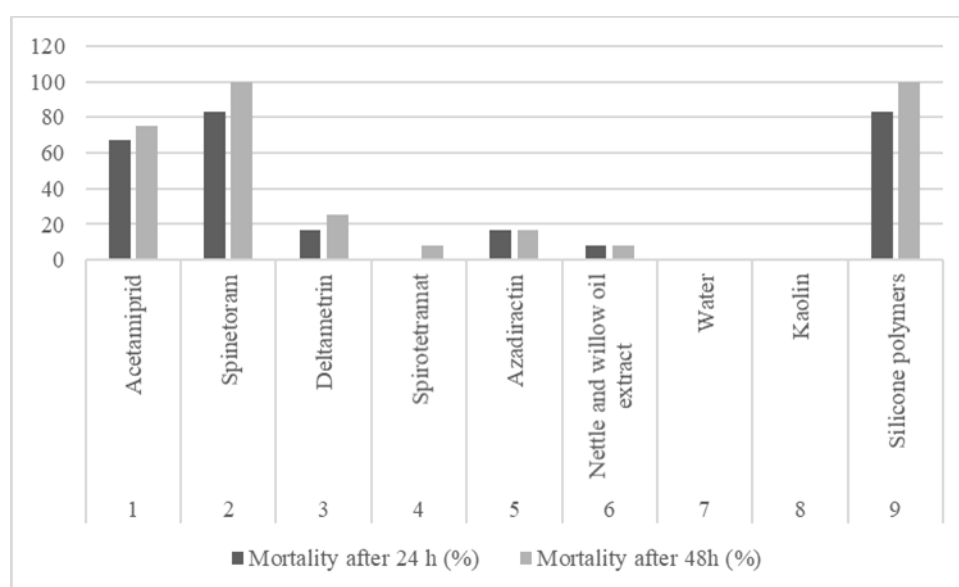


Figure 3 Mortality rate (%) of *Halyomorpha halys*

Slika 3. Stopa smrtnosti (%) *Halyomorpha halys*

The efficacy of a botanical oil preparation based on nettle and willow was tested. The mortality rate of the adult forms was extremely low, at 8.3% (Figure 3), and did not increase with the exposure of the preparation after 48 hours and there was no statistically significant difference compared to the control (Figure 2).

Kaolin-based preparation is known for its multiple positive actions. The use of kaolin clay corresponds to the aims of the organic and integrated protection strategy because it does not have a toxic effect but interferes with the basic life functions of pests and thus affects on the reduction of economic damages (Puterka et al. 2000, Pascual et al. 2010, Tomaš et al. 2018, Tomaš et al. 2022).

Leskey et al. (2012) investigated the immediate effects of kaolin exposure on adult *Halyomorpha halys*, and they obtained a low lethality index of 23% after seven days of monitoring. The result of our research after 24 and 48 hours of exposure to kaolin did not show toxicological efficacy. The adult forms were just slow in their movement but alive. The results were identical to those of the control treatment, so a statistically significant difference wasn't recorded compared to the control treatment (Figure 1,2).

Conclusion - Zaključak

Spinetoram and silicone polymers showed the highest rate of mortality (83.4%) in adult forms of *Halyomorpha halys* after 24 hours. An extremely high mortality rate of 100% was obtained after 48 hours. Statistical significance was recorded between them compared to other treatments (after 48 hours). The efficacy of acetamiprid was 67% after 24 hours and 75% after 48 hours of residual action. The efficacy of the deltamethrin, spirotetramat, azadiractin, nettle, and willow oil extracts was extremely low (8.3–16.6%). Kaolin didn't show a lethality index during the two days of observation. No statistically significant difference was recorded in comparison to the control treatment with water. The high mortality rate of treatment with silicone polymers was not expected. The research on insecticides with the highest efficacy will continue in field experiments to determine the reproducibility of the results under uncontrolled conditions.

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