Original scientific paper
DOI: /10.5513/JCEA01/22.3.3173
Journal of Central European Agriculture, 2021, 22(3), p.531-538

Rapid spread and first massive occurrence of *Halyomorpha halys* (Stål, 1855) in agricultural production in Croatia

Brzo širenje i prva masovna pojava vrste *Halyomorpha halys* (Stål, 1855) u poljoprivrednoj proizvodnji u Hrvatskoj

Ivana PAJAČ ŽIVKOVIĆ (✉), Sandra SKENDŽIĆ, Darija LEMIĆ

University of Zagreb, Faculty of Agriculture, Department of Agricultural Zoology, Svetošimunska 25, 10000 Zagreb, Croatia

✉ Corresponding author: ipajac@agr.hr

Received: January 29, 2021; accepted: March 15, 2021

ABSTRACT

The brown marmorated stink bug (*Halyomorpha halys* (Stål, 1855)) is an extremely polyphagous invasive insect originating from East Asia. It causes damage by feeding on fruit trees and shrubs, legumes, forest trees, and ornamental shrubs and trees. The pest has successfully established in North America and Europe and causes economic damage to agricultural production. The first discovery of *H. halys* in Croatia occurred in 2017 in the coastal region in Rijeka. In 2018, the pest was sporadically observed in urban areas of Sveta Nedelja, Zagreb and Vukovar, and a total of 22 specimens of *H. halys* were found in single and multi-family houses in eight locations. The discovery of the species in the continental part of the country is evidence of the spread of this species in Croatia. During 2019, the first mass occurrence of the pest was detected in the rural area of Zagreb (Drenčec) in a soybean field. A total of 723 specimens of *H. halys* were identified. The average number of stink bugs per 10 plants was 14 specimens, which poses a serious threat to soybean production in the area. The very rapid spread of the pest from urban to rural areas and the establishment of its local populations is evidence of the invasive nature of the species and a warning signal for farmers in Croatia. To prevent the spread and mass occurrence of *H. halys* on agricultural land and to minimise possible damage to agricultural production, it is necessary to constantly monitor the pest and, if necessary, to take appropriate protective measures in agriculture.

Keywords: brown marmorated stink bug, pest spreading, soybean, establishment of local populations, continental Croatia

SAŽETAK

Vrsta *Halyomorpha halys* (Stål, 1855) je polifagna invazivna štitasta stjenica koja dolazi iz istočne Azije. Štetu uzrokuje hraneći se na voćkama i grmovima, mahunarkama, šumskom drveću i ukrasnom grmlju i drveću. Štetnik se uspješno udomaćio u Sjevernoj Americi i Europi, te uzrokuje ekonomske štete u poljoprivrednoj proizvodnji. U 2018. godini, štetnik je sporadično opažen u urbanim područjima Svete Nedelje, Zagreba i Vukovara i ukupno su pronađena 22 primjerka vrste *H. halys* u obiteljskim kućama i stambenim zgradama na osam lokacija. Pronalazak vrste u kontinentalnom dijelu zemlje dokaz je širenja vrste u Hrvatskoj od njezinog prvog pronalaska u 2017. godini u obalnom području u Rijeci. Tijekom 2019. godine, prva masovna pojava štetnika je opažena u ruralnom području Zagreba (Drenčec) u polju soje. Ukupno su identificirana 732 primjerka vrste. Prosječni broj stjenica na 10 biljaka soje iznosio je 14 primjeraka, što predstavlja ozbiljnu prijetnju uzgoju soje na tom području. Vrlo brzo širenje štetnika iz urbanih u ruralno područje i uspostava lokalnih populacija dokaz su invazivnog karaktera vrste i upozorenje poljoprivrednicima u Hrvatskoj. Kako bi se spriječilo širenje i masovna pojava ove stjenice na poljoprivrednim površinama, te kako bi se minimizirale potencijalne štete u poljoprivrednoj proizvodnji, nužno je redovito pratiti štetnika i ako je potrebno, provesti odgovarajuće mjere zaštite u poljoprivredi.

Ključne riječi: smeđa mramorasta stjenica, širenje štetnika, soja, uspostava lokalnih populacija, kontinentalna Hrvatska

INTRODUCTION

The brown marmorated stink bug, *Halyomorpha halys* (Stål, 1855) (Hemiptera: Pentatomidae), is an invasive species originally from East Asia (China, Japan, Taiwan, and the Republic of Korea) (Lee et al., 2013). Since the early 2000s, *H. halys* has spread across most of the United States, has become established in Canada and some European countries, and has become a significant threat to agricultural production (Britt et al., 2019). The first adults in Europe were captured in a light trap in Liechtenstein in 2004. The trapped specimens were not identified until 2007, when the same individuals of the species were found on numerous exotic ornamental shrubs at five different sites in Zurich, Switzerland (Ciceoi, 2016). After Switzerland, *H. halys* was found in Germany (Heckman, 2012), France (Callot and Brua, 2013), Greece (Milonas and Partsinevelos, 2014), Italy (Maistrello et al., 2014), Hungary (Vétek et al., 2014), Romania (Macavei et al., 2015), Austria (Rabitsch and Friebe, 2015), Serbia (Šeat, 2015), Russia (Mityushev, 2016), Spain (Dioli et al., 2016), Slovenia (Rot, 2018), Bosnia and Herzegovina (Zovko et al., 2019), etc. The first report of *H. halys* in Croatia is from 2017, where the first individuals of the species (a female and a male) were found in January and February in a residential house in Rijeka. Later in the year, in May, four more individuals (one female and three males) were found on the trees of Ailanthus (*Ailanthus altissima* (Mill.) Swingle) in the vicinity of the building (Šerić Jelaska and Šapina, 2017).

H. halys is a very polyphagous insect with more than 120 known host plants, many of which are of agricultural, horticultural and ornamental importance. Primary hosts are fruit species and ornamental plants. The major hosts, including fruit trees and shrubs, are cherry (*Prunus avium* L.), plum (*Prunus domestica* L.), peach (*Prunus persica* L.), apricot (*Prunus armeniaca* L.), apple (*Malus* spp. Mill.), pear (*Pyrus* spp. L.), mulberry (*Morus* spp. L.), persimmon (*Diospyros* spp. L.), citrus (*Citrus* spp. L.), raspberry (*Rubus* spp. L.) and grape (*Vitis vinifera* L.); legumes such as pea (*Pisum sativum* L.), soybean (*Glycine max* L. (Merr.)) and field bean (*Phaseolus vulgaris* L.); forest trees such as willow (*Salix* spp. L.) and maple (*Acer* spp. L.); and ornamental shrubs and trees such as princess tree (*Paulownia tomentosa* (Thunb.) Steud.), butterfly bush (*Buddleja davidii* Franch.), firethorn (*Pyracantha coccinea* M. Roem), lilac (*Syringa* spp. L.), hibiscus (*Hibiscus* spp. L.), honeysuckle (*Lonicera* spp. L.), cypress (*Cupressus* spp. L.), and Japanese cedar (*Cryptomeria japonica* (L.f.) D. Don.) (Wermelinger et al., 2008). Damage in vegetable and field crops was reported on tomato (*Solanum lycopersicum* L.), pepper (*Capsicum anuum* L.), eggplant (*Solanum melongena* L.), corn (*Zea mays* L.), sunflower (*Helianthus anuus* L.), sorghum (*Sorghum bicolor* (L.) Moench), wheat (*Triticum aestivum* L.), cotton (*Gossypium hirsutum* L.), and hops (*Humulus lupulus* L.) (Rice et al., 2014). In addition, *H. halys* feeds on weeds (e.g., burdock, *Arctium* spp. L.) (Wermelinger et al., 2008).

Direct damage is caused by adults and nymphs sucking on flower buds, fruits, or stems and injecting digestive enzymes into plant tissues while feeding, resulting in various plant deformations, discolorations, and scars that render agricultural products unmarketable and increase the possibility of secondary fungal infections (Haye et al., 2014; Ciceoi et al., 2017). In addition, *H. halys* has become a serious household pest as adult individuals congregate and seek shelter in buildings where they spend the winter period in diapause (Wermelinger et al., 2008; Lee et al., 2013).

H. halys belongs to the family Pentatomidae, often called shield or stink bugs. They are relatively large, shield-shaped bugs that emit unpleasant odours from glands located on the ventral side of the thorax. Their head is relatively small and is often located below the anterior margin of the pronotum. Their antennae are composed of five segments. They have a large, triangular and broad scutellum, and the clavus of the forewings has a stronger structure than a membrane (Gotlin Čuljak and Juran, 2016). It is similar in biology and appearance to some other widespread European species from the same family, e.g. sloe bug (*Dolycoris baccarum* L.), spotted shield bug (*Raphigaster nebulosa* Poda) or species from the genus *Holcostethus*, so mistakes in its identification are

common (Wermelinger et al., 2008). It develops one to two generations per year (Leskey et al., 2012; Macavei et al., 2015). During development, it undergoes incomplete metamorphosis, and the differences between nymphs and adults are very small. Nymphs go through five stages of development, and with each moult they grow larger and increasingly resemble fully developed insects (Oštrec and Gotlin Čuljak, 2005).

Feeding activities of *H. halys* cause economic losses in Asia (Lee et al., 2013) and in some newly introduced parts of the world such as North America and Europe (Kapantaidaki et. al., 2019). In the USA, for example, *H. halys* populations caused millions of dollars of damage to fruit crops such as apples and peaches, vineyards, vegetables such as corn, peppers, and tomatoes, row crops such as field corn and soybeans, and ornamentals in nurseries and landscapes during the 2010 growing season (Bergmann et al., 2016). In Europe, economic losses have been reported in fruit production in Italy (Bariselli et al., 2016; Candian et al., 2018) and total losses in vegetable production in Hungary (Vétek i Korányi, 2017). Due to the invasive nature of the species, its establishment and further spread in Europe pose a serious threat to European agricultural production and the economy.

The study was based on the hypothesis that microclimatic conditions favour the spread of *H. halys* in Croatia, and the main objective was to evaluate the potential of the pest to become a locally abundant species.

MATERIALS AND METHODS

In October and November 2018, brown marmorated stink bugs were visually monitored in residential areas (single-family houses and apartment buildings) in the continental part of Croatia. In 2019, a farmer discovered a mass population of stink bugs (Pentatomidae) in the rural area of Zagreb in a soybean field in the village of Drenčec in late September (Table 1 and Figure 1). To assess the pest population in Drenčec, the method of random sampling with a quadrant (square frame with 1 m^2 wire) was used. On October 1, 2019, on an area of 0.5 ha, a square frame was thrown 10 times along the edges and diagonally along the soybean field and stink bugs were collected in it by hand picking. The collected specimens were placed in entomological cages and taken to Entomological Laboratory of the Faculty of Agriculture where they were identified, counted and preserved in 70% EtOH. The species *H. halys* was identified using the identification key of Hoebeke and Carter (2003).

Table 1. List of localities and geographical coordinates of *Halyomorpha halys* in Croatia for 2018 and 2019

Locality	Long	Lat
Sveta Nedelja (Klanjec 15, Rakitje)	45.799869	15.821165
Zagreb 1 (Trnsko 47A)	45.768494	15.964795
Zagreb 2 (Jarunska 2)	45.785149	15.947418
Zagreb 3 (Selska cesta 7B)	45.812296	15.942797
Zagreb 4 (Stara Pešćenica IV 11)	45.811713	16.006195
Zagreb 5 (I Resnički gaj I 16A)	45.809968	16.065992
Zagreb 6 (Vladimira Vidrića 12)	45.836050	16.119366
Zagreb 7 (Drenčec)	45.837889	16.200389
Vukovar (Domovinskog rata 42)	45.379658	18.955968

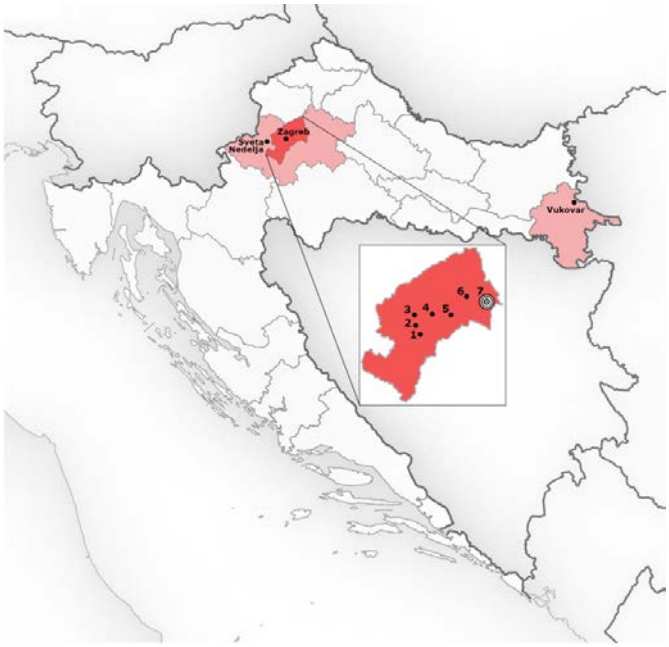

Figure 1. Map of Croatia with localities of *Halyomorpha halys*; the numbers in Zagreb correspond to those in Table 1

RESULTS AND DISCUSSION

At the end of 2018, a total of three specimens of *H. halys* were identified in a single-family house at the site Sveta Nedelja, and a similar small number of pests were found in other urban areas of Zagreb (Zagreb 1 - three specimens, Zagreb 2 - three specimens, Zagreb 3 - six specimens, Zagreb 4 - four specimens, Zagreb 5 - one specimen, Zagreb 6 - three specimens) and Vukovar (two specimens).

Similar to other European countries, the initial populations of *H. halys* in Croatia, were mostly confined to cities/urban areas (Stoeckli et al., 2020), and observed in Sveta Nedelja, Zagreb and Vukovar (Table 1 and Figure 1). As the pest was found relatively close to border areas, it is assumed that it was introduced to Croatia several times from neighbouring countries (e.g., Italy, Hungary, and Serbia).

In October 2019, various nymphal stages and adult specimens of *H. halys* were sampled in a soybean field in the village of Drenčec (Figure 2). A total of 723 specimens were sampled (21 specimens of the 2nd instar, 42 specimens of the 3rd instar, 67 specimens of the 4th instar, 275 specimens of the 5th instar and 318 specimens of the adults), with an average catch per 1 m^2 of 72.3 specimens.

The research was conducted with the aim of confirming the favourable climatic conditions for spread of *H. halys* in Croatia and the additional aim was to evaluate the pest potential to become locally abundant species. Zhu et. al. (2012) reported that *H. halys* has the potential to rapidly expand its range in Mediterranean countries, as this biogeographical region has the most favourable conditions for its establishment. According to Kiritani (2007), winter mortality of *H. halys* is correlated with mean winter temperatures, and favourable conditions for the survival of the species are expected when the mean winter temperature is above 2 °C. Since the mean winter temperature in Croatia is about 2.6 °C (CMHS, 2020), these conditions are favourable for overwintering of the species. The results of this study confirmed that the pest prefers microclimatic conditions in Croatia, as it was found in several different areas of the country from 2017 to 2019 (in the coastal part – Rijeka, and continental part - Zagreb and Vukovar), which makes it possible to accept the research hypothesis.

It has been observed that *H. halys* nymphs in Drenčec move very quickly between soybean plants, and the study by Lee et al. (2014) proved that nymphs have a strong dispersal ability, and therefore populations can easily move between host plants and spread very quickly. In addition, adults are very good fliers and can travel distances from a few to more than 100 km (Lee and Leskey, 2015). Haye et al. (2014) reported that the natural spread of *H. halys* in Switzerland was relatively slow over a period of almost 10 years. However, the results from Croatia indicated the pest has spread quite rapidly only one year after the first detection in 2018 in Zagreb.

Studies by Leskey and Nielsen (2018) have shown that *H. halys* can invade crops from adjacent forested habitats. The soybean field in Drenčec is surrounded by forest, so it is possible that bugs migrated from this area to the soybeans, which were their only food source during this part of the year. In addition to specimens of *H. halys*, the phytophagous species southern green stink bug, *Nezara viridula* (Linnaeus, 1758), was observed in high population in the soybean field as well. *N. viridula* probably originates from the Mediterranean region (Rabitsch, 2010) and is now a widespread species in Croatia. Nielsen et al. (2008) pointed out that *H. halys* is able to survive colder winter temperatures than *N. viridula*, so there is no doubt that temperature conditions favour the establishment and/or spread of *H. halys* in Croatia.

The observed pest population in the soybean field in Drenčec was preparing to overwinter and was feeding on the pods of the soybeans, posing a threat to the cultivation of this and other crops (e.g., maize) in the area. Owens et al. (2013) investigated feeding damage by *H. halys* on soybean and concluded that damage is similar to other native stink bugs, resulting in pod destruction and seed quality losses, with significant seed damage observed at densities of four stink bugs per 10 plants. In Drenčec, the average number of stink bugs per 10 plants was 14, which can be considered a massive population

that can cause serious damage to soybean crops. The identified abundance of the pest at the Drenčec site is evidence of an established local, high-density population in this rural area, which confirms the main objective of this study.

Although established in Europe for at least 13 years, *H. halys* is slowly changing from an urban and domestic pest to an agricultural pest. Its mass emergence in agricultural crops in Croatia, is of concern, as some cases of economic damage to agricultural production have already been reported in Europe (Bariselli et al., 2016; Candian et al., 2018; Vétek i Korányi, 2017).

Figure 2. Various developmental stages of *Halyomorpha halys* L. on *Glycine max* (L.) Merr

In Italy, the brown marmorated stink bug has become a major pest on various fruit crops after its first detection in Italy (Bariselli et al., 2016). The most damaged crops were pear and nectarine orchards in Emilia Romagna and Piedmont (Pansa et al., 2013; Cesari et al., 2015). Then, in 2015 and 2016, new reports of damage by *H. halys* feeding on apple, hazelnut, vegetables, ornamentals and row crops were observed (Bosco et al., 2017; Candian et al., 2018; Malek et al., 2019).

In Hungary, total losses were reported in the cultivation of green pepper and bean crops (Vétek i Korányi, 2017). In Slovenia, *H. halys* was detected mainly on agricultural crops in 2016 by visual observations and in 2017 by traps fitted with pheromone baits. In summer 2017, it was caught in a soybean field with a pheromone trap and detected by visual observation on an olive tree (Rot et al., 2018) and economic damage was observed in commercial production of apple (personal communication with Mojca Rot). In Serbia, thorough field inspections revealed the presence of *H. halys* nymphs and adults in soybean fields at two new sites one year after the first detection in the country. Therefore, this was a confirmation of the initial stage of *H. halys* population establishment (Musolin et al., 2018).

It is important to note that it took almost 14 years for *H. halys* to become a major pest in the US, and therefore it seems undoubted that Europe will face the same situation in the near future (Haye et al., 2014).

Given the invasive nature of the species, its polyphagy and apparent lack of natural enemies, *H. halys* will continue to spread in Europe. Current management of this pest is mainly based on chemical treatments. Pyrethroids and neonicotinoids have very good efficacy in controlling nymphs and adults of this species (Lee et al., 2013), but due to short residual activity, these treatments need to be applied more frequently in season (Leskey et al., 2014). In recent years, more attention has been paid to environmentally sound pest management and successful control of *H. halys* in commercial apple orchards has been achieved with the attract and kill method in the USA (Morrison et al., 2019) and by using exclusion nets to protect nectarine and apple orchards in Italy (Candian et al., 2018). Since the listed protective measures are already used in Croatia to control tortrix pests (Barić and Pajač Živković, 2017; Pajač Živković et al., 2016 and 2018), they also have a very good potential to control *H. halys*. To improve monitoring and control strategies of *H. halys*, the vibrational communication of this species has been studied, and preliminary results have shown that promising new acoustic baits and traps could be developed based on acoustic interference (Mazzoni et al., 2017; Bedoya et al., 2020).

In order to prevent the rapid spread and economic damage of this pest in Croatia and other invaded countries, regular monitoring of this species is strongly advised in the future.

CONCLUSION

The species *H. halys* was first discovered in 2017 in the Croatian coastal region of Rijeka. Only a year later, in 2018, it was discovered in the northwestern (Sveta Nedelja and Zagreb) and the very eastern continental part of Croatia (Vukovar). The very rapid and surprising spread of the species from urban to rural areas occurred in a soybean field near Zagreb in 2019, suggesting the presence of local pest populations and the establishment of the species due to favourable microclimatic conditions. This is the first mass finding of *H. halys* in an agricultural field and poses a threat to soybean and other crops growing nearby. Given the invasive nature of the species and the economic damage recorded in neighbouring countries, there is a need to strengthen pest surveillance in rural areas to identify key sites where urgent pest control is required.

ACKNOWLEDGMENT

The authors are indebted to Ana Bardić, Dana Čirjak, Marija Andrijana Galešić, Kristina Ivanov, Karla Iviček, Martina Kadoić Balaško, Dora Kapuđija, Ana Marija Kovačević, Josip Lakić, Helena Malović, Matej Orešković, Anja Škvorc, Stjepan Žabčić, Marija Živković and Josip Živković for their help in collecting stink bugs.

REFERENCES

Barić, B., Pajač Živković, I. (2017) Učinkovitost konfuzije u suzbijanju jabukova savijača u Hrvatskoj s posebnim osvrtom na troškove zaštite. Pomologia Croatica: glasilo Hrvatskog agronomskog društva, 21 (3-4), 125-133 [in Croatian].

Bariselli, M., Bugiani, R., Maistrello, L. (2016) Distribution and damage caused by *Halyomorpha halys* in Italy. Bulletin OEPP/EPPO Bulletin, 46 (2), 1-3. DOI: http://dx.doi.org/ 10.1111/epp.12289

Bedoya, C.L., Brockerhoff, E.G., Hayes, M., Leskey, T.C., Morrison III, W.R., Rice, K.B., Nelson, X.J. (2020) Brown marmorated stink bug overwintering aggregations are not regulated through vibrational signals during autumn dispersal. Royal Society Open Science, 7, 201371. DOI: http://dx.doi.org/10.1098/rsos.201371

Bergmann, E.J., Venugopal P.D., Martinson H.M., Raupp M.J., Shrewsbury P.M. (2016) Host Plant Use by the Invasive *Halyomorpha halys* (Stål) on Woody Ornamental Trees and Shrubs. PLoS ONE, 11 (2), e0149975. DOI: https://doi.org/10.1371/journal.pone.0149975

Bosco, L., Moraglio, S.T., Tavella, L. (2017) *Halyomorpha halys*, a serious threat for hazelnut in newly invaded areas. Journal of Pest Science, 91 (2), 661-670. DOI: https://doi.org/10.1007/s10340-017-0937-x

Britt, K.E., Pagani, M.K., Kuhar, T.P. (2019) First Report of Brown Marmorated Stink Bug (Hemiptera: Pentatomidae) Associated With Cannabis sativa (Rosales: Cannabaceae) in the United States. Journal of Integrated Pest Management, 10 (1), 17, 1-3. DOI: https://doi.org/10.1093/jipm/pmz014

Callot, H., Brua, C. (2013) *Halyomorpha halys* (Stål, 1855), la Punaise diabolique, nouvelle espéce pour le faune de France (Heteroptera Pentatomidae). L'Entomologiste, 69, 69-71.

Candian, V., Pansa, M.G., Briano, R., Peano, C., Tedeschi, R., Tavella, L. (2018) Exclusion nets: a promising tool to prevent *Halyomorpha halys* from damaging nectarines and apples in NW Italy. Bulletin of Insectology, 71 (1), 21-30.

Cesari, M., Maistrello, L., Ganzerli, F., Dioli, P., Rebecchi, L., Guidetti, R. (2015) A pest alien invasion in progress: potential pathways of origin of the brown marmorated stink bug *Halyomorpha halys* populations in Italy. Journal of Pest Science, 88 (1), 1-7. DOI: https://doi.org/10.1007/s10340-014-0634-y

Ciceoi, R. (2016) The status of brown marmorated stink bug, *Halyomorpha halys*, in Bucharest area. Journal of Horticulture, Forestry and Biotechnology, 20, 18-25. DOI: https://doi.org/10.5281/zenodo.267978

Ciceoi, R., Bolocan, I.G., Dobrin, I. (2017) The spread of brown marmorated stink bug, *Halyomorpha halys*, in Romania. Journal of Horticulture, Forestry and Biotechnology, 21, 15-20.

CMHS (2020) Croatian Meteorological and Hydrological Service. [Online] Available at: https://meteo.hr/klima.php?section=klima_podaci&param=k1&Grad=zagreb_maksimir [Accessed 09 March 2021]

Dioli, P., Leo, P., Maistrello, L. (2016) Prime segnalazioni in Spagna e in Sardegna della specie aliena *Halyomorpha halys* (Stål, 1855) e note sulla sua distribuzione in Europa (Hemiptera, Pentatomidae). Revista Gaditana de Entomología, 7 (1), 539-548.

Gotlin Čuljak, T., Juran, I. (2016) Poljoprivredna entomologija – sistematika kukaca, Sveta Nedjelja: Radin print d.o.o. [in Croatian].

Haye, T., Wyniger, D., Gariepy, T. (2014) Recent range expansion of brown marmorated stink bug in Europe. In: Proceedings of the 8th International Conference on Urban Pests, Zurich, Switzerland, 20-23 July 2014, (pp. 309-314). Executive Committee of the International Conference on Urban Pests.

Heckmann, R. (2012) Erster Nachweis von *Halyomorpha halys* (Stål, 1855) (Heteroptera: Pentatomidae) für Deutschland. Heteropteron, 36, 17-18.

Hoebeke, E.R., Carter M.E. (2003) *Halyomorpha halys* (Stål) (Heteroptera: Pentatomidae): a polyphagous plant pest from Asia newly detected in North America. In: Proceedings of the Entomological Society of Washington, Washington, 105 (1), 225-237.

Kapantaidaki, D.E., Evangelou, V.I., Morrison III, W.R., Leskey, T.C., Brodeur, J., Milonas, P. (2019) *Halyomorpha halys* (Hemiptera: Pentatomidae) Genetic Diversity in North America and Europe. Insects, 10, 174. DOI: https://doi.org/10.3390/insects10060174

Kiritani, K. (2007) The impact of global warming and landuse change on the pest status of rice and fruit bugs (Heteroptera) in Japan. Global Change Biology, 13, 1586-1595.

Lee, D.H., Short, B.D., Joseph, S.V., Bergh, J.C., Leskey, T.C. (2013) Review of the biology, ecology, and management of *Halyomorpha halys* (Hemiptera: Pentatomidae) in China, Japan, and the Republic of Korea. Environmental entomology, 42 (4), 627-641. DOI: https://doi.org/10.1603/EN13006

Lee, D.H., Nielsen, A.L., Leskey, T.C. (2014) Dispersal capacity and behavior of nymphal stages of *Halyomorpha halys* (Hemiptera: Pentatomidae) evaluated under laboratory and field conditions. Journal of Insect Behavior, 27 (5), 639-651. DOI: https://doi.org/10.1007/s10905-014-9456-2

Lee, D.H., Leskey, T.C. (2015) Flight behavior of foraging and overwintering brown marmorated stink bug, *Halyomorpha halys* (Hemiptera: Pentatomidae). Bulletin of Entomological Research, 105 (5), 566-573. DOI: https://doi.org/10.1017/S0007485315000462

Leskey, T.C., Hamilton, G.C., Nielsen, A.L., Polk, D.F., Rodriguez-Saona, C., Bergh, J.C., Herbert, D.A., Kuhar, T.P., Pfeifer, D., Dively, G.P., Hooks, C.R.R., Raupp, M.J., Shrewsbury, P.M., Krawczyk, G., Shearer, P.W., Whalen, J., Koplinka-Loehr, C., Myers, E., Inkley, D., Hoelmer, K.A., Lee, D.H., Wright, S.E. (2012) Pest status of the brown marmorated stink bug, *Halyomorpha halys* in the USA. Outlooks on Pest Management, 23 (5), 218-226. DOI: https://doi.org/10.1564/23oct07

Leskey, T.C., Short, B.D., Lee, D.H. (2014) Efficacy of insecticide residues on adult *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae) mortality and injury in apple and peach orchards. Pest Management Science, 70 (7), 1097-1104.

Leskey, T.C., Nielsen, A.L. (2018) Impact of the Invasive Brown Marmorated Stink Bug in North America and Europe: History, Biology, Ecology, and Management. Annual Review of Entomology, 63, 599-618. DOI: https://doi.org/10.1146/annurev-ento-020117-043226

Macavei, L.I., Baetan, R., Oltean, I., Florian, T., Varga, M.C.E., Maistrello, L. (2015) First detection of *Halyomorpha halys* Stål, a new invasive species with a high potential of damage on agricultural crops in Romania. Lucrări Ştiinţifice, 58, 105–108.

Maistrello, L., Dioli, P., Vaccari, G., Nannini, R., Bortolotto, P., Caruso, S., Costi, E., Montermini, A., Casoli, L., Bariselli, M. (2014) First records in Italy of the Asian stinkbug *Halyomorpha halys*, a new threat to fruit crops. Attidelle Giornate Fitopatologiche, 1, 283-288.

Malek, R., Zapponi, L., Eriksson, A., Ciolli, M., Mazzoni, V., Anfora, G., Tattoni, C. (2019) Monitoring 2.0: Update on the *Halyomorpha halys* Invasion of Trentino. ISPRS International Journal of Geo-Information, 8 (12), 564. DOI: https://doi.org/10.3390/ijgi8120564

Mazzoni, V., Polajnar, J., Baldini, M., Rossi Staccioni, M.V., Anfora, G., Guidetti, R., Maistrello, L. (2017) Use of substrate-borne vibrational signals to attract the Brown Marmorated Stink Bug, *Halyomorpha halys*. Journal of Pest Science, 90, 1219–1229. DOI: https://doi.org/10.1007/s10340-017-0862-z

Milonas, P.G, Partsinevelos, G.K. (2014) First report of brown marmorated stink bug *Halyomorpha halys* Stål (Hemiptera: Pentatomidae) in Greece. *EPPO* Bulletin, 44 (2), 183-186. DOI: https://doi.org/10.1111/epp.12129

Mityushev, I.M. (2016) First record of *Halyomorpha halys* in Russia. Zashchita i Karantin Rasteniĭ, (3). [Online] Available at: https://gd.eppo.int/reporting/article-5893 [Accessed 28 January 2021]

Morrison III, W.R., Blaauw, B.R., Short, B.D., Nielsen, A.L., Bergh, B.C., Krawczyk, G., Park, Y.-L., Butler, B., Khrimian, A., Leskey, T.C. (2019) Successful management of *Halyomorpha halys* (Hemiptera: Pentatomidae) in commercial apple orchards with an attract-and-kill strategy. Pest management science, 75 (1), 104-114. DOI: https://doi.org/10.1002/ps.5156

Musolin, D., Konjevic, A., Karpun, N., Protsenko, V., Ayba, L., Saulich, A. (2018) Invasive brown marmorated stink bug *Halyomorpha halys* (Stål) (Heteroptera: Pentatomidae) in Russia, Abkhazia, and Serbia: history of invasion, range expansion, early stages of establishment, and first records of damage to local crops. Arthropod-Plant Interactions, 12 (4), 517-529. DOI: https://doi.org/10.1007/s11829-017-9583-8

Nielsen, A.L., Hamilton, G.C., Matadha, D. (2008) Developmental rate estimation and life table analysis for *Halyomorpha halys* (Hemiptera: Pentatomidae). Environmental Entomology, 37 (2), 348-355. DOI: https://doi.org/10.1093/ee/37.2.348

Oštrec, LJ., Gotlin Čuljak, T. (2005) Opća entomologija. Čakovec: Zrinski d.d. [in Croatian].

Owens, D.R., Herbert, D.A., Dively, G.P., Reisig, D.D., Kuhar, T.P. (2013) Does feeding by *Halyomorpha halys* (Hemiptera: Pentatomidae) reduce soybean seed quality and yield? Journal of Economic Entomology, 106, 1317-1323.

Pajač Živković, I., Jemrić, T., Fruk, M., Buhin, J., Barić, B. (2016) Influence of different netting structures on codling moth and apple fruit damages in northwest Croatia. Agriculturae Conspectus Scintificus, 81 (2), 99-102.

Pajač Živković, I., Jemrić, T., Fruk, M., Barić, B. (2018) Upotreba fotoselektivnih mreža u zaštiti od važnih štetnika breskve. Glasilo biljne zaštite, 18 (4), 399-406 [in Croatian].

Pansa, M.G., Asteggiano, L., Costamagna, C., Vittone, G., Tavella, L. (2013) First discovery of *Halyomorpha halys* in peach orchards in Piedmont. Informatore Agrario, 69 (37), 60-61.

Rabitsch, W. (2010) True Bugs (Hemiptera, Heteroptera). Chapter 9.1. In: Roques, A., Kenis, M., Lees, D., Lopez-Vaamonde, C., Rabitsch, W., Rasplus, J.Y., Roy, D.B. (2010) Alien terrestrial arthropods of Europe. BIORISK-Biodiversity and Ecosystem Risk Assessment, (4). Sofia, PENSOFT Publishers. DOI: https://doi.org/10.3897/biorisk.4.44

Rabitsch, W., Friebe, G.J. (2015) From the west and from the east? First records of *Halyomorpha halys* (Stål, 1855) (Hemiptera: Heteroptera: Pentatomidae) in Vorarlberg and Vienna, Austria. Beiträge zur Entomofaunistik, 16, 115-139. [Online] Available at: https://www.zobodat.at/pdf/BEF_16_0126-0129.pdf [Accessed 29 January 2021]

Rice, K.B., Bergh, C.J., Bergmann, E.J., Biddinger, D.J., Dieckhoff, C., Dively, G., Fraser, H., Gariepy, T., Hamilton, G., Haye, T., Herbert, A., Hoelmer, K., Hooks, C.R., Jones, A., Krawczyk, G., Kuhar, T., Martinson, H., Mitchell, W., Nielsen, A.L., Pfeiffer, D.G., Raupp, M.J., Rodriguez-Saona, C., Shearer, P., Shrewsbury, P., Venugopal, P.D., Whalen, J., Wiman, N.G., Leskey, T.C., Tooker, J.F. (2014) Biology, ecology and menagement of brown marmorated stink bug (Hemiptera: Pentatomidae). Journal of Integrated Pest Management, 5 (3), A1-A13. DOI: https://doi.org/10.1603/IPM14002

Rot, M., Devetak, M., Carlevaris, B., Žežlina, J., Žežlina, I. (2018) First record of brown marmorated stink bug (*Halyomorpha halys* (Stal, 1855)) (Hemiptera: Pentatomidae) in Slovenia. Acta Entomologica Slovenica, 26 (1), 5-12.

Stoeckli, S., Felber, R., Haye, T. (2020) Current distribution and voltinism of the brown marmorated stinkbug, *Halyomorpha halys*, in Switzerland and its response to climatechange using a high-resolution CLIMEX model. International Journal of Biometeorology, 64, 2019-2032. DOI: https://doi.org/10.1007/s00484-020-01992-z

Šerić Jelaska, L., Šapina, I. (2018) First report of invasive brown marmorated stink bug *Halyomorpha halys* (Stal, 1855) in Croatia. EPPO Bulletin, 48 (1), 138-143. DOI: https://doi.org/10.1111/epp.12449

Šeat, J. (2015) *Halyomorpha halys* (Stål, 1855) (Heteroptera: Pentatomidae) a new invasive species in Serbia. Acta Entomologica Serbica, 20, 167-171. DOI: https://doi.org/10.5281/zenodo.45391

Vétek, G., Papp, V., Haltrich, A., Rédei, D. (2014) First record of the brown marmorated stink bug, *Halyomorpha halys* (Hemiptera: Heteroptera: Pentatomidae), in Hungary, with description of the genitalia of both sexes. Zootaxa, 3780 (1), 194-200. DOI: https://doi.org/10.11646/zootaxa.3780.1.8

Vetek, G., Koranyi, D. (2017) Severe damage to vegetables by the invasive brown marmorated stink bug, *Halyomorpha halys* (Hemiptera: Pentatomidae), in Hungary. Periodicum biologorum, 119 (2), 131-135. DOI: https://doi.org/10.18054/pb.v119i2.4935

Wermelinger, B., Wyniger, D., Forster, B. (2008) First records of an invasive bug in Europe: *Halyomorpha halys* Stal (Heteroptera: Pentatomidae), a new pest on woody ornamentals and fruit trees? Mitteilungen-Schweizerische Entomologische Gesellschaft, 81 (1/2), 1.

Zhu, G., Bu, W., Gao, Y., Liu, G. (2012) Potential geographic distribution of brown marmorated stink bug invasion (*Halyomorpha halys*). PLoS One, 7 (2), e31246. DOI: https://doi.org/10.1371/journal.pone.0031246

Zovko, M., Ostojić, I., Jurković, D., Karić, N. (2019) Prvi nalaz smede mramoraste stjenice *Halyomorpha halys* (Stal, 1855) u Bosni i Hercegovini. Radovi Poljoprivredno Prehrambenog Fakulteta Univerziteta u Sarajevu, 64 (69/1), 68-78.