

Preliminary field study of the life cycle parameters of the brown marmorated stink bug *Halyomorpha halys* (Stål, 1855) (Hemiptera: Pentatomidae) in Bulgaria

Проучване на жизнения цикъл на кафявата мраморна дървеница *Halyomorpha halys* (Stål, 1855) (Hemiptera: Pentatomidae) в България

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ABSTRACT

The brown marmorated stink bug (*Halyomorpha halys* (Stål, 1855)) is an invasive species that has entered Europe and has quickly managed to spread to most European countries. In Bulgaria, it was reported in 2016, and today it is widespread throughout the country. It is a polyphagous species that attacks many agricultural crops. This study aimed to investigate the biological parameters of the pest, which will contribute to the implementation of the right plant protection measures. For the climatic conditions of Bulgaria, *H. halys* develops only one generation per year. The results showed that the embryonic development was completed in 5.68 ± 1.24 days; the first nymphal instar – in 5.17 ± 0.38 days; the second – in 6.95 ± 1.68 days; the third – in 19.03 ± 3.74 days; the fourth – in 17.18 ± 2.58 days, and the fifth – in 30.7 ± 5.14 days.

Keywords: instar, generation, biological parameters, invasive species, phenology

АБСТРАКТ

Кафявата мраморна дървеница е вид, който е навлязъл в Европа и бързо е успял да се разпространи в повечето европейски страни. В България е съобщена за първи път през 2016 година, а днес е разпространена в цялата страна. Видът е полифаг и напада много видове земеделски култури. Целта на настоящото изследване е да се проучат биологичните особености на неприятеля, които ще допринесат за прилагането на правилните мерки за растителна защита. За климатичните условия на България *Halyomorpha halys* развива само едно поколение годишно. Получените резултати показваха, че ембрионалното развитие протича за 5.68 ± 1.24 дни; първа нимфна възраст – за 5.17 ± 0.38 дни; втора – за 6.95 ± 1.68 дни; трета – за 19.03 ± 3.74 дни; четвърта – 17.18 ± 2.58 дни и пета – за 30.7 ± 5.14 дни.

Ключови думи: стадии, поколение, биологични параметри, инвазивен вид, фенология

INTRODUCTION

The brown marmorated stink bug (*Halyomorpha halys* (Stål, 1855)) originated from East Asia – Japan, Korea, China and Taiwan (Chu and Lu, 1982; Hoebeke and Carter, 2003). The species has rapidly spread in North America and Europe. In Europe, *H. halys* was first established in 2007 on ornamental plants in Switzerland (Wermelinger et al., 2008). In 2012, Milonas and Partsinevelos (2014) discovered *H. halys* in Athens, Greece, and in the same year, Maistrello et al. (2014) reported it from the province of Modena, Italy. A year later, a survey was conducted to confirm the presence of the species in Italy, revealing that the brown marmorated stink bug is widespread in the Emilia-Romagna region, as well as in Lombardy and Piedmont (northern Italy) (Maistrello et al., 2014). In 2013, Véték et al. (2014) reported the occurrence of *H. halys* in Budapest, Hungary. Two years later, it was already found throughout the country (Véték et al., 2018). In 2016, the species was established in Bulgaria on ornamental plants (Simov, 2016). Based on forecast models, an invasion of this shield bug is expected in areas with latitudes between 30 °C and 50 °C, including Northern Europe, northeastern North America, Southern Australia, and the North Island of New Zealand. Angola in Africa and Uruguay in South America are also suitable (Zhu et al., 2012). The invasion of *H. halys* worldwide will continue in the coming years due to increasing international trade and also due to climate change (Stoekli et al., 2020).

Halyomorpha halys is a polyphagous species that attacks more than 300 host plants (Haye et al., 2015; Bergmann et al., 2016; Pajač et al., 2024). Nymphs and adults suck plant sap from leaves, buds and fruits of the host plants (Kuhar et al., 2012). On apple fruits (*Malus domestica* Borkh), the damage is expressed in the formation of brown corky tissue under the skin of the fruit (Day et al., 2009). As a result of the damage, dark green spots appear on the fruits of green apple varieties, and dark red spots – on red fruits (Brown, 2003). The damage is most severe at the end of the season before the fruit is harvested (Nielsen and Hamilton, 2009a). On tomato fruits (*Solanum lycopersicum* L.), the damage is expressed

in the formation of white, pale yellow, soft areas on the surface of the fruit, and the tissue under the skin is damaged. These damages reduce the quality and quantity of the fruits (Kuhar et al., 2012). Damages to berry fruits such as blueberries (*Vaccinium caesariense* Mack) and raspberries (*Rubus idaeus* L.) result in fruit discoloration, necrotic spots, and yield loss (Wiman et al., 2015).

In central and southern Hubei Province, China, *H. halys* develops one or two generations per year (Cuituan et al., 1993), while in South China, up to six generations per year (Sargent et al., 2011). In the USA, Eastern Pennsylvania, *H. halys* develops one generation per year, but a second generation is possible (Nielsen and Hamilton, 2009b). In Switzerland, the species develops one generation per year (Haye et al., 2014), and in Italy, two generations (Costi et al., 2017).

This study aims to investigate the life cycle parameters of the brown marmorated stink bug, *H. halys*, under field conditions in Bulgaria.

MATERIAL AND METHODS

The studies on the biological features of the brown marmorated stink bug were conducted in 2020 in outdoor isolators in the experimental field of the Agricultural University – Plovdiv, Bulgaria. The experiment was conducted on two-year-old hibiscus plants (*Hibiscus* sp.) with a height of about 50 cm, planted in pots of Ø25 cm. The plant species was selected based on our previous observations on the pest preference. The pots with the experimental plants were covered with organza fabric, which allowed easy observation and carrying out various manipulations (Figure 1). In late April and early May 2020, adults of the overwintered generation were collected from hibiscus plants on the campus of the Agricultural University – Plovdiv and used for the experiment.

Duration of the pest developmental stages

In late April and early May 2020, 10 pairs (one female and one male) of overwintered *H. halys* adults were placed in isolators to facilitate mating and egg-laying. After the detection of laid eggs, adults were removed



Figure 1. Outdoor isolators for studying the lifecycle parameters of the brown marmorated stink bug

from the isolator and placed in a new one. In this way, it was known that in each isolator, there were eggs laid on a specific date. The duration of the egg stage was studied on 111 eggs of the brown marmorated stink bug. After the eggs hatched, the duration of development of the nymphal instars and adult emergence was monitored. Nymphs that hatch from the respective egg cluster were observed daily until the first moult. As the nymphs passed into the second instar, they were moved individually to a new isolator, where observation of their transformation into the next instar and into adults continued. The date of emergence of the adults was recorded, and they were placed in a new isolator in pairs later. After the adults of the F1 generation emerged, they were moved to a new isolator in single pairs (one female and one male) for mating and laying eggs.

All results were processed with SPSS Statistics 26 for Windows. The data for the average daily temperature were measured and taken from the meteorological station located in the experimental field of the Agricultural University of Plovdiv.

RESULTS AND DISCUSSION

Under field conditions in isolators, the duration of the egg stage of *H. halys* was 5.68 ± 1.24 days. The development of first instar nymphs of *H. halys* lasted an average of 5.17 ± 0.38 days (Table 1). The typical behaviour of newly hatched nymphs was observed in the isolators to crowd on the empty egg chorions and remain on them until they passed into the next nymphal instar.

The second nymphal instar occurred in 6.95 ± 1.68 days. After it, the duration of development of the nymphal instars took much longer – third instar for 19.03 days, fourth instar for 17.18 days and fifth instar for 30.7 days (Table 1). The great difference in the duration of development of the nymphal stage under field conditions is due to variable air temperatures, especially those below $15\text{ }^{\circ}\text{C}$ or above $35\text{ }^{\circ}\text{C}$, at which development stops (Haye et al., 2014).

During field trials in isolators, the minimum air temperature in 2020 was below $15\text{ }^{\circ}\text{C}$ from June 1 to 11, June 23, June 27 and 28, July 10 and 11, and July 14 and 15. The maximum air temperature in 2020 exceeded $35\text{ }^{\circ}\text{C}$ on 30 June, 29, 30 and 31 July.

Table 1. Duration of the nymphal stage of *H. halys* under field conditions in the region of Plovdiv in 2020

Nymphal instar	1 st	2 nd	3 rd	4 th	5 th
Mean ± Std. Deviation	5.17 ± 0.38	6.95 ± 1.68	19.03 ± 3.74	17.18 ± 2.58	30.7 ± 5.14
Std. Error	0.04	0.21	0.59	0.63	1.63
Minimum	5	5	11	11	20
Maximum	6	10	25	23	36
Number	111	64	39	17	10

Under field conditions, as temperatures rose in the spring, adults of *H. halys* left their hibernation sites and began feeding. The average duration of development from egg to adult of the brown marmorated stink bug was 79.7 ± 6.63 days. The relatively low temperatures (average temperature 17.8 °C) and significant rainfall (average 80.7 mm) in May, as well as the slow gradual rise in temperatures (average temperature 21.4 °C) and prolonged rainfall (average 55.4 mm) in June were a prerequisite for delaying the development of individual instars of the pest, as a result of which the duration of development of one generation was significant.

Under field conditions in isolation, the lifespan of adults of the brown marmorated stink bug was found

to be 86 to 145 days (mean 116.75 ± 29.6 days) for females and 105 to 151 days (mean 135 ± 26 days) for male individuals. Because under our conditions this species developed only one generation per year, and in nature, adults remain overwintering, our observed life span in isolators does not provide insight into that of overwintering individuals.

During the observations made on the phenological development of the brown marmorated stink bug under field conditions, it was established that for one calendar year, under the climatic conditions of 2019 - 2021 in the region of the city of Plovdiv, the pest managed to develop only one full generation (Figure 2).

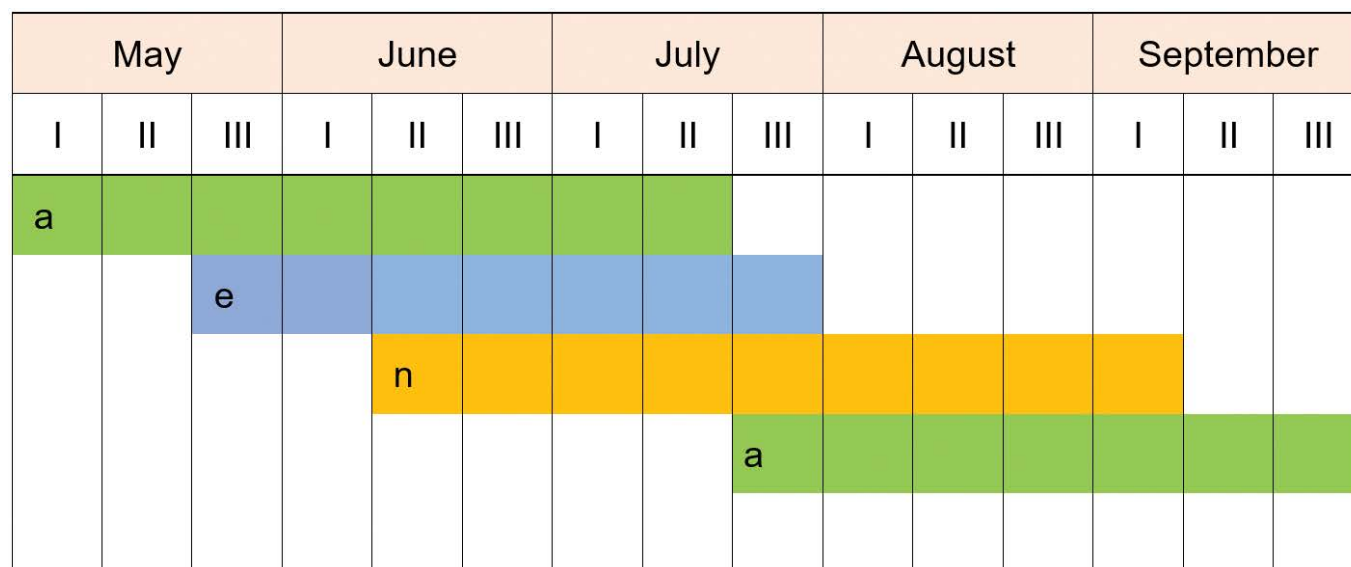


Figure 2. Phenological development of the brown marmorated stink bug in the Plovdiv region in 2019-2021 (a - adult; e - egg; n - nymph)

Adults of the F1 generation appeared in the third ten days of July, fed for some time and withdrawn in search of places for wintering. Overwintering adults that spend the winter months in reproductive diapause live very long. After reactivation in the spring, they feed for a while and start laying eggs in the third ten days of May. Eggs are discovered by the end of July, and nymphs begin to hatch in the second ten days of June. Nymphs of the last fifth instar were found until the end of the first ten days of September.

The duration of copulations in the brown marmorated stink bug varies widely, from ten minutes to four hours and 40 minutes, and the average duration is one hour and 59 minutes. All observed copulations took place in shaded areas on all aerial parts of the plants.

The pre-oviposition period of the brown marmorated stink bug is an average of 20.4 ± 5.5 days. Females prefer to lay their eggs on the underside of leaves. They lay 1-2 egg clusters, and the average number of eggs is 21.67 ± 7 . The average fecundity of *H. halys* is 30.4 ± 14.52 eggs.

CONCLUSIONS

For the first time in Bulgaria, the phenological development, the duration of individual stages and the number of generations per year of the brown marmorated stink bug were studied in outdoor conditions.

Under field conditions in Southern Bulgaria in the period 2019-2021, *H. halys* developed only one generation per year, and its development from egg to adult required an average of 79.7 days.

The reproductive behaviour of *H. halys* was also studied. It was found that adults copulate one to three times during their lifetime, and the preoviposition period is 20.4 days. The females laid an average of 30.4 eggs.

The obtained results on the biology of the species can be used to select the proper time for treatment with insecticides. In the last ten years, a relative increase in temperatures has been observed, which may lead to the development of a partial or complete second generation in this new species for Bulgaria.

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