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Developmental characteristics of the brown marmorated stink bug, *Halyomorpha halys*, under the conditions of Southeastern Kazakhstan

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ABSTRACT
The article presents the results of studies on the developmental biology of the brown marmorated stink bug, *Halyomorpha halys* on agricultural, ornamental, and forest plants under the conditions of Almaty City and Almaty Region in 2024-2025. It was established that overwintered populations in Almaty City appear during the second decade of May to June, whereas in the Almaty Region they emerge in the third decade of May. The first generation was formed in June, the second in July-August, and the third in August; adults entered diapause from late October. The duration of larval (nymphal) development differed among parts of the Almaty Region (Talgar District, Tuzdybastau village, and Enbekshikazak District, Turgen village): developmental stages occurred later and were characterized by different values of the sum of effective temperatures (SET) compared to Almaty City. Despite these differences, two generations were observed in both regions in 2024 and three generations in 2025. A gradual increase in SET from early to later nymphal instars was recorded, reflecting the adaptive plasticity of the species to regional climatic conditions.

Keywords: Brown marmorated stink bug, Sum of effective temperatures, Pheromone traps.

INTRODUCTION

The native range of the brown marmorated stink bug, *Halyomorpha halys* includes countries of East Asia: China, Japan, North and South Korea, Taiwan, and Vietnam (Lee *et al.* 2018). The species was first recorded in the United States, where it began to spread rapidly; and it had already been detected in 41 states (Hamilton 2009; Leskey & Nielsen 2018; Musolin *et al.* 2018). In Europe, the pest was first detected in Switzerland and Liechtenstein (Gariepy *et al.* 2015). Subsequently, it was recorded in Germany (Hess *et al.* 2022), Greece (Andreadis *et al.* 2021) France (Delbac *et al.* 2022), Italy (Costi *et al.* 2017; Maistrello *et al.* 2017), Hungary (Vétek *et al.* 2018), Abkhazia (Gapon 2016; Musolin *et al.* 2018), and in Kazakhstan (Šapina & Jelaska 2018).

The body of the brown marmorated stink bug is pear-shaped, slightly flattened, and 12-17 mm in length. The general coloration is brown; however, the head, pronotum, scutellum, and hemelytra bear light mottling that creates a characteristic marbled appearance. The ventral side is white or pale brown, sometimes with gray or black speckling. Alternating black and white triangular spots are present along the abdominal margin. White bands are visible at the base and apex of the fourth antennal segment and at the base of the fifth segment (Hamilton *et al.* 2018, Zhan *et al.* 2020). The legs are gray or brown, with white bands and numerous small dark spots. Eggs are white, spherical, and laid on the underside of leaves of various host plants. A single egg mass contains 15-40 eggs.

First-instar nymphs are black and orange, second instars are black, and later instars (III-V) gradually lighten, exhibit uneven coloration, and lack wings. The dorsal surface of nymphs bears orange-yellow spots, and spines are present on the lateral sides of the thorax (Zhan *et al.* 2020).

The brown marmorated stink bug is thermophilous and develops at temperatures ranging from +15 to +33 °C. At +15 °C, only embryonic development occurs, whereas nymphs do not survive; a temperature of +35 °C is critical for all developmental stages, and at +33 °C only about 5% of individuals survive (Costi *et al.* 2017). The optimal temperature range for normal development is +18-25 °C. Depending on regional thermal conditions, the pest may produce one to three generations per year. Adults overwinter mainly in large aggregations in dry buildings, while under natural conditions they shelter inside large stumps and decaying trunks (Rice *et al.* 2014; Acebes-Doria *et al.* 2016; Acebes-Doria *et al.* 2020). Emergence from overwintering sites occurs from the third decade of April to the second decade of May, depending on the region. After emergence, adults feed for 1-2 weeks before mating. At daytime temperatures of +6-8 °C and under sunny conditions, active movement of adults along building walls and fences is observed; with decreasing temperatures, bugs seek shelter. This behavior may be repeated until stable nighttime temperatures of +10-12 °C are reached and leaf emergence begins (Rice *et al.* 2014). Females lay eggs in batches of 15-40 at intervals of 5-14 days, and oviposition may last for 2-3 months. Total fecundity reaches 250-300 eggs per female (Morrison *et al.* 2015; Acebes-Doria *et al.* 2018). Embryonic development lasts 5-7 days, while development of the nymphal stages lasts 3-4 days for the first instar and 8-12 days for instars II-V. The complete development of one generation requires 40-50 days (Zhan *et al.* 2020).

During daytime hours, adults actively fly between host plants, sometimes over considerable distances. Toward dusk, activity decreases; however, directed movement toward light sources may occur, with insects circling and producing a characteristic buzzing sound (Zhan *et al.* 2020).

The spread of the brown marmorated stink bug occurs both through natural dispersal and via transportation pathways, including fresh vegetables and fruits, cut flowers, planting material, wood packaging materials, vehicles, and equipment (Gariepy *et al.* 2014; Gariepy *et al.* 2015; Fraser *et al.* 2017). The primary risks of introduction originate from countries within the native range (Japan, Korea, China, and Taiwan) and secondary invasive ranges (the USA and Europe; Hamilton 2009; Gariepy *et al.* 2014; Gariepy *et al.* 2015).

The pest feeds on more than 300 plant species belonging to 49 families, with a preference for members of the Rosaceae (Acebes-Doria *et al.* 2016, Fraser *et al.* 2017; Acebes-Doria *et al.* 2020). In its native range, *H. halys* does not cause significant damage due to the presence of natural enemies and pathogens; however, in invaded areas its harmfulness is extremely high. For example, in 2010, crop losses caused by this pest in the United States exceeded USD 21 billion (Costi *et al.* 2017).

The brown marmorated stink bug damages fruit crops (pear, apple, peach, apricot, and sweet cherry), subtropical crops (citrus, persimmon, fig, and olive), berry crops (grape, mulberry, rose hip, cherry laurel, and sea buckthorn), nut crops (hazelnut), vegetables (tomato, cucumber, pepper, eggplant, and bean), cereals and grain legumes (maize, wheat, barley, soybean, pea, and chickpea), as well as ornamental woody plants and forest tree species (Chuche *et al.* 2016; Costi *et al.* 2017). In addition to direct damage, *H. halys* is a vector of *Paulownia phytoplasmosis* and several other phytoplasma diseases (Baek *et al.* 2017; Acebes-Doria *et al.* 2020).

In areas of mass reproduction, the bug also represents a serious nuisance pest, as it invades residential buildings, emits an unpleasant odor, and may cause allergic reactions in humans (Costi *et al.* 2017).

Detection of the pest during the growing season is carried out through regular inspection of host plants and the use of aggregation pheromone traps. At low population densities, the use of an entomological sweep net and pheromone traps is recommended in accordance with the manufacturer's instructions (Acebes-Doria *et al.* 2018).

MATERIALS AND METHODS

From 2024 to 2025, monitoring was conducted in the southern and southeastern regions of Kazakhstan, including Almaty City as well as the Almaty, Zhambyl, Turkestan, and Kyzylorda regions. Standard entomological methods were used for material collection, including pheromone traps, hand collection, and visual inspections. Particular attention was paid to the distribution of the brown marmorated stink bug, *Halyomorpha halys*, which was recorded at both the adult (imago) and preimaginal stages, including egg masses and nymphs of different instars. The brown marmorated stink bug was repeatedly recorded in the Nauryzbay and Bostandyk districts of Almaty City, as well as in the Talgar and Enbekshikazak districts of Almaty Region. The pest damaged forage, woody, and ornamental fruit and berry crops and was also found in residential buildings and their surroundings. Surveys were conducted every 5-7 days from the moment the first *H. halys* individuals were detected, using pyramidal pheromone traps (Morrison *et al.* 2015; Acebes-Doria *et al.* 2020). After emergence from overwintering (from the second decade of May to the second decade of June), observations continued throughout the entire growing season until adults entered diapause (third decade of October, depending on the climatic zone).

The sum of effective temperatures (SET) was calculated using the following formula (Chernova 2008; Papaj & Lewis 2012):

$$C = (t - t_0) \times n$$

where t is the ambient temperature (°C), t_0 is the developmental threshold temperature (°C), and n is the number of hours or days during which the temperature exceeds the developmental threshold.

RESULTS

Monitoring of brown marmorated stink bug, *Halyomorpha halys* infestation in 2024-2025 showed that the pest regularly occurred on various fruit and forest crops in Almaty City and Almaty Region. In Talgar District (Tuzdybastau village), the bug was frequently recorded on common catalpa, *Catalpa bignonioides*, whereas in Enbekshikazak District (Turgen village) its occurrence on apple (*Malus*) was moderate (Table 1).

Table 1. Results of monitoring the occurrence of the brown marmorated stink bug on fruit, berry, and forest crops, 2024-2025.

Study site	Crop	Stink bug occurrence
Almaty Region, Talgar District, Tuzdybastau village, S. Ashimbayev Street	Northern catalpa *(Catalpa bignonioides)*	+++
Almaty Region, Enbekshikazak District, Turgen village, “Bakdala” LLP	Apple (*Malus*)	++
Almaty city, Medeu District, Abay Street	Apple (*Malus*)	+++
Almaty city, Bostandyk District, Al-Farabi Avenue, First President’s Park	Apple (*Malus*) Paulownia (*Paulownia*) Sour cherry (*Prúnus subg. Cérasus*) Linden *(Tília)* Northern catalpa *(Catalpa bignonioides)*	+++
Almaty city, Nauryzbay District, Kultobe 1 Street	Paulownia (*Paulownia*) Apple (*Malus*) Elm *(Ulmus)* Poplar (*Pópulus)*	+++ +++ + +
Almaty city, Bostandyk District, Almerek Street, “Okzhetpes” Sanatorium	Northern catalpa *(Catalpa bignonioides)* Apricot (*Prunus armeniaca)* Apple (*Malus*) Chestnut (*Castanea)*	+++ + +++ +

Note: (+) - rare occurrence; (++) - moderate occurrence; (+++) - frequent occurrence.

Within Almaty City, a high frequency of infestation was observed on apple (*Malus*) in the Medeu District, as well as on paulownia (*Paulownia*) and apple (*Malus*) in the Nauryzbay District. On elm (*Ulmus*) and poplar (*Populus*), the pest was recorded rarely. At the “Okzhetpes” sanatorium, the brown marmorated stink bug frequently infested common catalpa (*Catalpa bignonioides*) and apple (*Malus*), showed moderate occurrence on apricot (*Prunus armeniaca*), and rare occurrence on chestnut (*Castanea*). These data indicate a wide range of host plant preferences and a high capacity of *H. halys* to colonize diverse crops in the region.

The study of the biological characteristics of the brown marmorated stink bug under field conditions provides valuable information for the development of effective pest management strategies.

In 2024, under the conditions of Almaty City, overwintered populations of the brown marmorated stink bug appeared in the first decade of June, when SET reached 181 °C (Tables 2 and 3).

Table 2. Phenology of brown marmorated stink bug development (Almaty city: Nauryzbay and Bostandyk districts; Almaty Region: Enbekshikazak District, Turgen village), 2024.

April			May			June			July			August			September			October		
O	O	O	O	O	O															
						+	+	+	+	+	+	+								
						●	●	●	●	●	●	●								
							-	-	-	-	-	-								
												+	+	+	+	+	+	+		
												●	●	●	●	●	●	●		
													-	-	-	-	-	-		
																			O	O
Legend: O – overwintering adults; + – adults; ● – eggs; - – larvae (nymphs).																				

In Almaty City, the first generation of the brown marmorated stink bug appeared in the first decade of June (egg laying), the second generation from the first decade of August, and from the second decade of October adults entered diapause.

The first egg masses were detected in the first decade of June, when SET reached 233 °C (calculated from a developmental threshold of 13 °C). Hatching of first-generation nymphs was recorded in the second decade of June at a SET of 823 °C.

Table 3. Sum of effective temperatures required for the development of different stages of the brown marmorated stink bug (Almaty City: Nauryzbay and Bostandyk districts), 2024

Developmental stage	**Development period (decade)**	**Mean daily temperature (°C)**		**Relative air humidity (%)**	**SET > 13.0 °C**
		Minimum	**Maximum**		
Adult (imago)	I - June	16.5	20.0	47.6	181
Egg	I - June	20.0	23.5	39.0	233
Nymphs (I-V instars)	II - June - III - July	18.5	30.0	44.0	823
Second-generation adults	III - July	25.5	29.5	35.0	890
Egg	III - July	23.0	27.5	32.8	986
Nymphs (I-V instars)	I - August - II - September	20.0	25.0	41.5	1242

Emergence of second-generation adults of the brown marmorated stink bug began in the third decade of July, when SET reached 890 °C. Egg masses recorded during the same period corresponded to a SET of 986 °C. The sum of effective temperatures required for the development of nymphs (I-V instars) was 1242 °C. Under the conditions of the Almaty Region, development of overwintered populations began in the second decade of June at a SET of 214 °C (Table 4).

Table 4. Sum of effective temperatures required for the development of different stages of the brown marmorated stink bug (Almaty Region, Enbekshikazak District, Turgen Village), 2024

Developmental stage	**Development period (decade)**	**Mean daily temperature (°C)**		**Relative air humidity (%)**	**SET > 13.0 °C**
		Minimum	**Maximum**		
Adult (imago)	II - June	16.5	22.0	52.2	214
Egg	II - June	21.5	23.0	48.4	235
Nymphs (I-V instars)	II - June III - July	22.5	29.0	49.0	938
Second-generation adults	I - August	26.0	28.5	32.6	996
Egg	I - August	24.5	27.0	33.6	1077
Nymphs (I-V instars)	II - August - III September	10.0	25.5	51.1	1094

Emergence of second-generation adults was recorded in the first decade of August when SET reached 996 °C. During the same period, egg masses appeared at an SET of 1077 °C. The total thermal requirement for completion of nymphal development (I-V instars) amounted to 1094 °C.

To analyze the phenology of brown marmorated stink bug development under the conditions of Almaty City (Medeu, Bostandyk, and Nauryzbay districts) and the Almaty Region (Talgar District, and Tuzdybastau village) in 2025, phenological observation data reflecting the timing of major developmental stages were summarized (Table 5).

Table 5. Phenology of brown marmorated stink bug development under the conditions of Almaty city and the Almaty Region, 2025

April			May			June			July			August			September			October		
O	O	O	O																	
				+	+	+	+	+	+	+										
						●	●	●	●	●										
						-	-	-	-	-										
										+	+	+	+							
										●	●	●	●							
										-	-	-	-							
													+	+	+	+	+	+	+	O
													●	●	●	●	●	●	●	
													-	-	-	-	-	-	-	
Legend: O – overwintering adults; + – adults; ● – eggs; - – larvae (nymphs).																				

In Almaty City, the first generation of the brown marmorated stink bug appeared in the first decade of June (egg laying), the second in the second decade of July, and the third in the second decade of August; from the third decade of October, adults entered diapause. In Almaty Region, the corresponding stages occurred one decade later: the first generation in the second decade of June, the second in the third decade of July, and the third in the third decade of August, with adults entering diapause from late October.

In 2025, to assess thermal conditions for the development of the brown marmorated stink bug in Almaty City and Almaty Region, the sum of effective temperatures (SET) was calculated for individual developmental stages. The results are presented in Tables 6 and 7.

Table 6. Sum of effective temperatures required for the development of different stages of the brown marmorated stink bug under the conditions of Almaty City, during 2025.

Developmental stage	Development period (decade)	Mean daily temperature (°C)		Relative air humidity (%)	SET > 13.0 °C
		Minimum	Maximum		
Adult (imago)	II - May	15.0	23.0	51.0	195
Egg	I - June	17.5	23.5	51.6	318
Nymphs (I-V instars)	I - June I - July	20.0	31.0	39.4	792
Second-generation adults	II - July	25.0	30.5	32.7	822
Egg	II - July	25.5	31.0	24.7	880
Nymphs (I-V instars)	II - July - II - August	22.5	31.0	29.0	1273
Third-generation adults	II - August	21.0	29.0	30.2	1298
Egg	II - August	19.5	26.0	35.0	1326
Nymphs (I-V instars)	II - August - II - September	12.5	25.5	33.0	1559

Analysis of SET values showed that in Almaty City in 2025, overwintered adults appeared in the second decade of May at a SET of 195 °C. Egg masses of the first generation were recorded in the first decade of June at a SET of 318 °C, while nymphs (I-V instars) developed from June to July at a SET of 792 °C. Second-generation adults developed in July at a SET of 822 °C, with corresponding egg laying at a SET of 880 °C; nymphs of the second generation developed from July to August at a SET of 1273 °C. Third-generation adults formed in August at a SET of 1298 °C, their eggs at a SET of 1326 °C, and third-generation nymphs developed until the second decade of September at a SET of 1559 °C. In Almaty Region (Talgar District), emergence of overwintered populations of the brown marmorated stink bug was observed in the third decade of May at a SET of 202 °C; egg laying of the first generation occurred in the first decade of June at a SET of 326 °C, and nymphs (I-V instars) developed from June to July at a SET of 802 °C.

Table 7. Sum of effective temperatures required for the development of different stages of the brown marmorated stink bug under the conditions of the Almaty Region, 2025.

Developmental stage	**Development period (decade)**	**Mean daily temperature (°C)**		**Relative air humidity (%)**	**SET > 13.0 °C**
		Minimum	**Maximum**		
Adult (imago)	III- May	15.3	23.0	55.3	202
Egg	II - June	18.0	26.5	46.0	326
Nymphs (I-V instars)	II June - II - July	24.0	29.0	39.2	802
Second-generation adults	III - July	25.0	30.5	33.6	831
Egg	III - July	21.0	31.0	21.3	913
Nymphs (I-V instars)	III - July - III - August	20.0	30.0	24.3	1130
Third-generation adults	III - August	20.0	26.0	23.6	1174
Egg	III - August	20.0	25.5	22.0	1208
Nymphs (I-V instars)	III - August - III - September	12.5	25.0	33.2	1325

Second-generation adults developed in July at a SET of 831 °C; their eggs were recorded at a SET of 913 °C, and second-generation nymphs developed from July to August at 1130 °C. Third-generation adults were observed in August at a SET of 1174 °C, their eggs at 1208 °C, and third-generation nymphs developed until the second decade of September at 1325 °C.

To refine the thermal requirements for the development of the brown marmorated stink bug, the sum of effective temperatures was calculated separately for each nymphal instar (I-V). The results for 2024-2025 are presented in Tables 8 and 9.

Table 8. Sum of effective temperatures required for the development of nymphs of different instars of the brown marmorated stink bug, 2024.

Developmental stage	**Almaty City**		**Almaty Region**	
	Development period (decade)	**SET > 13.0 °C**	**Development period, decade**	**SET > 13.0 °C**
First-generation nymphs				
First instar	II - June	338	III - June	402
Second instar	III - June	460	I - July	485
Third instar	II - July	660	III - July	713
Fourth instar	III - July	587	I - August	844
Third instar	I - August	823	II - August	938
Second-generation nymphs				
First instar	II - August	902	III - August	981
Second instar	II - August	972	III - August	1023
Third instar	III - August	1191	I - September	1046
Fourth instar	I -September	1223	II - September	1065
Third instar	II - September	1242	III - September	1094

The data in Table 8 indicate differences in developmental timing and accumulation of the sum of effective temperatures (SET > 13.0 °C) in brown marmorated stink bug nymphs under the conditions of Almaty City and Almaty Region in 2024. In Almaty City, development of first-generation nymphs (I-V instars) occurred from the second decade of June to the first decade of August, with SET accumulation ranging from 338 to 823 °C. In contrast, in Almaty Region, the corresponding stages developed slightly later – from the third decade of June to the second decade of August – and at higher SET values (402-938 °C). Development of second-generation nymphs in Almaty City began in the second decade of August and continued until the second decade of September, with SET values ranging from 902 to 1242 °C. In Almaty Region, second-generation nymphs developed from the third decade of August to the third decade of September at lower SET values (981-1094 °C). Overall, both regions showed an increase in SET with progression from early to later nymphal instars. These differences reflect the influence of regional climatic conditions on developmental rates and confirm the adaptive plasticity of *H. halys* to different thermal regimes.

Table 9. Sum of effective temperatures required for the development of nymphs of different instars of the brown marmorated stink bug, 2025.

Developmental stage	Almaty City		Almaty Region	
	Development period (decade)	SET > 13.0 °C	Development period, (decade)	SET > 13.0 °C
First-generation nymphs				
First instar	I - June	343	II - June	395
Second instar	I - June	412	III - June	517
Third instar	II - June	535	III- June	633
Fourth instar	III - June	663	I - July	710
Third instar	I - July	792	II - July	802
Second-generation nymphs				
First instar	II - July	934	III - July	875
Second instar	III - July	1093	III - July	944
Third instar	I - August	1143	I - August	1015
Fourth instar	I - August	1205	I - August	1075
Third instar	II - August	1273	III - August	1130
Third-generation nymphs				
First instar	II - August	1324	III - August	1185
Second instar	III - August	1440	III - August	1254
Third instar	I - September	1466	I - September	1275
Fourth instar	I - September	1519	II - September	1296
Third instar	II - September	1559	III - September	1325

The data in Table 9 demonstrate the accumulation of the sum of effective temperatures and the timing of development of nymphs of different instars in Almaty City and Almaty Region in 2025. In Almaty City, first-generation nymphs (I-V instars) developed from the first decade of June to the first decade of July, with SET values ranging from 343 to 792 °C. In Almaty Region, the same stages developed from the second decade of June to the second decade of July, with SET values ranging from 395 to 802 °C, indicating a slight delay in development. Second-generation nymphs in Almaty City developed from the second decade of July to the second decade of August, with SET values of 934-1273 °C, whereas in Almaty Region development occurred from the third decade of July to the third decade of August at lower SET values (875-1130 °C). Development of third-generation nymphs in Almaty City took place from the second decade of August to the second decade of September, with SET accumulation ranging from 1324 to 1559 °C, while in Almaty Region it occurred from the third decade of August to the third decade of September at SET values of 1185-1325 °C. For both regions, a gradual increase in SET was observed with progression from early to later nymphal instars. Overall, the 2025 data confirm that developmental rates and SET accumulation in brown marmorated stink bug nymphs are strongly influenced by regional climatic conditions, with populations in Almaty Region developing slightly later and at lower thermal sums, particularly in the second and third generations.

CONCLUSION

The conducted studies demonstrated that the brown marmorated stink bug, *Halyomorpha halys* actively inhabits agricultural, ornamental, and forest plants. The highest infestation intensity was recorded on apple, raspberry, apricot, catalpa, and paulownia. The development of the pest under the conditions of Almaty City and Almaty Region is strongly dependent on regional thermal conditions. The timing of nymphal development and the accumulation of the sum of effective temperatures (SET) differed markedly between the regions: in Almaty Region, developmental stages occurred later and were characterized by altered SET values compared to those observed in Almaty City. Despite these differences, the number of generations remained stable – two generations in 2024 and three generations in 2025– indicating the species' ability to maintain its life cycle under varying climatic conditions. In both regions, a gradual increase in SET was observed from younger to older nymphal instars, reflecting the high adaptive plasticity of the species and its capacity to adjust to local thermal regimes. The obtained data refine the phenology and thermal requirements of *H. halys* development and may be applied in the development of integrated biological control measures and monitoring systems aimed at preventing damage to agricultural and forest crops.

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REFERENCES

Acebes-Doria, AL, Agnello, AM, Alston, DG, Andrews, H, Beers, EH, Bergh, JC, Bessin, R, Blaauw, BR, Buntin, GD & Burkness, EC 2020, Season-long monitoring of the brown marmorated stink bug (Hemiptera: Pentatomidae) throughout the United States using commercially available traps and lures. *Journal of Economic Entomology,* 113: 159–171.

Acebes-Doria, AL, Leskey, TC & Bergh, JC 2016, Host plant effects on *Halyomorpha halys* (Hemiptera: Pentatomidae) nymphal development and survivorship. *Environmental Entomology,* 45: 663–670.

Acebes-Doria, AL, MorrisonIII, WR, Short, BD, Rice, KB, Bush, HG, Kuhar, TP, Duthie, C & Leskey, TC 2018, Monitoring and biosurveillance tools for the brown marmorated stink bug, *Halyomorpha halys* (Stål; Hemiptera: Pentatomidae). *Insects,* 9: 82.

Andreadis, SS, Gogolashvili, NE, Fifis, GT, Navrozidis, EI & Thomidis, T 2021, First report of native parasitoids of *Halyomorpha halys* (Hemiptera: Pentatomidae) in Greece. *Insects,* 12: 984.

Baek, S, Hwang, A, Kim, H, Lee, H & Lee, J-H 2017, Temperature-dependent development and oviposition models of *Halyomorpha halys* (Hemiptera: Pentatomidae). *Journal of Asia-Pacific Entomology,* 20: 367–375.

Chernova, N 2008, General Ecology: Textbook for students of pedagogical universities. Moscow, Drofa, 416 p.

Chuche, J, Danet, JL, Salar, P, Foissac, X & Thiéry, D 2016, Transmission of 'Candidatus *Phytoplasma solani*' by *Reptalus quinquecostatus* (Hemiptera: Cixiidae). *Annals of Applied Biology,* 169: 214–223.

Costí, E, Haye, T & Maistrello, L 2017, Biological parameters of the invasive brown marmorated stink bug, Halyomorpha halys, in southern Europe. *Journal of Pest Science,* 90: 1059–1067.

Delbac, L, Rouzes, R, Hamidi, R & Thiéry, D 2022, First occurrence of *Halyomorpha halys* in *Bordeaux vineyards*. *OENO One,* 56: 253–257.

Fraser, D, Kumar, S & Aguilar, G 2017, Mapping the potential global range of the brown marmorated stink bug, Halyomorpha halys, with particular reference to New Zealand. *Climate,* 5: 75.

Gapon, D 2016, First records of the brown marmorated stink bug *Halyomorpha halys* (Stål, 1855; Heteroptera, Pentatomidae) in Russia, Abkhazia, and Georgia. *Entomological Review,* 96**:**1086–1088.

Gariepy, T, Bruin, A, Haye, T, Milonas, P & Vétek, G 2015, Occurrence and genetic diversity of new populations of Halyomorpha halys in Europe. *Journal of Pest Science,* 88: 451–460.

Gariepy, T, Fraser, H & Scott-Dupree, C 2014, Brown marmorated stink bug (Hemiptera: Pentatomidae) in Canada: recent establishment, occurrence, and pest status in southern Ontario. *The Canadian Entomologist,* 146: 579–582.

Hamilton, GC 2009, Brown marmorated stink bug. *American Entomologist,* 55: 19.

Hamilton, GC, Ahn, JJ, Bu, W, Leskey, TC, Nielsen, AL, Park, Y-L, Rabitsch, W & Hoelmer, KA 2018, *Halyomorpha halys* (Stål). Invasive stink bugs and related species (Pentatomoidea). CRC Press.

Hess, B, Zimmermann, O, Baufeld, P, Reißig, A, Lutsch, B & Schrader, G 2022, Current distribution and spatial spread patterns of *Halyomorpha halys* in Germany. *EPPO Bulletin,* 52: 164–174.

Lee, W, Guidetti, R, Cesari, M, Gariepy, T, Park, Y-L & Park, C-G 2018, Genetic diversity of *Halyomorpha halys* (Hemiptera, Pentatomidae) in Korea and comparison with COI sequence datasets from East Asia, Europe, and North America. *Florida Entomologist,* 101: 49–54.

Leskey, TC & Nielsen, AL 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.

Maistrello, L, Vaccari, G, Caruso, S, Costi, E, Bortolini, S, Macavei, L, Foca, G, Ulrici, A, Bortolotti, PP & Nannini, R 2017, Monitoring of the invasive Halyomorpha halys, a new key pest of fruit orchards in northern Italy. *Journal of Pest Science,* 90: 1231–1244.

MorrisonIII, WR, Cullum, JP & Leskey, TC 2015, Evaluation of trap designs and deployment strategies for capturing *Halyomorpha halys* (Hemiptera: Pentatomidae). *Journal of Economic Entomology,* 108: 1683–1692.

Musolin, DL, Konjević, A, Karpun, NN, Protsenko, VY, Ayba, LY & Saulich, AK 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: 517–529.

Papaj, DR & Lewis, AC 2012, Insect learning: Ecology and evolutinary perspectives.

Rice, KB, Bergh, CJ, Bergmann, EJ, Biddinger, DJ, Dieckhoff, C, Dively, G, Fraser, H, Gariepy, T, Hamilton, G & Haye, T 2014, Biology, ecology, and management of brown marmorated stink bug (Hemiptera: Pentatomidae). *Journal of Integrated Pest Management,* 5: A1–A13.

Šapina, I & Jelaska, LŠ 2018, First report of invasive brown marmorated stink bug *Halyomorpha halys* (Stål, 1855) in Croatia. *EPPO Bulletin,* 48: 138–143.

Vétek, G, Károlyi, B, Mészáros, Á, Horváth, D & Korányi, D 2018, The invasive brown marmorated stink bug (*Halyomorpha halys*) is now widespread in Hungary. *Entomologia Generalis,* 38.

Zhan, H-X, Chen, J-H, Mi, Q-Q, Li, W-J, Zhang, F & Zhang, J-P 2020, Development, fecundity and nymph morphology, of the brown marmorated stink bug *Halyomorpha halys* (Stål).