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Distribution and population density of *Halyomorpha halys* (Stål, 1855) (Hemiptera: Pentatomidae) in Black Sea Region of Türkiye

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Abstract: Brown marmorated stink bug (BMSB), *Halyomorpha halys*, is a polyphagous invasive pest whose spread and damage are increasing with global commercial activities. In this study, following the invasion of Black Sea Region in 2018, spread, population density and change of the pest were investigated in the years 2019, 2020, and 2021, possible causes of spread and measures to be taken were evaluated. Course of population was monitored with pheromone traps placed in 141, 120, and 162 locations in 8 provinces along the coastline of Black Sea Region. High population density was detected at all locations of Artvin and Rize provinces. Since the population interactions continued near the Georgian border, about 98% of the total population in the region was seen in these two provinces. Weekly average population level was 7.36 adults/traps in Artvin and 9.11 adults/traps in Rize Province; spread of the pest continued from east to west and irregular and further-apart local populations were detected at some points. It was determined that it caused population density-dependent economic damage on different hosts including hazelnut, kiwi, citrus, maize and beans. This research examined the *H. halys* population distribution in Türkiye, potential problems associated to that too, ways that it spreads, and possible solutions.

Key words: Brown marmorated stink bug, invasive species, spread

1. Introduction

Halyomorpha halys (BMSB) is an invasive Pentatomidae species with natural habitats in China, Japan, and South Korea. It has been recorded in many countries on different continents, including the USA, Canada, Chile, Germany, France, Spain, Italy, Greece, Austria, Hungary, Romania, Bulgaria, Slovakia, Serbia, Croatia, New Zealand, Russia, Georgia and Türkiye over a period of nearly 20 years (Eppo, Paris, France).[1] BMSB, a polyphagous pest has a wide host range including fruit, vegetables, ornamental plants and forest plants. It causes both direct and indirect damage to many vegetables and fruits throughout a two period in one season, as it can fly and walk long distances during the active period (Bergmann et al., 2016, Musolin et al., 2017, Leskey and Nielsen, 2018). Firstly, overwintering adults emerge in spring, and in season adults, nymphs, and many agricultural crop eating insects feed on various plant parts, which reduces crop productivity and quality. Secondly, BMSB is a significant annoyance to homeowners due to the nasty smell they emit; adults enter sites such as homes and other man-made structures for overwintering in the fall (Inkley, 2012; Lee et al., 2013). Typically, BMSB has one or two generations in a year, depending on climatic conditions.

Vehicle traffic is the most effective factor in transport of *H. halys* to a new area. In the USA, periodic east to west transportation activities of people have been indicated as potential transportation routes in the States of California, Washington and Idaho. Commercial activities of exporter countries such as China, Korea, Japan and the USA, especially in August and September play an important role in transportation of pest adults. Materials that have been kept fixed in one place for a long time, luggage, containers, packaging materials, etc., relocated materials and machinery, furniture and automobiles transported by ships have an important role in the spread of *H. halys* adults. In this way, the first entry to the USA in 1990 was thought to be through oversea commercial activities (Hoebeke and Carter 2003; Rice et al., 2014; Hamilton et al., 2018).

[1] European and Mediterranean Plant Protection Organization (2022). EPPO global data base [online], Website www.gd.eppo.int/taxon/HALYHA/distribution [accessed 01 December 2022].

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First time in 2017, a small number of BMSB specimens were discovered in İstanbul, Türkiye. However, firstly significant population with BMSB was discovered in the province of Artvin, which is close to the Georgian border, the same year. The BMSB population and infested region increased starting in the first observation year and fastly spread to additional provinces along Türkiye's Black Sea coast. At the same time, there was an increase in BMSB cases in the western portion of the country, particularly in İstanbul and the neighboring provinces of Yalova and Sakarya in the Marmara Region. The potential that BMSB may have entered Türkiye from two different places is raised by this.

Main infestation area of BMSB is Black Sea Region of Türkiye on which many fruits and vegetables including hazelnut, corn, tea, kiwi, persimmon, chestnut, mulberry, medlar and pear has been produced (Öztürk and Serttaş, 2018). Hazelnut is by far the most prevalent crop of this region with about 700,000 ha orchards. This region is also the main hazelnut growing area of the World. Besides hazelnut constitutes about 13% of Türkiye's agricultural exports. Türkiye owns 75% of world hazelnut production areas, realizes 62% of world hazelnut production and exports 80%–85% of the production. According to average of the last five years, an annual production of 610,000 t was made in Türkiye and about 74% of the production areas are located in the Eastern and Central Black Sea Region (TMO, Ankara, Türkiye).[2]

In terms of prevalence and population density in hazelnut orchards of Türkiye, there are about 15 harmful species that may cause significant economic losses in both yield and quality. Especially the Pentatomidae family with piercing-sucking mouth type cause both indirect and direct loss of yield and a decrease in kernel quality of hazelnut fruits as well as production (Tuncer et al., 2002; Tuncer et al., 2018). The hazelnut kernels caused by these insect species in hazelnut orchards of Türkiye was found to be 7.44% on average (Ak et al., 2018). On the other hand, spread of invasive harmful species between countries has become easier in recent years with the increase of international trade and transportation (Hızal et al., 2015; Valentin et al., 2017). Then, besides existing pests, new pest species are continuously incorporated into pest fauna. *Halyomorpha halys* detected in 2018 in Artvin (Kemalpaşa, Hopa, Arhavi, Borçka) and Rize (Fındıklı) was recorded into pest fauna of hazelnut orchards as an invasive species (Ak et al., 2019). *Halyomorpha halys* has rapid spreading capacity and poses a risk especially on hazelnut and many other agricultural products of Türkiye based on ecological spread of the pest (Özdemir and Tuncer, 2021). *H. halys* caused significant economic losses in the hazelnut orchards in western Georgia in 2016 (Dumbadze et al., 2019, Kereselidze et al., 2022).

Detection of the first entry of the pests to any place and monitoring subsequent population are important issues for research and control activities. There are many types of traps that can be used for this purpose. *H. halys* secretes two separate pheromones, aggregation pheromones and sex pheromones. Generally, aggregation pheromone is used as an attraction source in BMSB monitoring traps. In this study, aggregation pheromones, effective at longer distances, were preferred to track changes in pest population.

H. halys, which was first reported in hazelnut orchards in Oregon in 2012, soon became an economic pest of hazelnut. It causes various damages through feeding in different periods of hazelnut. *H. halys* can feed on hazelnuts (hazelnuts or green parts) in all biological stages, except for the first period nymphs, and can complete entire life cycle by feeding only on hazelnuts (Hedstrom et al., 2014). In Italy, *H. halys* was compared with the local hazelnut pests of *Gonocerus acuteangulatus, Nezara viridula* and *Palomena prasina* and with survival capacity and high reproductive power, it was identified as the most damaging species in hazelnut kernels (Bosco et al., 2018).

Ak et al. (2019) determined the population density of *H. halys* in Artvin, the border of Türkiye with Georgia, and indicated that pest would continue to spread in the region due to suitable ecological conditions and potential hosts in these locations (Güncan and Gümüş, 2019). With that much spread, *H. halys* may cause damage to many agricultural products as well as hazelnut (Tuncer et al., 2018).

In this study, with the use of pheromone traps along 900 km coastal line of Central and Eastern Black Sea Region, population distribution, density and change of the pest were determined. Thus, evaluations were made about the current situation in Türkiye, its future risks and steps to combat it.

2. Material and methods

2.1. Pheromone source and placement

Pherocon BMSB Dual Lure pheromone traps were used to catch the BMSB adults. Pheromone baited transparent two side sticky trays (15 × 30 cm) were used as the trap material. These traps were hung in hazelnut, kiwi and citrus orchards before in early May at a height of 1.5–2.0 m from the ground surface and traps were checked twice a week. Periodic checks continued from May to November until the migration of pests to overwintering sites. The pheromones used in the traps were replaced

[2] Toprak Mahsulleri Ofisi Genel Müdürlüğü (2022). 2020 Yılı Fındık Sektör Raporu. [in Turkish] Website www. https://www.tmo.gov.tr/Upload/Document/sektorraporlari/findik2020.pdf [accessed 05 December 2022].

in every 3 months and the sticky sheets were replaced in every 45 days.

2.2. Locations

Trap locations were selected from the provinces and districts where the pest is currently present and expected to spread along the coastal part of Central and Eastern Black Sea Region (Table 1).

In each district where the study was conducted, traps were placed in 3 orchards and pest population was monitored in 141 orchards in 2019, 120 in 2020, and 162 in 2021.

3. Results

3.1. Spread and population density of *Halyomorpha halys*

The population of *H. halys* has reached high density in Artvin and Rize, according to the overall results of the last three years in the traps. The population density in these 12 districts (Kemalpaşa, Hopa, Arhavi, Borçka, Rize, Ardeşen, Çayeli, Derepazarı, Fındıklı, Güneysu, İyidere, Pazar) is set at a specific level for the duration of the season. The provinces of Trabzon, Giresun, Ordu, and Samsun, which are situated to the west of Artvin and Rize provinces, were found to have the pest's new population in 21 separate places spread out over a distance of about 500 km (Figure 1).

H. halys overwintering exited (observed first in the orchards) between 4 and 18 May; the two-year data revealed that 83.33% of the initial exit were identified after 10 May. The population of Artvin and Rize peaked 6.92–8.04 adult per trap between July 2 and August 31 in 2021, 12.53–11.80 adult per trap 11 August–29 September in 2020, and 14.33–16.42 adult per trap 27 August–27 September in 2019. In general, the population is low between May and early July. A constantly increasing population is also encountered between July and early October. The population reaches a high density before overwintering stage, reaching peaks between the end of August and the end of September, as can be shown (Table 2).

When the population fluctuation of the pest in Artvin Province was examined, it was determined that three year population fluctuation was similar and three year average was similar to the years. When three year population density was compared, the highest population was seen in 2020 (308.40 adult/trap) (Figure 2).

The population fluctuation of the pest in Rize Province was followed in 2019 and 2021 and it was determined that population fluctuation of two years was not similar, although the population was highest in autumn of 2019, it was higher in summer period of 2021 (Figure 3).

When the average population density for 3 years in Artvin and 2 years in Rize was compared, the similarities were seen in the population fluctuation by month of the pest in Eastern Black Sea Region. The average number of insects caught in the traps per week is 7.36 adults/traps in Artvin for three years and 9.11 adults/traps in Rize for two years.

In Artvin, the total number of BMSB captured during the season in a district was 55.73, 308.40, and 170.07 in 2019, 2020, and 2021, respectively; and in Rize, it was 201.21 and 190.54 in 2019 and 2021, respectively. Accordingly, in six-month period between the beginning of adult emergences from the overwintering sites at the beginning of May and completion of retreat to overwintering sites at the end of October, *H. halys* was active for a long time in orchards. With the population density determined, it was understood that the pest has definitely settled in these locations (Figures 2 and 3). On

Table 1. Surveillance of *Halyomorpha halys* in the Middle and Eastern Black Sea Region.

Province	District	Total number of traps (3 traps per district)
Artvin	Kemalpaşa, Hopa, Arhavi, Borçka, Şavşat	15
Rize	Rize (town center), Ardeşen, Güneysu, Pazar, Çayeli, Fındıklı, Derepazarı, İyidere	24
Trabzon	Of, Hayrat, Sürmene, Araklı, Arsin, Yomra, Maçka, Ortahisar, Akçaabat, Çarşıbaşı, Vakfıkebir, Beşikdüzü	36
Giresun	Giresun (town center), Tirebolu, Görele, Espiye, Keşap, Eynesil, Bulancak, Piraziz, Yağlıdere	27
Ordu	Gülyalı, Altınordu, Perşembe, Fatsa, Ünye, Ulubey, Kumru, Çaybaşı, Çatalpınar	27
Samsun	Terme, Çarşamba, Salıpazarı, Tekkeköy, Ondokuzmayıs	15
Sinop	Merkez, Erfelek, Ayancık	9
Kastamonu	Cide, İnebolu, Bozkurt	9
TOTAL	54	162

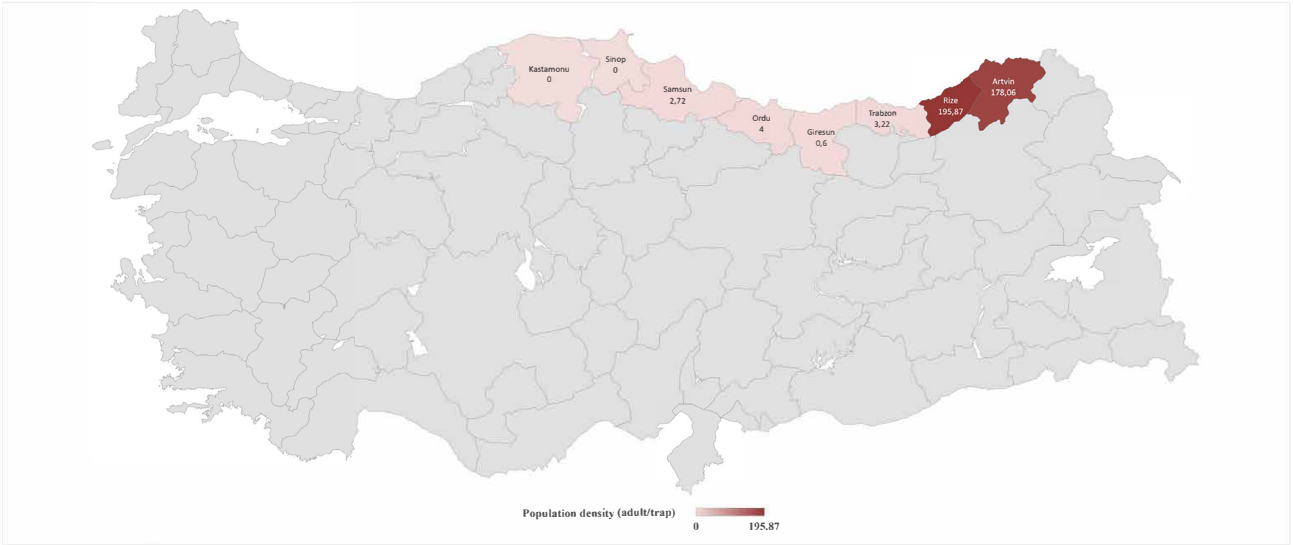

Figure 1. Infested area in Middle and Eastern Black Sea Region.

the other hand, traps were also placed in Şavşat district, another location on Georgian border; over the season 18.33, 33.67, and 36.00 adults were caught in 2019, 2020, and 2021, respectively. Insignificant change between the years means that there was no or limited transition from this point.

The average number of insects in the local populations detected in Trabzon, Giresun, Ordu, Samsun and 21 districts in the west of the region for 3 years remained between 0.33 and 31.33, which were quite low compared to other places (Table 2). In the western part of the region, apart from these locations shown in Table 2, there were not pest incidences in some places.

Trap findings confirmed the existence of *H. halys* population with negative economic effects in the region between Artvin (Kemalpaşa) and Rize (İyidere) provinces. In surveys of the year 2021, it was determined that 98.25% of the total population was in Artvin and Rize provinces (47.58%; 50.67%) and unlike the other locations, such pest density was at a level that can be detected by visual inspection methods. There is a little population (local population) detection in Trabzon, Giresun, Ordu, Samsun and there is not population in Sinop and Kastamonu provinces.

4. Discussion

There are several studies in which different types of traps have been used successfully to monitor *H. halys* and the other pentatomids (Nielsen and Hamilton, 2009; Leskey et al., 2012; Nielsen et al., 2013; Aigner and Kuhar, 2014; Sargent et al., 2014; Murvanidze et al., 2018; Dumbadze et al., 2019). Although an economic damage threshold was not specified for most crops, population monitoring with traps is used to estimate a population increase that will cause economic damage and to determine the time of control (Nielsen et al., 2013). In this study, sticky traps were used for population monitoring and the first determination, distribution and density of pest, additionally disperse from retreat to overwintering sites were effectively monitored.

Spread of invasive species takes place under a number of triggering or recessing factors. While economic losses were experienced in many agricultural products in the first years following the contamination in Georgia (Dumbadze et al., 2019), it was experienced about 10 years later in the USA (Leskey et al., 2012). Although no large scale agricultural loss has been recorded in Türkiye yet, traps, field observations, partial economic losses (on hazelnut, kiwi, citrus, maize, and beans, as well as other hosts) and the complaints of regional people clearly revealed that population formed in provinces of Artvin and Rize, which is closest to the Georgian border, continued to exist in the region with certain fluctuations. In addition, a total of 22 adults were detected in the controls made with a pheromone trap in a hazelnut orchard in Artvin (Murgul) once in June, July, and August and a large number of insects were detected in closed areas by visual inspection. Therefore, spread of pest continued in interior sections of the region. The new spreads in the west of the region, on the other hand, exist in the form of local determinations at 5-6 distant points. However, a small number of adults were seen before overwintering stage in these locations; such a case is an initial sign of population growth in a short time. Following the similar complaints of the local people in settlements of Artvin (Kemalpaşa) border in 2017, there

Table 2. The presence and distribution of the *Halyomorpha halys* population in Türkiye (Middle and Eastern Black Sea Region).

District	Captured total number of insect overall season			Dates and estimated abundance, by district
	2019	2020	2021	
Kemalpaşa	53.33	265.66	158.00	**2019:** June 25-September 3, sporadic; September 10-October 8, highly abundant **2020:** May 15-June 26, sporadic; June 30-October 6, highly abundant **2021:** May 7-June 8, sporadic; June 11-October 12, abundant
Hopa	33.66	342.00	119.33	**2019:** July 5- August 23, sporadic; August 29-October 1, highly abundant **2020:** May 29-June 26, sporadic; July 10-October 16, highly abundant **2021:** May 21-July 30, abundant; August 24-October 15, abundant
Arhavi	96.00	336.00	329.00	**2019:** September 10-October 11, highly abundant **2020:** May 12-July 14, sporadic; August 11-October 15, highly abundant **2021:** May 18-October 15, highly abundant
Borçka	77.33	564.66	208.00	**2019:** July26-October 15, highly abundant **2020:** May 12-July 3, sporadic; July 17-October 16, highly abundant **2021:** May 21-September 3, highly abundant; September 7-October 26, abundant
Şavşat	18.33	33.66	36.00	**2019:** June 25-July 23, sporadic; August 29-October 8, sporadic **2020:** May-June-July, not insect; July 24-October 20, sporadic **2021:** May 18-September 19, sporadic
Rize (town center)	225.00	-	259.33	**2019:** June 28-August 9, abundant; August 16-October 8, highly abundant **2021:** May 4-June 29, sporadic; July 2-September 3, highly abundant; September 7-October 26, sporadic
Ardeşen	117.00	-	134.66	**2019:** June 25-August 9, abundant; August 16-October 8, highly abundant **2021:** May 7-June 25, sporadic; June 29-August 24, abundant; August 27-September 22, sporadic
Çayeli	95.33	-	201.66	**2019:** July 16-August 23, sporadic; August 27-October 11, highly abundant **2021:** May 11-July 6, sporadic; July 9-September 28, highly abundant; September 1-26, sporadic
Derepazarı	225.67	-	215.66	**2019:** June 25-August 6, sporadic; August 16-October 8, highly abundant **2021:** May 18-July 9, sporadic; July 11-September 3, highly abundant; September 10-October 22, sporadic
Fındıklı	289.00	-	238.33	**2019:** June 28-August 9, sporadic; August 16-October 18, highly abundant **2021:** May 18-September 28, highly abundant; October 1-19 low level
Güneysu	151.00	-	278.00	**2019:** June 28-August 13, sporadic; August 16-October 11, highly abundant **2021:** May 11-June 29, sporadic; July 2-September 24, highly abundant; September 28-October 15, sporadic
İyidere	208.67	-	74.66	**2019:** July 5-August 13, sporadic; August 16-October 11, highly abundant **2021:** May 7-July 13, sporadic; July 16-August 31, abundant;
Pazar	298.00	-	122.00	**2019:** June 28-August 2, sporadic; August 6-October 15, highly abundant **2021:** May 18-28, low level; July 2; October 1, abundant
Hayrat	0	19.66	2.00	**2020:** June 9, single; September 8-23, sporadic **2021:** June 8, low

Table 2. (Continued).

Sürmene	6.66	13.66	10.33	**2019:** September 20 and October 4-11, sporadic **2020:** September 1-October 16, sporadic **2021:** June 15 and July 27, single; August 17-October 12, sporadic
Arsin	0.66	5.00	2.33	**2019:** September 17, single **2020:** July 7, single; September 4-October 13, sporadic **2021:** August 27, single; September 28-October 19, sporadic
Yomra	0	0	1.33	**2021:** July 2-13, sporadic; August 13, single
Ortahisar	0.33	2.00	5.66	**2019:** August 16, single **2020:** September 1-22, sporadic **2021:** June 21, single; July 30-August 24, sporadic; September 21, low
Akçaabat	0	4.33	0	**2020:** August 7, single; September 15-October 2, sporadic
Çarşıbaşı	0	0	3	**2021:** June 15, single; August 31, low
Beşikdüzü	0	0.33	0	**2020:** September 18, single
Giresun (town center)	1.33	4.00	1.00	**2019:** September 20-October 18, sporadic **2020:** June 26, single; September 11-October 16, sporadic **2021:** September 10-October 15, sporadic
Tirebolu	0	0.30	0	**2020:** October 16, single
Espiye	0.33	0	0	**2019:** September 6, single
Eynesil	0	0	0.33	**2021:** July 2, single
Piraziz	0	1.66	0	**2020:** August 11-September 4, sporadic
Çaybaşı	0	0	0.33	**2021:** October 22
Fatsa	2.33	31.33	13.33	**2019:** September 3, single; October 18, low **2020:** May 18 and June 19, single; August 28-October 2, abundant **2021:** May 21-July 2, sporadic; 30 July, single; August 31-September 17, sporadic
Çatalpınar	0	0	0.33	**2021:** September 10, single
Ünye	0	0	0.33	**2021:** September 10, single
Çarşamba	0	0.33	3.00	**2020:** October 16, single **2021:** October 1, low
Salıpazarı	0	1.00	0	**2020:** October 13, single
Tekkeköy	0	0.66	1.66	**2020:** September 22 and October 9, single **2021:** October 12-November 1, sporadic
Terme	0.33	16.66	9.00	**2019:** September 6, single **2020:** June 9, single; August 11-October 13, sporadic **2021:** May 28-June 11, sporadic; August 3-September 21, sporadic

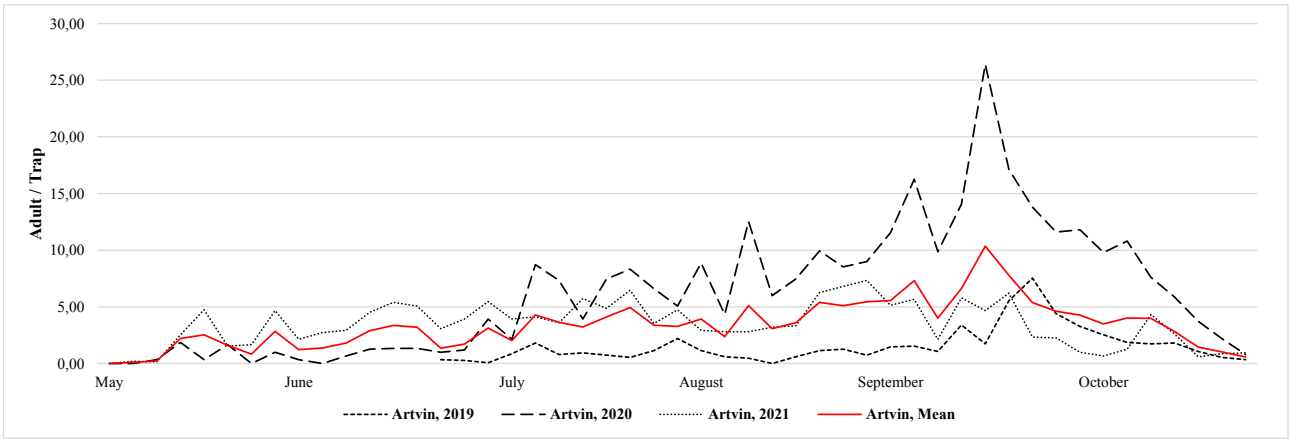

Figure 2. Average change in *H. halys* population in Artvin in the years 2019, 2020, and 2021.

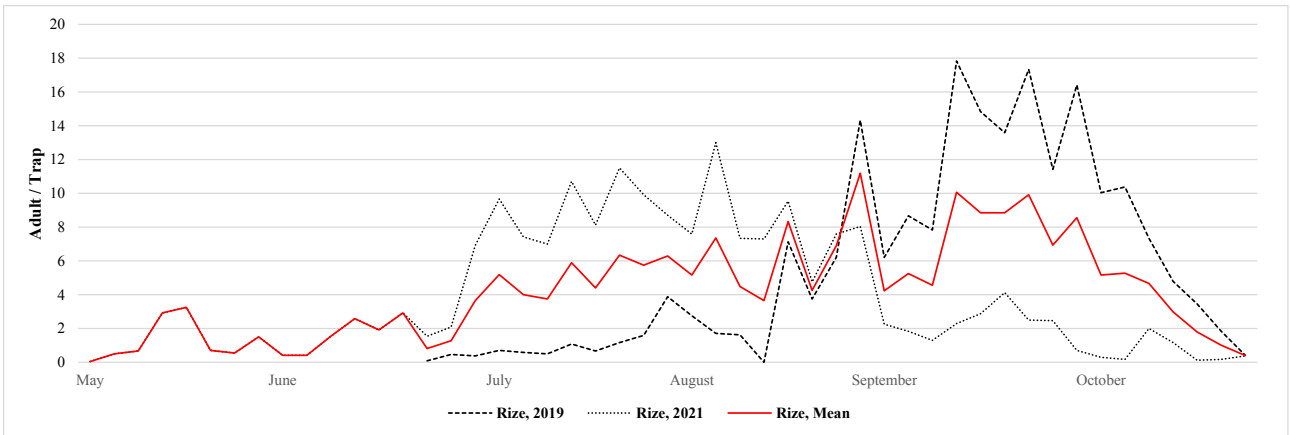

Figure 3. Average change in *H. halys* population in Rize in the years 2019 and 2021.

was a rapid population increase in these areas in 2018 (Ak et al., 2019). In general, population level of invasive species is expected to increase exponentially before peaking and this increase is expected to accelerate from year to year (Mack et al., 2000). In the USA (New Jersey), *H. halys* populations were monitored with light traps between the years 2004 and 2011 and it was determined that pest population increased by 75% every year (Nielsen et al., 2013). In this study, a similar spread was detected in Rize in 2019 and a resident population was formed in all districts of the province in a short time.

In this study; it can be observed that *H. halys* is spreading irregularly (nonchronologically) and that it is continuing to spread towards the west of the area. A similar irregular spread was also detected in spread of *H. halys* in France between 2012 and 2019 (Streito et al., 2021). It was understood that vehicle traffic was much more effective than natural flights in the spread of *H. halys*. In this context, there is risk associated with intensive commercial activity between the Black Sea and the Marmara Region. Namely, populations detected in Terme and Fatsa districts close to the forest product enterprises where raw materials are purchased from Artvin Province also supports this inference. Especially in August-September months, materials such as containers, luggage, and packaging that remain on the ground for a long time increase the rate of spreading with adults (Hamilton et al., 2018; Streito et al., 2021). It is considered that long lines of commercial trucks at the Georgian border, where the workspace is numerous, encourage in the spread of the pest. Therefore, human induced factors alone are the only causes of long distance initial contamination. Wallner et al. (2014) indicated that *H. halys* was transported to long distances by vehicles after the first contamination and referred this case as stratified diffusion.

BMSB is thought to have entered Türkiye from Georgia, which was at the time in severely infested in 2017 and 2018, that population density of *H. halys* among the similar piercing-sucking insects in hazelnut orchards

was 84% in Georgia in 2016 (Moraglio et al., 2018). At this point, the periodic effect of abiotic factors (such as average temperature, humidity, vegetation) should also be taken into consideration. Therefore, the sudden increase in pest population in 2020 or recess in 2021 showed that the pest could quickly make an epidemic when it reaches suitable conditions. Therefore, the population increase in 2020 seen in almost all locations brings forward the effect of climate factors.

Spread of *H. halys* takes place parallel to ecological areas suitable for the pest. In this sense, it is predicted that the entire Black Sea coastline of Türkiye was in danger. However, apart from these, it is known that there were agricultural basins or suitable microclimate areas that can host *H. halys*. And also in a study conducted with 6 different climate forecasting models, it was predicted that distribution areas of the pest in Türkiye would expand towards the inner regions by the year 2040 (Streito et al., 2021). Therefore, it is necessary to slow down the spread with internal quarantine measures, especially before overwintering stage. Control and spraying of products, packages, large vehicles (cargo, transport) waiting for a long time in September-October at the points where the population is located are among the primary measures to be taken.

On the other hand, in density populated areas, where agricultural areas and settlements (house, warehouse, garage, etc.) were intertwined, number of pests trapped increased with the effect of pheromones (confusion) during the aggregation before overwintering stage. In addition, during this period, flying and feeding activity among the hosts decreases and a passive density (not damaging agricultural lands) is observed only in the plants near the traps and closed areas. Similarly, in a study conducted in 115 locations in the USA, an increase in the number of insects on sticky traps was noted in the last phase of retreat to overwintering sites (Acebes-Doria et al., 2020). Intensive population of the pest is generally encountered in September-October period when they started to aggregate in human made structures (homes, storages, facilities, etc.) for overwintering. To prevent discomfort at home, some isolation measures may be necessary. For this, covering windows, doors, and ventilations with grilles tighter than 7 mm will be sufficient and closing cracks, crevices, and openings larger than 3 mm in homes will indeed satisfy (Chambers et al., 2019).

Additionally in the first stages, when the contagion is felt by the local people of the new spread areas, aforementioned attract-kill treatments and overall mechanical control in closed areas are among the primary measures to be taken. Increasing awareness of regional people, especially against *H. halys*, will increase the efficiency of these measures.

Training and promotion for BMSB should take place in areas of not contamination as part of internal quarantine requirements. It is expected that prompt intervention (mechanical, chemical) in a narrow area will deceleration the spread of new contaminations. As a result, an opportunity for adaptation in support of native natural enemies can be established. However, control of *H. halys* sustainably over the long term, the most effective egg parasitoid, *Trissolcus japonicus*, should be used (Jarrett et al., 2019). It is important that Türkiye's perspective of control this pest is on classical biological control.

5. Conclusion

Since *Halyomorpha halys* continues to spread to new locations and the pest shows heterogeneous distribution in areas with high population density, as it was in present study, extend of similar studies should be kept wider and such a case will in turn facilitate data assessments. Additionally, in the virtue of the risks of climate changes to expand suitable habitats for invasive and polyphagous pests such as *H. halys*, climate forecasting models should be used to prepare current/future risk maps and efficient control strategies should be developed in Türkiye.

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