Journal of Agricultural, Food and Environmental Sciences Vol 76 No 7 (2022) 1-12
DOI: https://doi.org/10.55302/JAFES22767001l

HALYOMORPHA HALYS STÅL, 1855 (PENTATOMIDAE: HEMIPTERA) IN NORTH MACEDONIA

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ABSTRACT

The invasive species Brown Marmorated Stink Bug (BMSB) *H. halys* is native for East Asia, and has been present in Europe since 2004. The first finding of the pest in North Macedonia was in 2018 (unpublished data), while the monitoring programme for this pest, supported by the company Socoterra, Bitola, started at 2020 and was carried out on 9 localities with pheromones for aggregation Pherocon – BMSB, Trécé. According to the monitoring results based on caught adults, *H. halys* was well established in the urban area of Skopje and accidentally appeared in the urban part of Prilep in 2020 and Resen in 2022(western part of the NMK). *H. halys* was also registered in the rural area nearby Skopje (v. Stajkovci) in 2020 and 2021, and close to Bitola (v. Alinci) in 2020. In 2022 the bug *H. halys* has shown higher level of spreading and was registered in v. Golemo Konjari near Prilep (western part) and v. Otosnica near Kriva Palanka (eastern part). The pest overwintered as an adult. Overwintered adults appeared at the end of April when they fed on different plants, copulated and laid eggs in May. The first larvae instar appears in the first decade of June. Larvae in different development stages were present until mid-September. The adults of the new generation emerged at the beginning of August and stayed active until mid-October. In the researching period 2020-2022 there were registered damages on the persimmon and apple fruits, gathered from the orchard with mixed fruits in the locality Skopje-FASF.

Key words: *Halyomorpha halys*, distribution, North Macedonia.

INTRODUCTION

Halyomorpha halys (Stål, 1855) (Hemiptera: Pentatomidae), well known as Brown Marmorated Stink Bug (BMSB) is an invasive species native for East Asia. Outside of its natural range the bug is noted in the mid-90s in Pennsylvania, USA. The examinations confirmed that it originated from China (Wermelinger et al., 2008). Later, when the bug began to spread and was recorded in Ontario, Canada in 2010, the examinations showed that it originated from the bugs populations in the USA (Gariepy et al., 2013).

In August 2007 it was announced that *H. halys* was registered in Zurich, Switzerland on decorative trees (Wermelinger et al., 2008), for the first time in Europe, although Gariepy et al. (2013) considered that the bug has been present since 2004 with a genetic similarity with the

populations in China. In 2007, *H. halys* was registered in Lichtenstein (Arnold, 2009), in 2011 in south Germany (Heckmann, 2012), 2012 in west France (Calot&Brua, 2013) and Italy (Pansa et al., 2013), in 2014 in Greece (Milonas&Partsinevelos, 2014) and Hungary (Vetec et al., 2014), in 2015 in Romania (Macavei et al., 2015) and Serbia (Šeat, 2015), in 2016 in Bulgaria (Simov, 2016) and Russia (Mityushev, 2016), in 2017 in Slovenia (Rot et al., 2022) .

The first record in North Macedonia was in 2018 in the capital city Skopje, close to the fruit orchard of the Faculty of Agricultural Sciences and Food (personal findings, not published results). Later, Konjevic (2020) found the pest in Gevgelija, near the Greek border.

The bug is feeding on more than 170 agricultural and ornamental host plants (Rice et al., 2014; Lara et al., 2016). As a phytophagous species BMSB is an economically important pest on fruits, nuts and vegetable crops according to Lee et al., (2013). In 2010, BMSB caused more than $37 million losses to the apple industry in US Mid-Atlantic States (Leskey et al., 2012). Lara et al., (2017) highlights this bug as a dangerous pest for pistachio, Bosco et al., (2017) counts it as a serious treat for the hazelnut, while Pansa et al., (2013) points out this bug as very harmful for the peaches and nectarines.

Damage from the brown marmorated stink bug is similar with the damages by other stink bugs, but the appearance of *H. halys* is specific with high numbers of individuals present on a single fruit. Since one bug can feed on many fruits, losses can be severe. The appearance of the crop injury varies depending on the crop type. Feeding on tree fruit, nuts and some vegetables can lead to corky spots in the flesh directly below the feeding site. Feeding can also cause discoloration, necrosis or chlorotic spots due to tissue damage (Leskey&Nielsen, 2018). Feeding on developing fruit, particularly peaches, can cause cat facing damage, in which the growing fruit fails to expand at the site of feeding injury, resulting in a malformed fruit. In most cases feeding by nymph and adult stages renders the fruit unmarketable.

Adults and nymphs inject tissue-destroying enzymes as part of their feeding, followed by juice sucking from the affected fruits. Initial damage may appear as oozing of sap. Damaged flesh under the skin turns hard and pithy. When feeding occurs on younger fruit, discoloration may form, followed by pockmarks or fruit distortion as the fruit expands. Any such feeding damage makes fruits and vegetables unmarketable. They can also feed on buds, flowering structures, leaves, stems, branches, and small tree trunks. Feeding on trunks and branches does not appear to harm mature plants, but the effect on the health of young trees is still being evaluated. Damage is generally greatest on late-maturing fruit when the numbers are highest and the bugs become more concentrated, but even early season damage on some species, such as peaches and nectarines, can be severe (Ingels&Zalom, 2017).

Besides being a problem in agriculture, this species is also annoying people in urban environments, especially in autumn when they appear in gregarious form searching for overwintering sites (Šeat, 2015; Martens Forney& Feaster, 2022).

Determination of the presence of *H. halys* in North Macedonia and the dangers of its spreading, especially the possibilities of economic damages on agricultural crops, were the main reasons for starting the studies on the species. The examinations of BMSB started in 2020 and were supported by the Socoterra DOOEL company from Bitola, on 9 localities in the country. The survey program continued in 2021 and 2022.

MATERIALS AND METHODS

Monitoring of *H. halys* has been done by the pheromones for aggregation Pherocon – BMSB, Trécé – with two active substances (3S, 6S, 7R, 10S)-10,11-epoxy-1-bisabolen-3-ol and (3R, 6S, 7R, 10S)-10,11-epoxy-1-bisabolen-3-ol co methyl (2E, 4E, 6Z)-decatrienoat.

This trap captures both adults and nymphs. The examinations have clarified the time of occurrence of *H. halys* in North Macedonia, its seasonal dynamic and dispersion through the country. The field trials had carried on from 2020 to 2022. The placement of the traps began in August 2020, in May 2021 and March in 2022. The period of monitoring usually ended at mid-November. The traps were placed on 9 different locations: The Faculty of Agricultural Sciences and Food (FASF) in Skopje in mixed orchard of apple, plum, pear, cherry, sour cherry, persimmon (N 42°00.125' E 21°27.466'; elevation 260 m); v. Stajkovci - Skopje in hazelnut orchard (N 42°01.713' E 21°31.046', elevation 263 m); v. Otosnica - Rankovci in hazelnut orchard (N 42°10.421' E 22°05.339', elevation 542 m); v. Voislavci - Radovish in hazelnut orchard (N 41°35.625' E 22°29.420', elevation 348 m); Rosoman in peach orchard (N 41°32.911' E 21°57.078', elevation 165 m); v. Gorno Konjari - Prilep in vegetables (pepper, tomato) (N 41°20.860' E 21°25.582', elevation 614 m); v. Alinci - Bitola in hazelnut orchard (N 41°09.726' E 21°30.715', elevation 621 m); v. Dragozani - Bitola in hazelnut orchard (N 41°07.299' E 021°17.010', elevation 605 m) and v. Gorno Dupeni - Resen in apple orchard (N 41°03.507' E 20°58.589', elevation 888 m).

In 2021 the examinations were extended on two more locations v. Kostinci - Prilep (N 41°94.240' E 21.349.868', elevation 630 m) and v. Sogle - Veles (N 41°04.675' E 21.83.179' elevation 460 m) in hazelnut orchards.

In 2022 the examinations were conducted on the same locations as in 2021.

All orchards had their own plant protection programs.

RESULTS AND DISCUSSION

Description of Brown Marmorated Stink Bug *H. halys* according Hoebeke & Carter, 2003

Adults are approximately 1.7 cm long and about as wide. They are generally dark brown on the dorsal side and creamy white-brown on the underside. Some individuals can be with various shades of red, grey, light brown, copper, or black. The term "marmorated" it received is because of the many white spots and lines, like marble. This species has alternating light-colored bands on the antennae and alternating dark and white bands on the thin outer edge of the abdomen. The legs are brown with white spots or banding. The glands that produce defensive smell chemicals are located on the underside of the thorax between the first and second pair of legs.

Nymphs are black or very dark brown, with red integument between the sclerites. First instar nymphs have no white spots, but second through fifth instar nymphs have black antennae with a single white band. The legs of nymphs are black with varying number of white banding. Freshly molted individuals of all stages are pale white with red markings.

Eggs are laid on the underside of leaves in masses of 28 eggs, light green when laid, gradually turning white.

Fig. 1 – *Halyomorpha halys*- Skopje-FASF - 12/06/2018

Appearance of *H. halys* in North Macedonia

The first record of *H. halys* in North Macedonia was detected in 2018 in Skopje close to the mixed fruit orchards of the Faculty of Agricultural Sciences and Food in Skopje (unpublished data). Because of these previous findings in Skopje, the monitoring program for *H. halys* was organized and started in 2020 on 9 localities in the country, mostly located in fruit orchards (hazelnuts, peach and apple, and mixed fruit) and vegetables (pepper, tomato).

The presented results were based on 83 adults in 2020, 82 adults and 57 nymphs in 2021 and 103 adults and 51 nymphs in 2022 (101captured in Skopje-FASF, 1 in v. Golemo Konjari, 1 in v. Otosnica) (Fig. 2).

After three years of survey and monitoring, it became clear that *H. halys* was present in North Macedonia. The pest was established in the northern part of the country, dominantly in the urban area of Skopje, but also in v. Stajkovci, rural area near to the capital city in a hazelnut orchard.

The pest was accidentally registered in the urban area of Prilep in 2020 and Resen in 2022.

In 2020, *H. halys* was also accidentally registered in rural area of Bitola (v. Alinci) in a hazelnut orchard.

In 2021, *H. halys* was recorded only in Skopje and a rural area in v. Stajkovci.

In 2022, *H. halys* spread and was registered on two more monitored places. On 18th August 2022, the bug was caught only once in v. Golemo Konjari, close to Prilep on mixed vegetables. Later, on 15th September, *H. halys* was registered in a hazelnut orchard in Kriva Palanka (v. Otosnica). Three years of monitoring of BMSB have shown that *H. halys* is present in North Macedonia. In 2020 and 2021 the bug was located dominantly in the northern part of the country in Skopje and rural areas close to the capital city. But, in 2022 BMSB spread in the south-western parts of the country in urban and rural areas (Resen and v. Golemo Konjari - Prilep) and rural area in the eastern part of the country (v. Otosnica - Kriva Palanka).

In North Macedonia, *H. halys* was registered in hazelnut, apple, peach and persimmon orchards and also in fields with mixed vegetables (pepper, tomato).

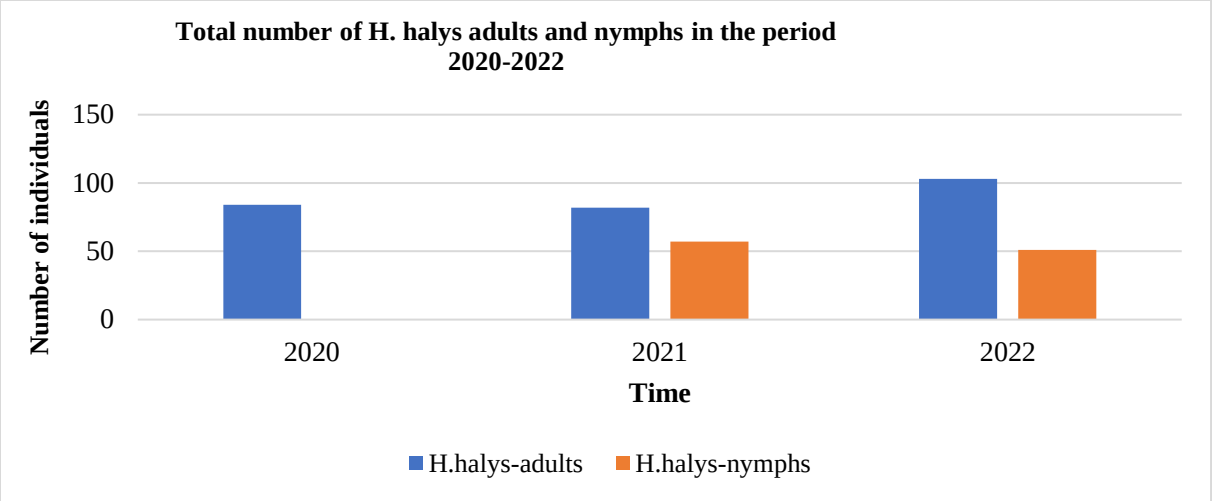

Fig. 2 – Total number of caught *Halyomorpha halys* adults and nymphs in the period 2020-2022

According to the data collected in Skopje-FASF, where the bug was well established, this species developed 1 generation till the beginning of August. The possibility to develop one more generation to the mid-October was not confirmed by the pheromone caught. It overwintered as an adult and appeared at the end of April the next year. The adults fed during May and June, copulated and laid eggs on different plants. Eggs masses have not been found on the fruit plants, they were most likely laid on the weeds around the orchard. The first nymphs on pheromone traps in Skopje-FASF were caught on 23thJune in 2021 and 9th June in 2022. The presence of *H. halys* nymphs were recorded in 12 weeks in 2021, until September 8th and 14 weeks in 2022, also until September 8th. The adults of the new generation appeared at the beginning of August. The adults stayed active and fed until the end of October (28.10.2020 – Fig.3; 13.10.2021 – Fig.4; 13.10.2022 – Fig. 5), after which they overwintered. *H. halys* was present and active around 25 weeks during the year, generally from April to October. The period of BMSB activity coincided with the period of intensive crop's vegetation in North Macedonia.

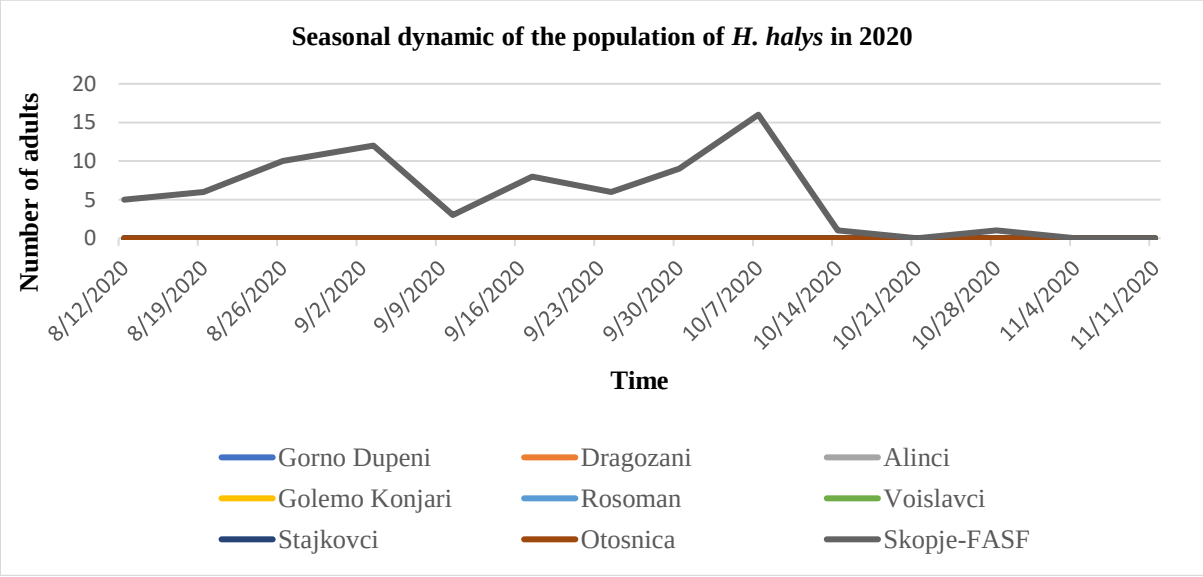

Fig. 3 – Seasonal dynamic of the population of *Halyomorpha halys* in 2020

The study of *H. halys* started very late in 2020, from August to October. In this short period the number of the caught adults was 83. The newly emerged adults were active until the end of October when they went to overwinter (28.10.2020) (Fig. 3).

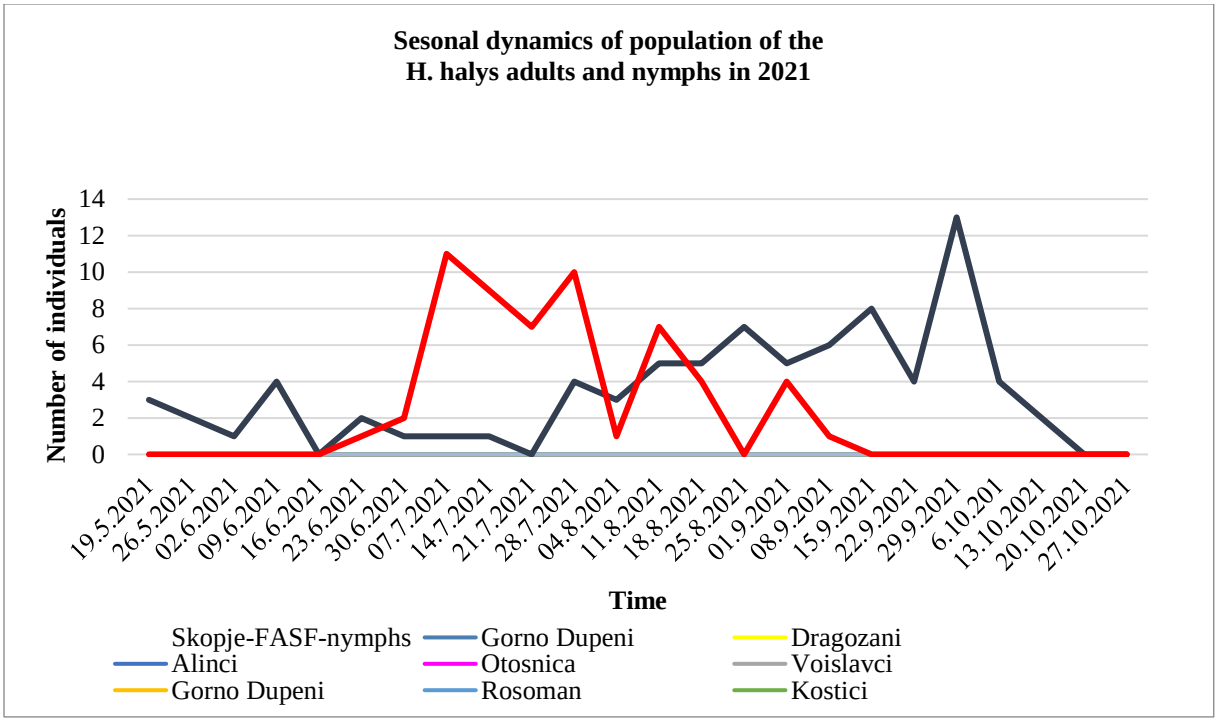

Fig. 4 – Seasonal dynamics of the population of *Halyomorpha halys* adults and nymphs in 2021

In 2021 the total number of caught individuals of *H. halys* was 82 adults and 57 nymphs. The period of activity lasted 22 weeks. The first nymphs appeared in the last decade of June (23.06.2021). The nymphal stage lasted until the middle of September (8.09.2021). In this period of 12 weeks, nymphs of all developmental stages were registered. The largest number of nymphs was noticed at the end of July (28.07.2021). The adults of the new generation appeared at the beginning of August and went to overwinter in the middle of October (13.10.2021).

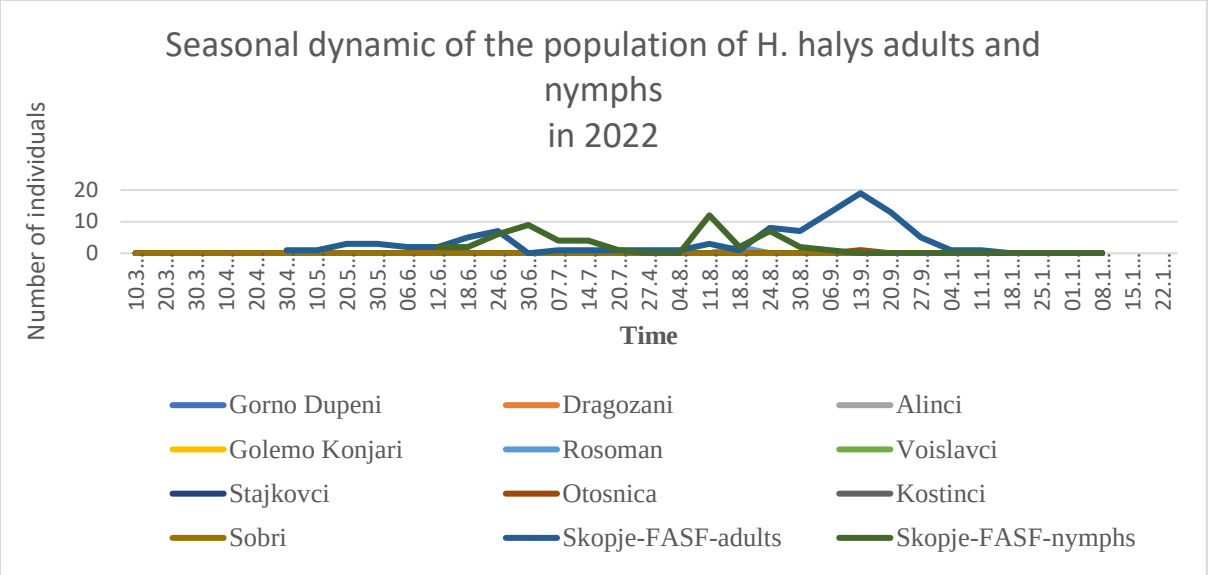

Fig. 5 – Seasonal dynamics of the population of *Halyomorpha halys* adults and nymphs in 2022

The population of *H. halys* in 2022 was presented by 106 adults and 51 nymphs, mostly caught in Skopje-FASF. The period of activity lasted 25 weeks, from 26th April until the middle of October. The first nymphs were registered on 9th June. The period of detection of nymphs in different development stages lasted 14 weeks, up to 9th September. The biggest number of caught nymphs was on 12.8.2022. The adults of the new generation appeared at the end of July and beginning of August. The biggest number of caught adults (19) was in mid-September (8-22.09.2022). In this period, they fed on late-maturing fruit. They appeared concentrated on the fruits and made injuries on them. The *H. halys* adults stayed active until the middle of October (Fig. 5).

In 2020 the pest was registered only in the hazelnut's orchards.

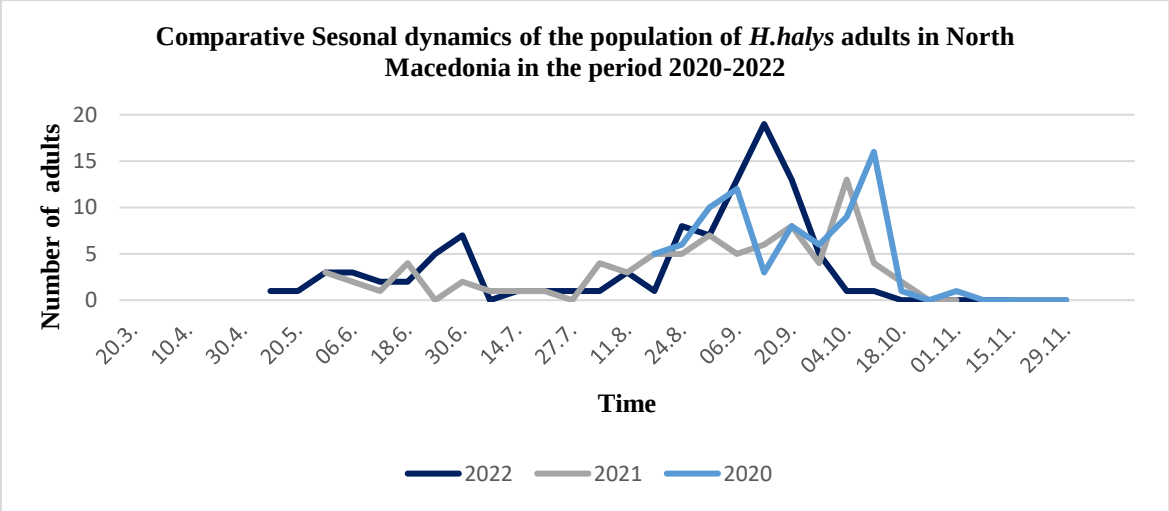

Fig. 6 – Comparative seasonal dynamics of the population of *Halyomorpha halys* adults in the period 2020-2022

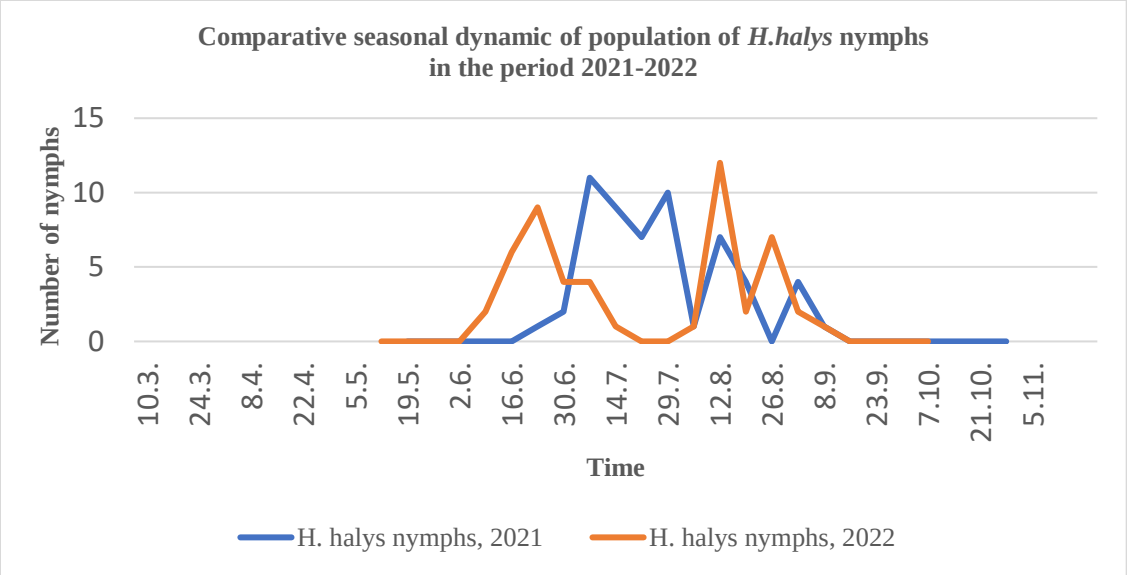

Fig. 7 – Comparative seasonal dynamics of the population of *Halyomorpha halys* nymphs in the period 2021-2022

Three-year results of *H. halys* monitoring showed that the total number of caught individuals (adults and nymphs) per year and their seasonal dynamics (Fig. 6 and 7) showed similar trends. The overwintered adults appeared at a very low number at the end of April. The first nymphs appeared in the first decade of June or later, depending on the weather conditions of the year. They developed until the first decade of September. The nymphs were most numerous in the period of mid-June to mid-August, when they fed on different crops or wild threes or weeds. This is the period when the nymphs could make injuries on the young fruits, not registered in the researching period. The adults of the new generation appeared at the beginning of August. The highest number of adults was caught in September that coincided with fruit ripening. In this period, damages on ripe persimmon and apple fruits in the locality Skopje-FASF were registered.

The phenological development of *H. halys* in North Macedonia is determinated by the pheromone catches of the adults and nymphs in period 2020-2022. We registered, in region of Skopje, where the pest is established, one generation of *H. halys* per year, but there is a possibility for one more generation before the overwintering. Rot et al., (2022) reported two overlapping generations *of H. halys* per year in Slovenia and generalized that this is the situation for the sub-Mediterranean climate. They confirmed their conclusions with researching results in Italy, south of Alps where *H. halys* develops one or two generations per year (Maistrello et al., 2012) and Sochi Region in Russia where there are two or three generation per year as well (Neimorovets, 2018). Hess et al., (2022) indicates a possibility for development of a partial second generation in Germany from August to October. The pest develops two generations per year also in the region of Beijing China, one of the origin places. But, northern than Alps in area of Zurich, Switzerland there is one generation per year. Hoebeke&Carter, (2003) also found out one generation of *H. halys* in Pensylvannia (USA) where overwintered adults appear in the mid od April, and the imagoes of the new generation generally observed early to mid-August.

The development and phenology of *H. halys* strongly depend on the temperature of the region and its photoperiod. Haye et al., (2014) stressed that temperature accelerates the development of each stage of the *H. halys*, but the photoperiod is a crucial factor. Overwintering

adults appear under the long day conditions (day length greater than 14.47h) which has been happening since mid-April, when overwintered adults appear.

These ecological facts also influence *H.halys'* development in North Macedonia and according to their value the pest can appear by the end of April and be active until mid-October.

Injuries of *H. halys*

The monitoring of *H. halis* at 9 localities in the RN Macedonia in the period 2020-2022 showed the presence of MBSB in the locality of Skopje-FASF, near an orchard with mixed fruits. Damages on fruits caused by the *H. halys* were registered during September and October on the fruits of persimmon (Fig. 8, 9, and 10) in 2020-2022 and on apple (Fig. 11, 12) in 2022. The injuries on the fruits were caused by the *H. halys* adults of the new generation, in the short period after the emergence and before the overwintering.

Sucking the ripe fruits, the adults caused shallow brown spots outside the persimmon and apple fruits, which decreased the quality of the fruits and their markets value. If the surface of the fruits is cut, on the place where the dark brown spots have been noticed, the fruits flesh was completely destroyed, represented with corky tissue (Fig. 8, 9, 10, 11, 12).



Fig. - 8, 9 - Injuries on persimmon caused by *Halyomorpha halys* – 29.10.2020;
Fig. - 10 - Injuries on persimmon caused by *Haliomorpha halys* 29.09.2022–Skopje-FASF


Fig. - 11, 12 - Injuries on apple caused by *Haliomorpha halys* – 29.09.2022 – Skopje, FASF

CONCLUSIONS

The invasive Brown Marmorated Stink Bug *H. halys* was determent in RN Macedonia. The first record of the bug in 2018 on the Faculty of Agricultural Sciences and Food in Skopje was one of the reasons for a more intensive study of the species.

Monitoring of the *H. halys* started in 2020 in 9 localities in the country, mostly located in fruit orchards (hazelnuts, peach, apple or mixed fruits) and vegetables (pepper and tomato), and was carried out until 2022.

The presented results were based on 83 adults in 2020, 82 adults and 57 nymphs in 2021 and 103 adults and 51 nymphs in 2022.

The Brown Marmorated Stink Bug was well established in the urban area of Skopje (2020-2022). The pest was accidentally noticed in Prilep (2020) and Resen (2022). The pest was also present in the rural area close to the capital city Skopje in the hazelnut orchards in v. Stajkovci and in hazelnut orchard in v. Alinci near Bitola (2020).

In 2022 *H. halys* has spread and was registered in mixed vegetables in v. Golemo Konjari close to Prilep and hazelnut orchard in v. Otosnica close to Kriva Palanka.

In 2020 and 2021 the bug was located dominantly in the northern part of the country in Skopje and rural areas close to the capitol city. But, in 2022 BMSB has spread in south-western part of the country in urban and rural areas (Resen and v. Golemo Konjari - Prilep) and rural area in eastern part of the country (v. Otosnica - Kriva Palanka).

H. halys was registered as a pest in hazelnut, apple, peach, persimmon orchards and mixed vegetables (pepper, tomato).

BMSB developed 1 generation per year in North Macedonia. It overwintered as an adult and appeared at the second part of the month April (26.04.2022). The adults fed during May and June, copulated and laid eggs on different plants, most likely on weeds. There was no record of egg masses in monitored fruits and vegetable crops.

First larvae of *H. halys* appeared in June, in the beginning or end of the month depending on the weather conditions of the year. The larvae of *H. halys* have been recorded in the period of 12-14 weeks (June to August). The adults of the new generation appeared at the beginning of August.

The highest population of *H. halys* appeared in September, when the adults fed until mid-October and went to overwinter.

H. halys was present and active for about 25 weeks during the year, from April to October, in the period of the most intensive crops season in North Macedonia.

H. halys was registered as a pest on fruits of persimmon and apple in Skopje-FASF location. The damages were registered at the end of the season, during September and October, before the harvest of the ripe fruits. There were shallow brown spots on the persimmon and apple fruits and destroyed corky tissue in the fruits flesh. All damaged fruits were unmarketable.

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