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Halyomorpha halys Stål, (Hemiptera:Pentatomidae) feeding effects on some agricultural fruits in Georgia

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Abstract: Feeding effects of the invasive, polyphagous brown marmorated stink bug (BMSB), *Halyomorpha halys* (Hemiptera:Pentatomidae), on some agricultural fruits (hazelnut, blueberry, mandarin, lemon) were investigated in Guria and Samegrelo regions of Georgia in 2019 and 2020. The damage to hazelnut kernels was evaluated when *H. halys* adults were allowed to feed on kernels in different stages of development. Furthermore, BMSB adults were allowed to feed on almost ripened fruits of blueberry, on small mandarin fruits which were not yet well developed, and on ripened fruits of mandarin. The evaluation of damage on lemon was recorded after allowing adult BMSB on small, not yet developed fruits and on almost developed fruits. It was shown that hazelnuts are susceptible to damage caused by feeding of BMSB throughout the entire period of kernel development (100 % of kernels were damaged and did not develop at all). Furthermore, BMSB damages blueberry severely (100% damage) when the fruits are almost ripened. Damage to mandarin fruits in early development stages was over 90%, and 100% of ripened mandarin fruits dropped to the ground. We did not find any damage when BMSB was allowed to feed on Lemon throughout the development of the fruits.

Key words: *Halyomorpha halys*, hazelnut, blueberry, mandarin, lemon, damage

1. Introduction

Insects of the family Pentatomidae (stink bugs) are serious economic pests of many food crops and ornamental plants around the world. This includes hard-shelled nuts such as pistachio (Rice et al., 1985), pecan (Turner, 1923), macadamia (Mitchell et al., 1965), and hazelnut (Tavella et al., 1997). Studies in Turkey report damage to hazelnut kernels by *Palomena prasina* L. (Hemiptera: Pentatomidae) feeding in the form of kernel abortion, malformation, and the occurrence of dry, necrotic tissue (Saruhan and Tuncer, 2010).

The same kind of damage and problems are caused by the brown marmorated stink bug (BMSB), *Halyomorpha halys* (Stål) (Hemiptera:Pentatomidae), which is a nonnative invasive, polyphagous stink bug in Georgia. Its known native range is China, Japan, Korea, and Taiwan (Hoffman, 1931; Kobayashi, 1967; Hoebeke and Carter, 2003; Bernon, 2004). *H. halys* was detected in North America in 1998 and since then has spread within the US (Hoebeke and Carter, 2003; Leskey et al., 2012a) and has also been found in Europe (Callot and Brua, 2013; Haye et al., 2015; Wermelinger et al., 2008), and South America (Faúndez and Rider, 2017). In 2012, it was detected in North Italy and by 2018 reached North-western Italy (Bosco et al. 2020). In 2013, *H. halys* was first reported from Russia (Musolin et al., 2018) and in 2017 from Turkey (Artvin Province; Özdemir and Tuncer, 2021).

H. halys was first observed in the Samegrelo region, West Georgia, in 2015 and later spread to the Guria and Imereti regions (Kereselidze et al., 2019). BMSB exhibits a very wide range of host species that includes economically important tree fruit crops, tree nuts, vegetable crops, legumes, ornamentals and wild plants in both its native area of origin in Asia (Kobayashi, 1967), in the United States (Hoebeke and Carter, 2003), and parts of Europe (Zakharchenko et al., 2020).

Since its first detection, *H. halys* has become and remains a major threat to Georgian agriculture. It feeds on many agricultural plants, but significant damage has been caused in hazelnuts (*Corylus avellanae* L.). Feeding on the hazelnut is very detrimental to the nut quality and results in losses to the farming sector as well as to the national

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economy at large because hazelnut is one of the main agro-export products for Georgia (Georgia produces 5.2% of total world production of hazel nut) (FAOSTAT 2016; http://www.fao.org/faostat).

H. halys damages its host plants by inserting its piercing-sucking mouthparts into the fruit, injecting saliva, and sucking out plant juices (Owens et al., 2013). Feeding on the fruit early in the growing season usually causes abscission of the fruit but feeding on fruit in the mid and late season may leave internal scars and cat-facing on the fruit, rendering it unmarketable (Nielsen and Hamilton, 2009; Lee et al., 2013). In US orchards, damage can exceed 25% at the final harvest in New Jersey and over 70% in Pennsylvania (Nielsen and Hamilton, 2009; Leskey et al., 2012b). Other studies document BMSB and other stink bug feeding impacts on Sweet corn yield and quality (Cissel, 2015) and on small fruits such as blueberries (Wiman, 2015). Joseph et al. (2015) studied the temporal effects on the incidence and severity of BMSB feeding effects on peaches and apples during the fruiting period in Virgina, US. They found more internal than external injuries at harvest from peaches and apples showed equal or very similar numbers of both kinds of injury.

Martinson et al. (2015) reported that despite *H. halys* is considered a broad feeding generalist it is specialized on finding mature fruits in US landscapes with highly heterogeneous and ephemeral resources. Acebes-Doria et al. (2016) showed that BMSB success of development depends on a mixed diet, including fruits.

As BMSB is a highly polyphagous pest, it has the potential to be a pest of many specialty crops grown in Georgia. The objective of this study was to determine the effects of fruit feeding caused by BMSB on the most important agricultural crops in Georgia such as hazelnut, blueberry, lemon and mandarin. Characterization of damage is important because it is a key factor for successful management.

2. Materials and methods

2.1. Experiment on hazelnut

The experiments on damage of hazelnut (*Corylus avellana*) kernels caused by BMSB were conducted in 2019 and 2020 in the warmest regions in Georgia (Guria 41°98′46.22″E 41°90′18.65″N; and Samegrelo 41°89′04.32″E 42°48′67.62″N regions). The climate is moderate, but also offers a few sultry months with high humidity and high temperatures. The aim of this study was to determine which physiological stages of kernel development may be most susceptible to damage from feeding activity of BMSB. The magnitude of damage to hazelnut kernels was evaluated when *H. halys* adults were allowed to feed on early development stages of kernels (exp. 1, Guria, 2019), on kernels with not yet hardened shells (exp. 2, Guria and Samegrelo, 2020), and on fully developed kernels (exp. 3, Samegrelo, 2019).

Observations started from initial kernel development (early spring) and continued until hazelnut harvest (fall). Hazelnut branches with developing nuts were put in cotton sleeve cages (90 cm × 50 cm, number of sleeve cages in 2019 and in 2020 was 23 and 9, respectively) and BMSB adults were allowed to feed on hazelnut (ten adults per branch). The open ends of the sleeve cages were closed securely with nylon mason twine or a plastic zip-tie. Developing nuts not exposed to feeding by *H. halys* served as a control treatment.

At the end of the experiment, damage was evaluated by ocular inspection of each kernel with a magnifying glass. After external inspection, kernels were cut in half and the percentage of damaged or empty shells was recorded and compared with healthy hazelnuts. All kernels with any visible sign of damage caused by BMSB were judged as "damaged".

2.2. Experiments on blueberry, mandarin, lemon

Studies on blueberry, mandarin and lemon were conducted in Guria region in 2021.

Experiments on almost ripened fruits of the blueberry variety "Brijitta" were carried out from July 1st until July 30th.

Experiments on damage caused by BMSB adults on the mandarin variety "Miyagawa" were conducted in two periods: first from June 22nd when fruits were still small and not well developed (11 mm in diameter), and second from September 13th on almost ripened fruits of mandarin.

Evaluation of damage caused by BMSB adults on lemon fruits of the variety "Meyer" was done on July 7th, when fruits were small and not yet developed (approx. 24 mm in diameter) and on September 13th on almost developed fruits (approx. 55 mm in diameter).

For the experiments, two branches of blueberry or mandarin, resp., were put in cotton sleeve cages (90 cm × 50 cm) and ten BMSB adults were placed in each bag as described above. Regarding lemon, two branches (in experiment of July 7th) and one branch (in experiment of September 13th) were used (Table 1). Fruits not exposed to feeding by *H. halys* served as a control.

At the end of the experiments, the number of dropped or damaged fruits was counted in comparison with controls without BMSB presence. Furthermore, mandarin fruits with discoloration and mandarins which were difficult to be peeled and dry inside were counted. It was not possible to include same numbers of fruits in all experiments, as the younger trees used in the experiments developed different number of fruits.

3. Results and discussion

Our results show that when *H. halys* were allowed to feed on early development stage of hazelnut kernel (Guria 2019; exp. 1), 100% of kernels were damaged and did not develop at all. However, when adults were exposed to fully-grown kernels (exp. 3), 41% of nuts were not damaged (Samegrelo, 2019). The percentage of damaged and empty shelled nuts were 45% (50%–60%) and 14% (0%–40%), respectively (Figure 1).

When adult bugs were feeding on not yet fully grown hazelnut kernels (Guria, 2020; exp. 2), only 3% (0%–7%) of nuts were healthy, 80% (71%–88%) of kernels appeared malformed, shriveled or with necrotic tissue in kernels, and 17% (12%–22%) of the shells were empty (Figure 2).

Similar results were obtained in Samegrelo region (2020) where the percentages of healthy or damaged hazelnut kernels and empty shells were 9% (0%–22%), 41% (33%–52%), and 50% (39%–67%), respectively (Figure 3).

These results are similar with these of Hedstrom et al. (2014) who reported that commercial hazelnuts are susceptible to damage caused by the feeding of *H. halys* throughout the entire period of kernel development.

Our observations show that damage caused by BMSB adults on lemon, mandarin and blueberry were different. In particular, the feeding of BMSB damaged 100% of blueberry fruits when they were almost ripened (Table 1). Our results correspond with Wiman et al. (2015) who report increased levels of external discoloration, internal damage of blueberries in the form of tissue necrosis as well as decreasing berry weights and lower soluble solids in fruits after feeding of *H. halys.*

Small, young fruits of mandarin did not develop at all because of bug feeding. Furthermore, 100% of almost ripened mandarin fruits were damaged and dropped down after BMSB adults were allowed to feed on them (Table 1). All fruits were dried out and the skin was difficult to remove. Other

Table 1. Fruit damage by BMSB (10 adults per experiment) on three types of agricultural fruits.

Fruit species	Duration of experiment	Description of fruit	No. of fruits	No. of not developed fruits	No. of dropped/ damaged fruits
Blueberry	1.07–30.07	Almost ripened fruits	28	0	28
Control	1.07–30.07	Almost ripened fruits	28	0	0
Mandarin	22.06–20.07	Small, not developed fruits (1.1 mm diameter)	11	10	1
Control	22.06–20.07	Small, not developed fruits (1.1 mm diameter)	8	0	0
Mandarin	13.09–13.10	Almost ripened fruits	10	0	10
Control	13.09–13.10	Almost ripened fruits	12	0	0
Lemon	7.07–21.08	Small, not developed fruits (approx. 2.4 mm diameter)	8	1	0
Control	7.07–21.08	Small, not developed fruits (approx. 2.4 mm diameter)	10	0	0
Lemon	13.09–12.10	Almost developed fruits (approx. 5.5 mm diameter)	5	0	0
Control	13.09–12.10	Almost developed fruits (approx. 5.5 mm diameter)	5	0	0

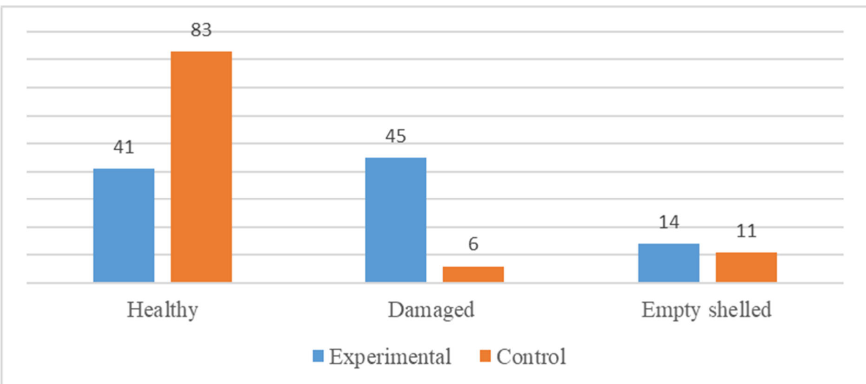

Figure 1. Damage (%) caused by BMSB feeding on fully grown hazelnut kernels in Samegrelo, 2019.

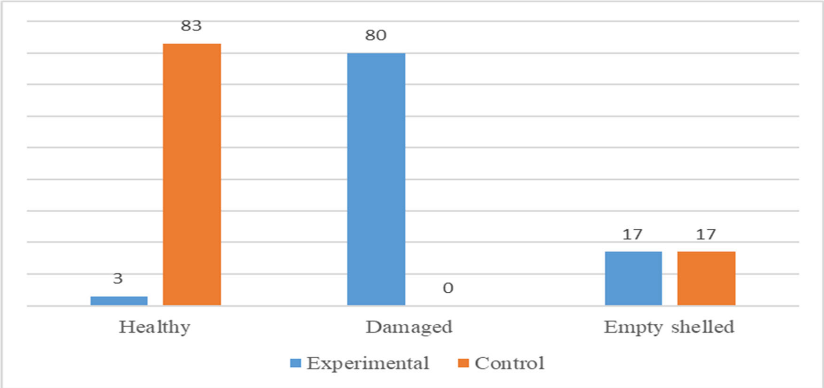

Figure 2. Damage (%) caused by BMSB feeding on not fully grown hazelnut kernels in Guria, 2020.

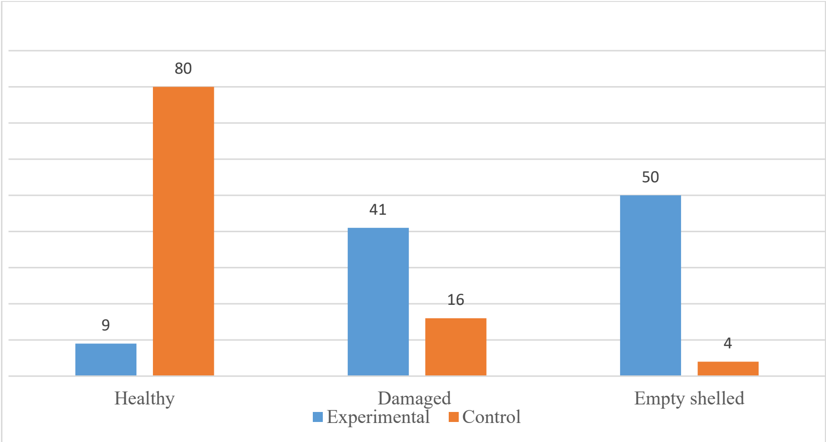

Figure 3. Damage (%) caused by BMSB feeding on not fully grown hazelnut kernels in Samegrelo, 2020.

studies report a severe impact of BMSB on various fruits in Europe: In Abkhazia (Georgia), the yield of mandarin orange and other crops fell by up to 87.4% in 2016 (Musolin et al., 2018) and in Italy, Maistrello et al. (2017) report of up to 80% damage in pear orchards. In North America, Acebes-Doria et al. (2016) observed varying reactions of different fruit species to BMSB feeding: While damage to apples was highest late in the season, peaches were damaged in early season.

Regarding lemon, feeding damage by BMSB was not visible at all in both experiments conducted, whether bug adults were allowed to feed on small, not yet developed fruits or on almost developed fruits (Table 1). Musolin et al. (2018) and Zakharchenko et al. (2020) found BMSB on various Citrus spp. but did not report damage as well.

We conclude that BMSB may become an important economic pest in Georgia. It has the potential to severely damage hazelnut, blueberry, and mandarin.

It was shown that hazelnuts are susceptible to damage caused by feeding of BMSB throughout the entire period of kernel development, especially in early developmental stages of kernels.

BMSB damages blueberries severely when the fruits are almost ripened. Mandarin fruits in early as well as later developmental stages are also damaged by the pest and drop to the ground prematurely. Lemon fruit do not seem to be susceptible to damage caused by feeding of BMSB adults. This might be caused by lemon-specific semiochemicals; however, no information on this hypothesis were found in literature.

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