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Effectivenes of pest management options for managments of brown marmorates stink bug *Halyomorpha Halys* (Hemiptera: Pentatomidae) in hazelnut orchids in the Republic of Georgia

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ABSTRACT

Distribution and management of *Halyomorpha halys* (Stål) in commercial hazelnut orchards were investigated during 2019 and 2020. Efficacies of management strategies including attract and kill strategy and border sprays were compared to grower's standard management practices. Seasonality of *H. halys* were similar during both years with the first *H. halys* adults observed near the end of April and all instar nymphs being present from July 20 (820-900 $DD_{13.9}$) to the end of September (1600-1655 $DD_{13.9}$). Although no difference was detected between the treatment types before harvest, after harvest data suggest attract and kill strategy to be the most effective management program during both seasons. Evaluations of hazelnut quality demonstrated higher presence of healthy kernels in nuts collected from trees located in the interior of the block than on trees from the perimeter of the block. Corking damage was higher on nuts collected from trees near the edge of the orchard. Observed increase in corking damage of nuts on trees located inside of the block, was indirectly associated with the mid- and late season *H. halys* feeding in the interior of the orchard. *H. halys* management decisions in hazelnut orchards should be based on the documented presence of *H. halys* populations but growers should also factor in the potential influx of the pest from surrounding areas. In areas surrounded by wild vegetation use of insecticide treated nets as used in the attract & kill plots provides the most effective strategy in protecting nut crop.

Keywords: management strategies, attract and kill, monitoring, rescue traps, hazelnut quality.

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Introduction

Brown marmorated stink bug, *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae), presence in the Republic of Georgia was first documented during the 2015 season [1]. Since the initial detection, *H. halys* has become and remains a major threat to Georgian agriculture causing intensive damage in hazelnuts (*Corylus avellane* L.). Damage caused by brown marmorated stink bug to the hazelnut sector is widely acknowledged [2, 3]. Georgia is one of the main suppliers of hazelnut worldwide (5.2% of total world production) [4] and the severity of damage to nuts caused by *H. halys* leads to significant economic losses to Georgian farmers and country budget.

High pressure from *H. halys* populations in pome and stone fruit orchards during the 2010-2011 seasons in the Mid-Atlantic region of USA has resulted in at least a 4-fold increase in the number of insecticide applications caused mainly by additional sprays and by shortening intervals between applications [5]. Frequent applications of broad-spectrum insecticides (e.g., pyrethroids, neonicotinoids, carbamates) negatively influenced populations of beneficial arthropods and often lead to outbreaks of secondary pests [6, 7].

Various pest management tactics within the frame of the Integrated Pest Management (IPM) practices have been developed and tested specifically to limit the number of insecticide applications while at the same time effectively control *H. halys* populations. Some *H. halys* specific management strategies include attract and kill (A&K) approach [6], insecticide treated nets [8], use of window screens [9] and sprays of orchard borders [10, 11, 12, 13]. None of these alternative strategies to manage *H. halys* were evaluated in Georgia prior to this project.

The presence of stink bugs in fields, timing of reproductive activities and migration to overwintering sites is influenced mostly by abiotic factors such as ambient temperature and length of daylight [14, 15, 16]. As degree day (DD) models have not been developed for *H. halys* in our region, we aimed to investigate phenology of this insect pest to find out if there is any edge effect congregation like in other orchard crops such as apple. Precise information about DD accumulation is especially useful for farmers when pesticide applications should target only specific stages during insect life cycle [17].

The main objectives of this project were to compare the effectiveness of grower's standard management, border applications of insecticides, and "attract and kill" (A&K) strategy applied within the integrated pest management program for *H. halys* in the western region of the Republic of Georgia. The following hypotheses were tested: 1) orchard blocks surrounded with insecticide treated nets used as an attract and kill strategy and blocks where orchard border sprays were applied will have lower numbers of *H. halys* compared to blocks with only grower's standard insecticide practices. This hypothesis is based on the assumption that *H. halys* is a perimeter driven insect pest [10, 18] and protection of the orchard borders by A&K stations and/or border applications of insecticides might effectively control *H. halys* populations inside of the orchard and at the same time reduce the necessity for multiple applications of insecticides on the whole area of orchard; 2) the results of management strategies are influenced by both the numbers of *H. halys* and the location of hazelnut trees within the orchard (edges *versus* inside of the block); and 3) the phenology of *H. halys* is similar from year to year [19].

Material and methods

Field site

Our investigations were conducted in Zugdidi Municipality, Samegrelo Region, Republic of Georgia (Sakartvelo). This area represents part of the Kolkheti Lowland and is characterized by high precipitation (annual average precipitation between 1500 – 2000mm, with maximal amount – 4500mm) [20] and rich and diverse wild vegetation [21].

The experimental site was located in Darcheli village (N42.4182282° E41.6508108°). It was composed of a 12-hectare hazelnut orchard planted in 1995-1996. The orchard was surrounded by the Patara Enguri River from western and southern sides, by corn field from the eastern side and by an uncultivated field from the northern side. Hazelnut trees were planted at a spacing of about 4m between the trees and 5m between the rows (Figure 1).

Different management strategies were deployed in three blocks with each block having approximately 2 ha in size: 1) attract and kill (A&K) treatment with block A&K 1 surrounded from one side by the river and from two other sides by hazelnut trees, and block A&K 2 surrounded by the river, corn field and hazelnut trees; 2) border (BRD) treatment with block BRD 1 surrounded by the river, open area and hazelnut trees, and block BRD 2 surrounded by corn field, open area and hazelnut trees; and 3) grower standard (GS) treatment with block GS 1 surrounded by the river and hazelnut trees and block GS 2 surrounded by the corn field and hazelnut trees (Figure 1). As the whole orchard received grower's standard management treatments (details see below) GS blocks were regarded as the control and the effectiveness of BRD and A&K strategies were compared to them. The GS application scheme was decided by a farmer following standard recommendations for the region developed by Georgia National Food Agency (https://nfa.gov.ge/Ge/Page/BrownMarmoratedStinkBug).

In order to determine the direction of pest influx into the orchard, five traps (numbered 13-17) were placed on wild vegetation surrounding the plot (Figure 1)

Monitoring of H. halys population

Monitoring of *H. halys* was conducted during 2019 and 2020 from late April until mid-October. Stink Bug Rescue traps (Sterling International Inc, Spokane, WA, USA) were used for standard stink bug monitoring. Each trap was baited with a single BMSB monitoring lure, Pherocon BMSB (Trece Inc, Adair, OK, USA) and were placed on the twigs of the hazelnut trees, approximately 1.5m above ground, shaded by the leaves. Two traps were placed inside each block for the total of twelve monitoring traps in six blocks. Five additional Rescue traps were placed around the orchard in unmanaged areas and utilized as a control. Information from traps was utilized to assess the movement of *H. halys* from surrounding areas into the orchard.

All A&K stations were placed outside of the hazelnut orchard; surrounding A&K blocks as indicated on Figure 1. This was done in order to attract bugs away from the orchard towards the sprayed nets. Plastic black nets used as window screens (Scley Insect Nets, KAEM Inc., Baranowo, Poland) were fixed from two sides on the wooden frame about 1.5 -2m each. Individual nets were baited with five Pherocon *H. halys* monitoring lures. White square polyethylene tarp (2m × 2m) was placed on the ground around each trap base to collect dead adults and nymphs. The distance between individual A&K stations was about 50m. A total of fourteen A&K stations were utilized around the A&K blocks (Figure 1).

Traps were monitored for *H. halys* nymphs and adults in every other week. Additionally, during each visit visual observations were conducted to evaluate the presence of alive stink bugs within a 10m diameter from each treatment tree and around A&K stations. Rescue traps were used season long but pheromone lures were replaced every 12 weeks as recommended by manufacturer. *H. halys* adults and nymphs starting from the 2ndinstar were counted and recorded. The first instar *H. halys* nymphs were not present inside the traps as they usually aggregate only on or around egg masses they hatched from. During 2019 on-site monitoring of *H. halys* was conducted from 4 May to 12 October while during the 2020 season monitoring was conducted from 9 May to 15 October. Local weather information was obtained from the meteorological station (iMETOS® Pessl Instruments GmbH, Austria) located nearby (N41.7911679°, E42.4726416°). Degree-day accumulations were calculated as DD= (t°min + t°max)/2 – 13.9 with the 13.9 °C used as the lower temperature developmental threshold [22].

Treatments

Standard management practices

Grower's standard management practices (GS) which included applications of pesticides and fertilizers were applied to whole orchard as presented in Tables 1 and 2. No additional treatment was applied to GS blocks. Full orchard insecticide applications were terminated in the end of June during the 2019 season and in early July during the 2020 season. Decision on termination of treatments was made by the farmer based on the results of *H. halys* captures by monitoring traps and hazelnut quality.

"Attract and Kill" stations

Plastic nets used for the A&K stations were sprayed weekly from 5 May to 9 September in 2019 and from 9 May to 4 October in 2020 using a pyrethroid insecticide bifenthrin, (Talstar, 10% active ingredient, FMC Chemical S.p.r.l., USA). The spray solution for this treatment was prepared as solution of 60mL bifenthrin in 12L of water (Tables 1 and 2). Applications were performed using backpack sprayer Solo Port 423 (Solo® Kleinmotoren GmbH, Germany) from the distance 1.2m from the nets.

Border sprays

In order to reveal effectiveness of border sprays for controlling *H. halys* population, blocks used for the border spray treatment were treated by spraying exclusively only border tree rows that were located at the border of the orchard and surrounded area. This was done in addition to the GS applications as shown in Tables 1 and 2. The sprays reached about 3m deep from orchard border to the interior of the orchard. Pesticide applications inside the orchard and around BRD blocks were applied using 400L of solution per hectare using a Jinma 254 tractor (Jiangsu Yueda Group, Jiangsu, China) equipped by Jarmet orchard sprayer (Eko 400L, Poland). Border sprays were maintained through the whole season as indicated in Tables 1 and 2.

Evaluation of hazelnut injuries.

During 2019 and 2020, injuries to hazelnuts were evaluated three times each year using nuts collected from each block on 7 July, 20 July and 3 August during the 2019 season and 12 July, 24 July and 7 August during the 2020 season. Total crop yield was harvested on 5 August in 2019 and on 10 August in 2020. Hazelnuts in each block were picked from six trees, with four trees located in the outer rows and two – in the interior of each block. From each tree 10 hazelnuts were randomly collected for a total 60 hazelnuts from each block, 360 nuts in total per count. Kernel quality was classified as healthy, corked, blank or with developed fungal disease (mold) as described by Hedstrom et al. [23]

Data analyses

For results processing, the data were split into two subunits: before harvest (5 August 2019 and 10 August 2020) and after harvest.

The effects of treatments were compared using parametric (one-way and two-way ANOVA) and nonparametric (Independent Samples Kruskal Wallis test) tests. For the comparison of seasons and treatment type statistics the nonparametric test (Independent Samples Kruskal Wallis H *aka* One-Way ANOVA on ranks) was used as assumptions of normality. Equal variances were violated as for before as after harvest data. The analysis of mean ranks of captured bugs were done for each category of variables (season, treatment type). In order to examine the influence of more than one factor (season, treatment strategy, harvest) on *H. halys* population before and after the harvest, Two-way ANOVA with multiple comparison Dunnett's test (for Treatment Type effects) was used, which evaluated interaction between different predictors (years × treatment type/harvest etc.). Dunnett test regarded GS blocks as a control and compared all other groups against it. For the assessment of distribution of hazelnut injury categories Independent Samples Kruskal Wallis H test was applied. Comparisons and assessments of statistical significance for full data sets from different plots, years and management strategy were performed at $p<0.05$. All data analysis was performed using statistical software IBM SPSS Statistics for Windows, v.23.

Results

The first *H. halys* adults in hazelnut orchards were observed in the beginning of May during both seasons when average daily high temperatures exceeded 17°C in 2019 and 15°C in 2020 (89 and 81 $DD_{13.9}$ respectively from January 01). Eggs were first detected by visual observations in the beginning of June, while the second instar nymphs were observed in the traps located outside the orchard, in wild vegetation on 23 June 2019 and 5 July 2020 at 598 and 620 $DD_{13.9,}$ respectively (Figure 2).

Comparison of H. halys populations between plots with alternative management strategies

The overall *H. halys* captures were lower during the 2020 season than during the 2019 ($H(1)=12.5$, $p<0.001$). The analysis of variations by seasons (2019, 2020) and by treatment type (A&K, BRD, GS) before harvest performed using Kruskal Wallis H test demonstrated difference between the captures by season ($H(1)=12.5$, $p < 0.001$) and no difference between treatment types ($H(2)=4.158$, $p= 0.125$). The numbers of captured bugs were extremely low before the harvest as almost no nymphs were detected and adult population was regulated by GS management practices (Figure 3).

Number of captured stink bugs started to increase after the harvest when the farmer stopped application of insecticides and the orchard was protected only by A&K stations surrounding A&K blocks and border sprays around BRD blocks (Table 3, Figure 3). Two-Way ANOVA analysis of overall *H. halys* captures revealed interaction between the seasons and post-harvest number for adults, nymphs and both of them combined ($F(1,308)=28.252$, $p<0.001$; $F(1,308)=6.802$, $p<0.05$; $F(1,308)=31.512$, $p<0.001$ correspondingly), as well as for harvest and treatment type for adults and total number of bugs ($F(1,306)=4.84$; $p<0.05$; ($F(1,306)=3.90$; $p<0.05$). There was no significant interaction between the seasons and treatment type for combined (before and after harvest) data ($F(2, 306) = 0.003$, $p> 0.05$)

A strong difference ($H(1)=101.299$, $p<.001$) exists between H. halys numbers captured before *and after harvest.* The difference between the seasons (2019, 2020) was maintained after the harvest for both, adults ($H(1)=9.158$, $p= 0.002$) and nymphs ($H(1)=4.21$, $p= 0.04$) and there were differences detected in captures per trap between A&K and BRD blocks during both seasons ($H(1)=6.297$, $p < 0.04$ for adults and nymphs combined).

The Dunn's pairwise comparison tests revealed that after the harvest, blocks with border application of insecticides demonstrated higher number of *H. halys* captures compared to the A&K blocks ($p < 0.05$, adjusted using the Bonferroni correction) (19.636, $p= 0.04$) which had lowest number of captured stink bugs, both, adults and nymphs (Figure 3).

Evaluation of hazelnut injuries.

The lowest percentage of healthy kernels was observed in nuts collected from trees located in the outer rows (margins) and healthy nuts increased on trees located in the interior of the managed blocks. Corking damage by *H. halys* was higher on nuts collected from trees located on the outside rows of the orchard. Percentage of blank nuts was generally low compared to other types of damage (Figure 4). Overall hazelnut quality was strongly associated with the location of trees (outer *vs* interior rows) ($F(4,150)=190.03$, $p <0.001$ for 2019 and $F(4,150)=413.474$; $p<0.001$, for 2020). The increased levels of injured nuts in outside rows supports the notion of *H. halys* to be a perimeter driven insect pest in hazelnut.

The Kruskal Wallis test revealed differences in distribution of hazelnut injury by the number of kernels within each category for both 2019 ($H(4)=98.06$; $p<0.001$) and 2020 ($H(4)=112.89$; $p<0.001$) seasons. Number of healthy kernels were higher ($p<0.05$) compared to the damaged kernels in both years and in all blocks, but there were no differences between the damaged kernel categories (blank, corked, mold and shrivel) as well as there were no differences in damage between the treatment types for 2019 ($H(2)=0.804$; $p=0.669$) and 2020 ($H(2)=0.545$; $p=0.761$) (Figure 4).

Discussion

Seasonality of *H. halys* was similar during both seasons. Emergence of the first generation nymphs during the 2019 season started earlier than during the 2017 season [19]. The 2017 year study was performed in another orchard, located only about 30 km from the 2019 and 2020 site, but both of them share similar regional peculiarities. The early emergence of BMSB nymphs can be potentially associated with higher temperatures in 2019, while in 2020 the DD accumulation curve was similar to that of the 2017 season (Figure 2). *H. halys* adults and all nymphal instars were observed in all blocks from mid-July to mid-September ($DD_{13.9}$ 889 - 1719). In laboratory observations conducted in Minnesota, *H. halys* showed maximum survival and fecundity at 27 and 23°C, respectively, while the mean generation time was the shortest at 30°C [24]. During field-based experiments, where constant temperature cannot be maintained, the average daily temperatures in the range of 20-27°C supports higher *H. halys* populations and presence of overlapping generations.

Finding second instar nymphs near the end of September supports the hypothesis there are at least two adult generations of *H. halys* in subtropical regions of Georgia [19], while in the eastern part of the country presence of this pest in apple and peach orchards was not confirmed [25]. Two generations of *H. halys* are also reported for regions at similar latitudinal range as Georgia. Two generations of *H. halys* are documented for Maryland and West Virginia [26], for Minnesota [25] and for Eastern United States [27]. Similar pattern is observed by our investigation showing, in addition to overwintering *H. halys* adults in the spring, two adult peaks on traps located outside the orchard – in mid-June and mid- September (Figure 5).

Using insecticide treated nets as an alternative management strategy against *H. halys* was first proposed in 2014 at the peak of the infestation of apple orchards in Pennsylvania (G. Krawczyk, personal communication). Multiple field and laboratory experiments were performed to evaluate the efficacy of insecticide treated nets baited with *H. halys* attractants as a management tool to attract and kill the pest and in consequence to reduce numbers of pesticide applications inside plots [8, 28]. Similar version of the attract and kill strategy is relying on utilizing wild trees baited with pheromone lures and located outside or at the border of the orchard which are being frequently treated with insecticides effective against *H. halys.* This approach has been demonstrated to be very effective in killing of high numbers of stink bugs through the growing season [6, 29], namely, two years trials showed reduction in fruit damage inside of blocks by half to a third compared with the standard blocks treated with insecticides only [29]. Insecticide treated nets were also tested and found very effective in killing pests of storage products. Warehouses deploying nets show 89-100% reduction of storage insects attacking commodities [30]. Our investigation also proved effectiveness of A&K stations surrounding orchard blocks in killing *H. halys* adults and nymphs. Monitoring traps located inside the A&K blocks showed lowest captures of *H. halys* through the study. Although the difference with other management strategies was not clearly evident before harvest when total number of captured bugs within the orchard was low, this difference became significant after the harvest when standard treatment practices were abandoned by the farmer (Table 3, Figure 3).

Surprisingly, additional applications of pyrethroid insecticides around the border of the hazelnut orchard did not reduce the numbers of *H. halys* in the interior of the blocks as effective as attract and kill strategy ($p>0.005$). The number of captured *H. halys* in the BRD blocks after harvest were even higher than in blocks designed for only grower's standard applications. Our finding contradicts with study which demonstrated that the border application of insecticides in peach orchards significantly reduced the volume of insecticide applications compared to standard blocks, however the border targeting applications still effectively managed *H. halys* and other key pests keeping them at levels close to levels observed in orchards utilizing standard practices of pesticide application [10].

Protection of hazelnuts by alternative management strategies lead to reduction in the number of insecticide applications in the experimental plots, where the last full application of insecticides was performed on 15 June in 2019 and 5 July in 2020. This decision was made by the farmer based on the monitoring results and the hazelnut quality. After these dates, no more whole orchard insecticide applications were made and only the protected parts of the orchard were the blocks with A&K nets and with border spray treatments (Tables 1 and 2). Unfortunately, but consequently an increase in the number of observed stink bugs within the orchard began after mid - August when hazelnuts were already harvested (Figure 5).

The wild vegetation surrounding orchard area most likely provides shelter for *H. halys* populations and let them survive insecticide applications done in the managed areas. Stink bug adults and nymphs developing outside of the orchard can continuously migrate into the interior of the orchard, making *H. halys* mobile forms a typical border driven pest [31]. In order to observe this occurrence, we used traps (traps number 13-17) located outside the orchard placed on wild vegetation in locations serving as potential source of *H. halys* (Figure 1). Trap number 14 captured high numbers of stink bugs during both study years (Figure 6). This trap was located on the bank of the Patara Enguri River, with dense forest vegetation on the other bank of the river. Width of the river on this location is about 60m which seems an easy obstacle to be crossed knowing the *H. halys* adults are capable to travel 2 to 5 km in 24 hours [32, 33, 34]. However, the trap number 15 that was also located on the bank of the river about 120 m away from the other bank of the river, captured much lower numbers of stink bugs (Figure 6). This difference in the number of captured stink bugs at least partially can be attributed to both, difference in the width of the river and absence of vegetation in immediate surroundings of the trap number 15 (Figure 1). As expected, traps located in areas without surrounding wild vegetation (16 and 17) recorded the lowest captures of stink bugs. As trap number 14 with highest number of captured bugs was placed adjacent to A&K blocks (Figure 1), it serves as additional evidence supporting effectiveness of A&K strategy.

H. halys is known to feed on hazelnuts at all stages of kernel development. Early stage feeding can result in blank kernels while feeding on mature hazelnut leads to development of corking damage [23]. In semi-field trials conducted in northwestern Italy, *H. halys* was found to be more harmful species compared to the native bug species causing the highest damage of kernels [2]. Recent investigation provided in California tree crops show also almond to be very effective attractant for *H. halis* [35]. The higher numbers of captured stink bugs at the orchard borders than in the interior of the orchard coupled with higher numbers of corking damage of hazelnut kernels collected from trees at the orchard edges (Figure 4) supports the hypothesis of *H. halys* being a perimeter driven insect pest. This type of behavior was also observed in our earlier studies [19] as well as by other investigations [5, 6, 18, 34]. The level of blank hazelnut was very similar during both years, while the levels of corking damage in nuts was higher during the 2020 season (Figure 4). The levels of nut damages did not appear to be correlated with different pest management strategies. Although A&K blocks show much less numbers of captured stink bugs, the levels of corking damage were slightly higher on the trees located on the border of A&K blocks, while numbers of blank kernels were higher on border trees of BRD blocks in 2019 season. In GS blocks incidences of different types of damage were similar, however higher prevalence of blank and corked kernels was observed on trees located in the borders of the blocks (Figure 4).

In summary, under environmental conditions existing in Kolkheti Lowland (Western Georgia), the results of this research documented overwintering adults of *H. halys* started to emerge at the end of April and first-generation eggs were observed in early June. Overlapping generations were observed from the mid-July to mid-September. Landscape features influenced *H. halys* pressure as measured by traps, as orchards surrounded by dense wild vegetation were under higher pressure of *H. halys* due to potential influx of pests from surrounding areas. Under such conditions, special attention should be directed to the utilization of alternative management approaches such as attract and kill strategies. Insecticide treated nets should be placed outside of the orchards to be able to attract bugs coming from both, the area surrounding the orchard as well as from the interior of the orchard. Use of attract and kill stations can be utilized to reduce the numbers of insecticide applications. In orchards not surrounded by wild vegetation, these strategies can potentially decrease the necessity of insecticides use and reduce the number of sprays by half, from 5-6 times in 2018 (personal communication) to 3 times (Tables 1 and 2).

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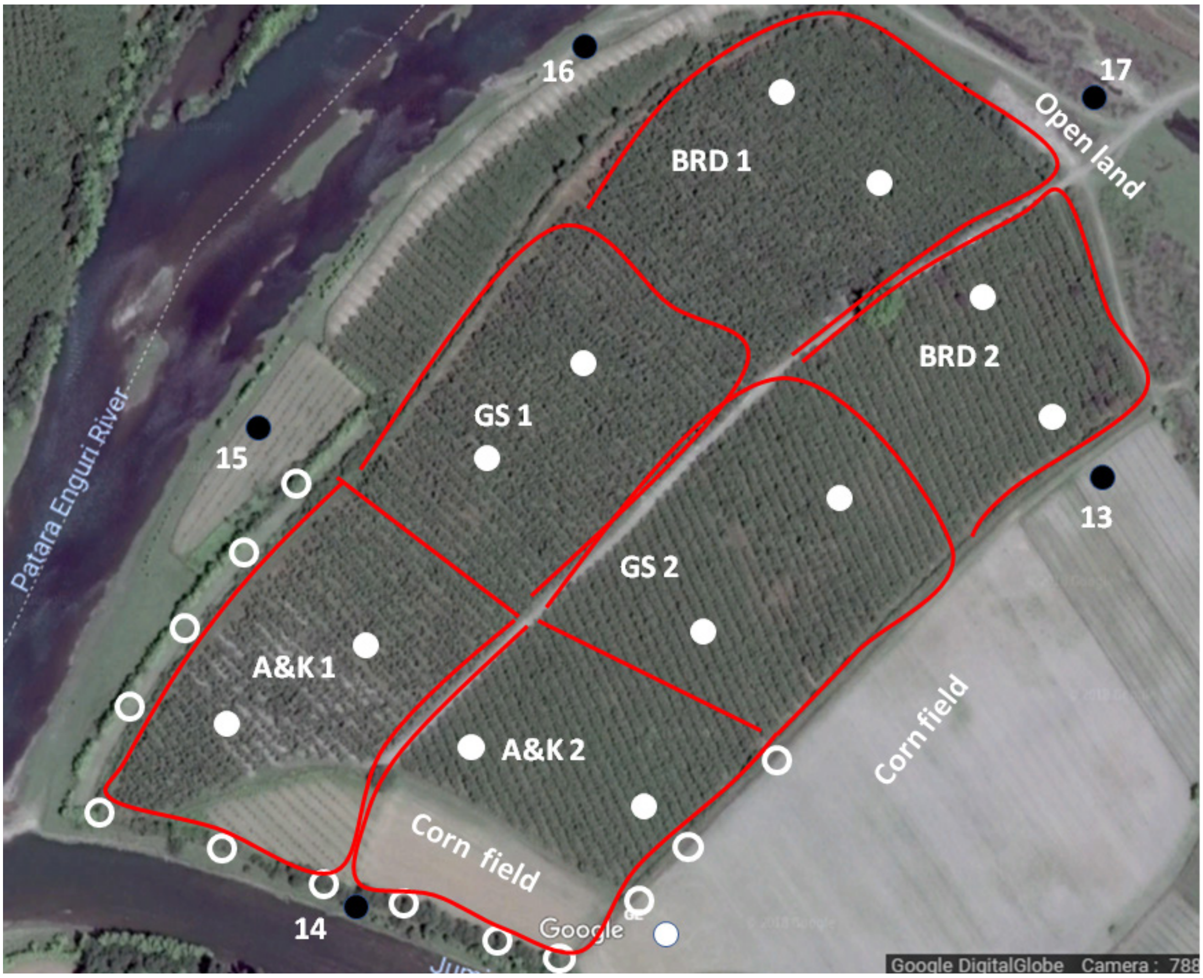

Figure 1. Placement of *H. halys* attract and kill stations and monitoring traps within the experimental plots. Solid white circles indicate placement of monitoring Rescue traps inside the orchard; solid black circles indicate placement of Rescue traps outside the orchard; open circles indicate placement of A&K stations (A&K – attract and kill; BRD – border applications; GS – grower's standard); numbers indicate respective numbers of Rescue traps outside of the orchard

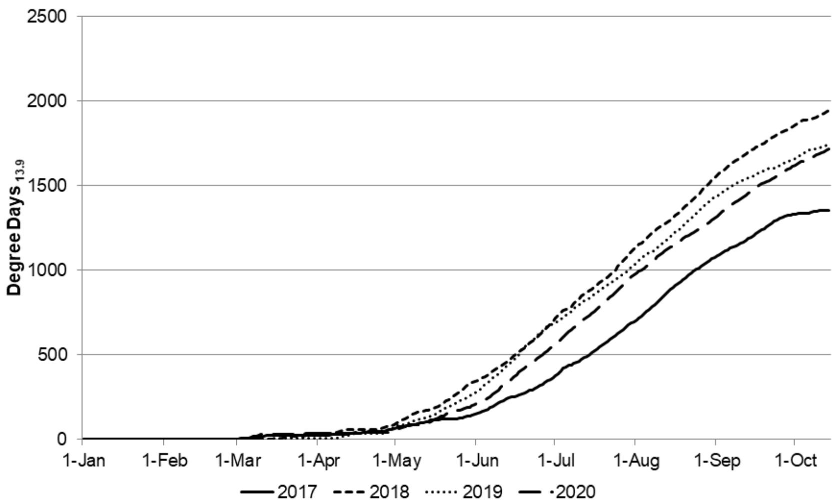

Figure 2. Accumulation of developmental degree days $(DD)_{13.9}$ for the 2017-2020 seasons in the Zugdidi Municipality, Samegrelo Region, Western Georgia.

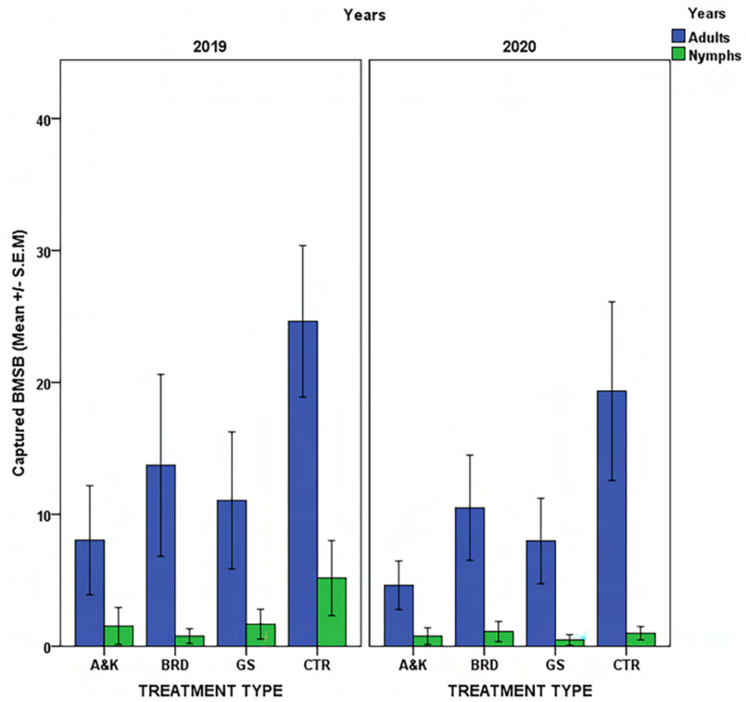

Figure 3. *Differences in numbers of captured H. halys between the 2019 and 2020 seasons before and after the harvest for adults and nymphal instars in plots with different management strategies (A&K – attract and kill; BRD – border applications; GS – grower's standard; CTR – traps #13-17, located outside the orchard, on wild vegetation).*

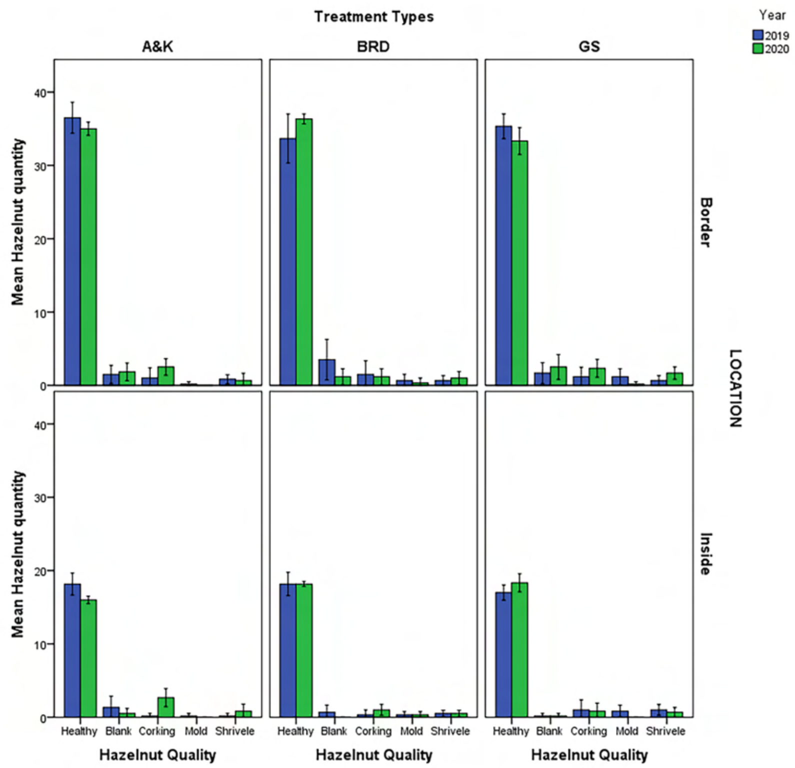

Figure 4. *Estimation of hazelnut average quality by treatment type (A&K – attract and kill; BRD – border applications; GS – grower's standard). "Border" – refers to the margin row of trees in each block that serve as "border" between the orchard and surrounding area, "Inside" – refers to the trees located in the interior of the corresponding block*

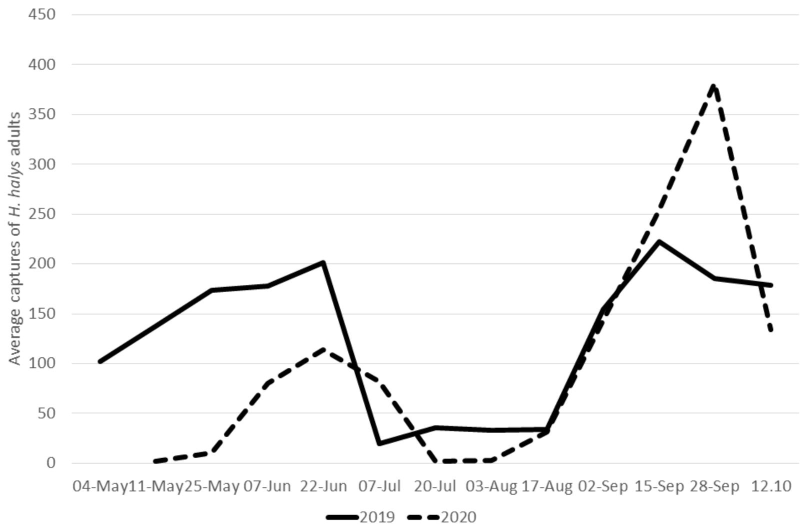

Figure 5. Average seasonal captures of *H. halys* adults by traps located outside the orchard during 2019 and 2020 seasons.

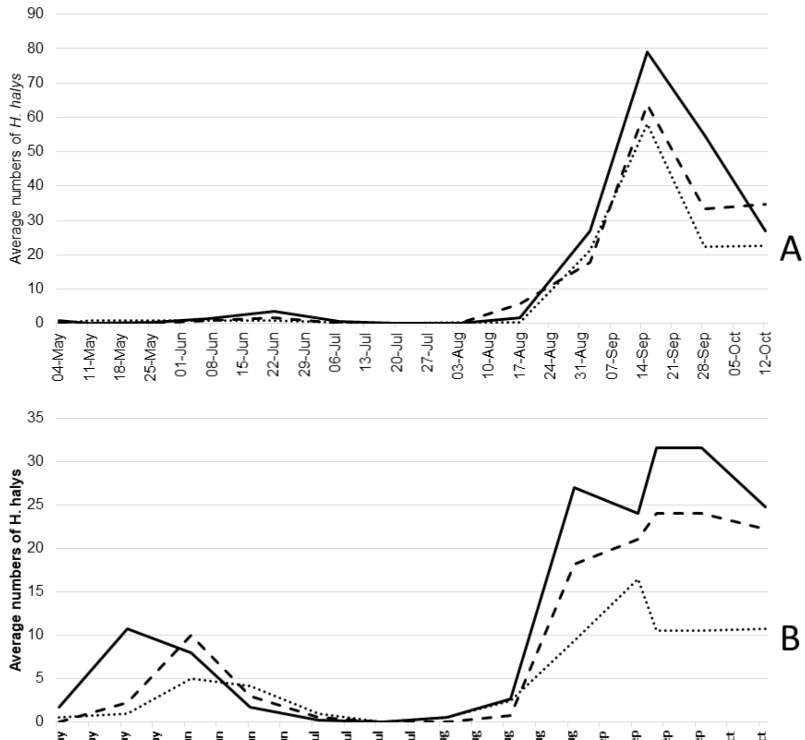

Figure 6. Seasonality of *H. halys* adults and nymphal instars in plots with different management strategies: a) Season 2019; b) Season 2020 (A&K – attract and kill; BRD – border applications; GS – grower's standard).

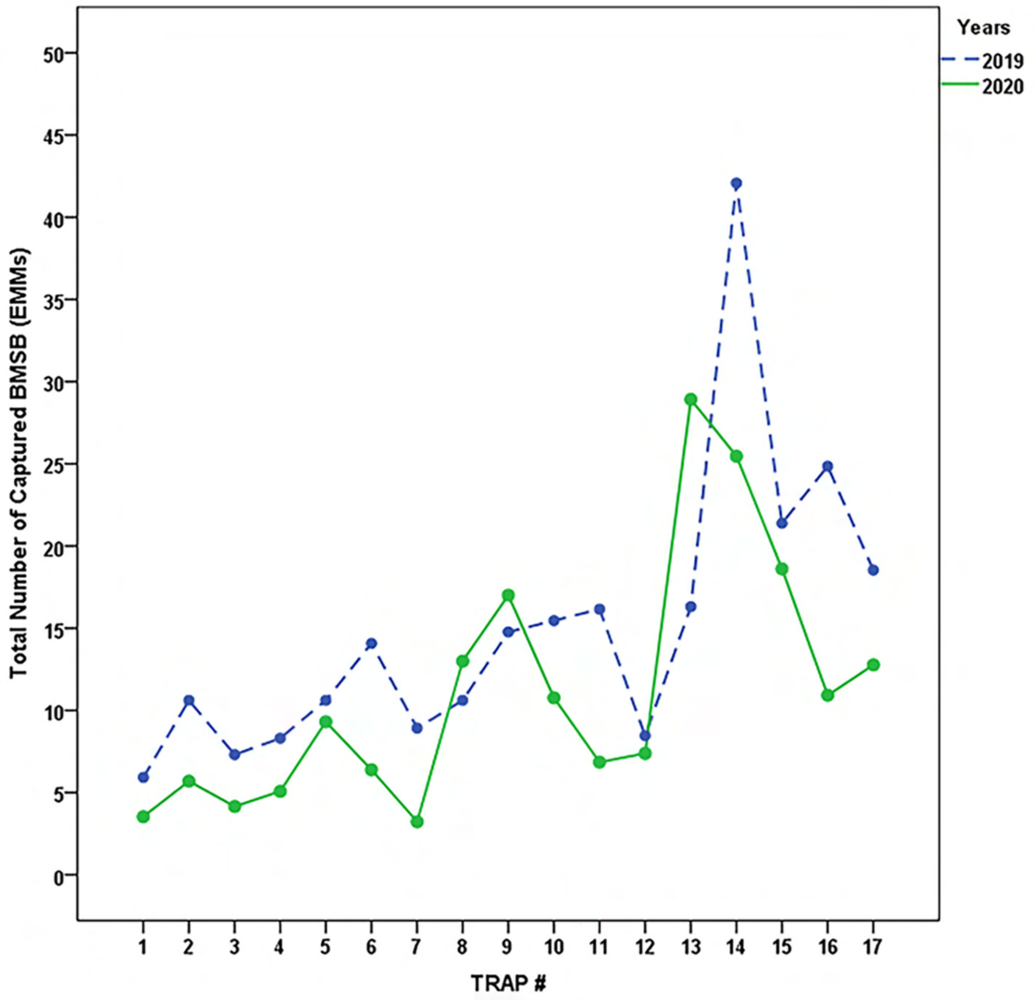

Figure 7. *Estimated marginal means (EMMs) for the number of H. halys adults and nymphal instars captured in the traps during both study seasons. Numbers: 13-17 indicate location numbers of Rescue traps utilized out of the orchard. Location of each trap is shown on Figure 1.*

Table 1. *Pesticide and fertilizer* applications at the experimental plot for 2019 season. All rates per 400 liter of water per ha.*

Date 2019	Location	Volume/ha	Pesticide* and rate of application
8 Apr.	All blocks	400 l	Kocide (2kg)+Superkill Forte (1l)+Trend (200gr)
9 Apr.	All blocks	400 l	Kocide (2kg) + Kaiso (300gr) +Trend (200gr)
24 Apr.	All blocks	400 l	Grogrin Gel 27-27-27 vegetation (3 kg)
10 May	All blocks	400 l	Bayomca (400 ml)
15 May	All blocks	600 l	Balista (600ml) + Grogrin Gel 27-27-27 vegetation (3kg) +Trend (200gr)
21 May	BRD	400 l	Talstar (450gr) + Trend (250gr
27 May	All blocks	400 l	Gurador (150gr)
7 Jun.	BRD	400 l	Lannate (400 gr) + Trend (100 gr)
15 Jun.	All blocks	400 l	Talstar (400gr) + Kodafil maximus 8-11-3, (500 gr), Gurador (100gr)

25 Jun.	All blocks	600 l	Grogrin fruit 18-11-59 3kg
20 Jul.	BRD	400 l	Talstar (600gr) +Trend (150gr)
10 Aug.	BRD	400 l	Lannate (400 gr) +Trend (100 gr)
24 Aug.	BRD	400 l	Talstar (450g)
06 Sep.	BRD	400 l	Talstar (450gr) +Trend (250gr)
12 Sep.	All blocks BRD	400 l	Ortus (500g) Talstar (450g)

*Pesticide *descriptions*: ***Kocide****- copper (II) 8% + hydroxyl 53;* ***Superkill Forte*** - cypermethrin, 50 g/l + chlorpyriphos, 500 g/l; **Trend** -*ethoxylated isodecile alcohol, 90% water solution;* **Grogrin** – NPK fertilizer, contains **B, Cu, Fe, Mn, Mo, Zn; Bayomca** – triadimenol, 250g/l ; **Balista** – alpha cypermethrin, 100g/l; **Talstar** – bifenthrine, 100g/l; ***Lannate–*** *methomyl 200g/l;* **Ortus –** fenpyroximate 51, 2g/l.

Table 2. *Pesticide and fertilizer* applications at the experimental plot for 2020 season. All rates per 400 liter of water per ha.*

Date 2020	Location	Volume/ha	Pesticide* and rate of application
9 Apr.	All blocks	400 l	Kocide (2kg)+Superkill Forte (1l)+Trend (200gr)
26 Apr.	All blocks	400 l	Grogrin Gel 27-27-27 vegetation (3 kg)
12 May	All blocks	400 l	Saga (1l) + Mystik (0.5l) + Grogrin Gel (2kg) + Trend (250mg)
26 May	All blocks	24 l	Kaiso (300gr) + Broder (100mg)
26 May	BRD	24l	Talstar (300mg) – Broder (100mg)
6 Jun.	All blocks	400 l	Talstar (600mg) + Broder (200mg) Kaiso (300g) + Broder (200mg)
9 Jun.	BRD	400l	Talstar 800g
21 Jun.	BRD	400 l	Talstar 800g
05 Jul.	All blocks	400 l	Prius (1l) + Grogrin Gel (2.5kg), Fulpas (0.5l) + Talstar (0.6l)
23 Jul.	BRD	400 l	Talstar 800g
31 Jul.	BRD	400 l	Talstar 800g
28 Aug.	BRD	400 l	Talstar 800g
04 Oct.	BRD	400 l	Talstar 800g

*Pesticide *descriptions*: ***Kocide****- copper (II) 8% + hydroxyl 53;* ***Superkill Forte*** - cypermethrin, 50 g/l + chlorpyriphos, 500 g/l; **Trend** - *ethoxylated isodecile alcohol, 90% water solution;* **Grogrin** – NPK fertilizer, contains **B, Cu, Fe, Mn, Mo, Zn)**; **Talstar** – bifentrine, 100g/l ; **Mystik** –Tebukonazol 250g/l; **Kaiso** – **Lambda-cyhalothrin**, 50g/kg; **Broder –** chlorpyrifos 250ml; **Saga** – chlorpyrifos, 480g/l; **Fulpas** –penconasole 100g/l; **Prius** – pyrimethanile, 400g/l.

Table 3. *Average captures of BMSB adults and nymphal instars in stink bug Rescue traps once in two weeks in plots with different management practices. Average numbers of individuals were counted from 2 traps in each managed block and from 5 traps at the control site outside the orchard (A&K – attract and kill; BRD – border applications; GS – grower's standard; CTR – unsprayed control). Before harvest season envelopes period from the beginning of the monitoring to August 5 for 2019 and to August 10 for 2020 when crop was harvested; after harvest - from the second week of August to the end of the season.*

Season 2019

Period	Adults						2nd and 3rd instars						4th and 5th instars					
	GS1	GS2	A&K1	A&K2	BRD1	BRD2	GS1	GS2	A&K1	A&K2	BRD1	BRD2	GS1	GS2	A&K1	A&K2	BRD1	BRD2
Before harvest	1	0.2	1.5	0.4	2	1.5	0	0	0	0	0	0	0	0	0	0	0	0
After harvest	62	50	41	40	63	76	0.4	4	2	0	0	2	5	7	11	2	4	2

Season 2020

Period	Adults						2nd and 3rd instars						4th and 5th instars					
	GS1	GS2	A&K1	A&K2	BRD1	BRD2	GS1	GS2	A&K1	A&K2	BRD1	BRD2	GS1	GS2	A&K1	A&K2	BRD1	BRD2
Before harvest	5	4	2	6	3	10	0	0	0	0	0	0	0	0	0	0	0	0
After harvest	36	22	16	15	27	49	0.3	2	1	5	1.5	6	1.5	0	1	0	1	0.6