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Comparative field evaluation of two pheromone types and trap designs for Halyomorpha halys (Stål, 1855) (Hemiptera: Pentatomidae) in two Georgian regions (Sakartvelo)

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Abstract

Field experiments conducted in three Georgian localities from July to October 2025 evaluated two pheromone types and trap designs for monitoring *Halyomorpha halys* (Stål, 1855) (Hemiptera: Pentatomidae). Captures of adults and nymphs were analyzed using two-way ANOVA.

Pheromone type A consistently produced higher catches than type B across rocket and sticky traps, while locality effects varied between trap types. Population peaks occurred in late August-September, with nymphs disappearing by October and adults dominating late-season captures.

Results indicate strong seasonal dynamics and regional differences in abundance. Overall, pheromone type A proved more reliable for field monitoring, supporting its use in integrated pest management programs against this invasive species in Georgia (Sakartvelo).

Keywords

Pheromone traps, Stink bug, Fruits, Hazelnut, Control.

Introduction

The brown marmorated stink bug, *Halyomorpha halys* (Stål, 1855) (Hemiptera: Pentatomidae), is a highly invasive and polyphagous pest native to East Asia that has rapidly expanded its range across Europe and North America. Since its introduction, *H. halys* has become a serious agricultural pest due to its broad host range, high dispersal capacity, and ability to reach outbreak population levels in invaded regions (Murvanidze et al., 2018; Japoshvili et al., 2022).

In Georgia (Sakartvelo), *H. halys* was first recorded in the western part of the country in the mid-2010s, followed by a rapid population increase and severe damage to agricultural crops (Gapon, 2016; Murvanidze et al., 2018). Subsequent studies documented its widespread establishment in western Georgia and its gradual expansion eastwards, confirming the pest as one of the most economically important invasive insects in the country (Kereselidze et al., 2018; Japoshvili et al., 2022).

Climatic conditions in western Georgia, characterized by high humidity and mild winters, appear especially favorable for the development and persistence of *H. halys* populations.

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Effective monitoring represents a cornerstone of integrated pest management programs against *H. halys.* Numerous studies have demonstrated that pheromone-based trapping is a reliable tool for early detection, population monitoring, and assessment of seasonal dynamics (Morrison et al. 2016; Murvanidze et al., 2018; Acebes-Doria et al., 2020).

The aggregation pheromone of *H. halys* has been widely applied in monitoring programs; however, capture efficiency may vary substantially depending on pheromone formulation, trap design, environmental conditions, and local population structure (Kereselidze et al., 2018; Japoshvili et al., 2022).

In Georgia, research efforts have primarily focused on documenting the distribution, seasonal biology, and impact of *H. halys*, as well as on surveys of native and adventive natural enemies, including egg parasitoids (Murvanidze et al., 2018; Talamas & Japoshvili, 2022).

These studies have substantially improved our understanding of the invasion process and biological control potential of *H. halys* in Georgia. Nevertheless, comparative field evaluations of different pheromone types and trap designs under Georgian conditions remain limited, particularly across multiple localities and throughout the full activity season of the pest.

Such comparative assessments are essential because trap performance and pheromone attractiveness may differ between regions and habitats, potentially influencing monitoring accuracy and management decisions. Regional field validation is therefore required to optimize pheromone-based monitoring tools for local agroecosystems in Georgia (Sakartvelo).

The present study aims to address this knowledge gap by conducting a comparative field evaluation of two pheromone types and trap designs across three Georgian localities: Tkviri (Abasha) and Kvaloni (Senaki) in western Georgia, and Lagodekhi in eastern Georgia. Trapping was carried out from July to October, covering the main seasonal activity period of *H. halys.*

Specifically, we aimed to (i) compare capture efficiency between the tested pheromone–trap combinations, (ii) analyze seasonal patterns of adult and nymphal abundance, and (iii) assess locality-dependent differences in trap performance.

The results provide practical information for improving monitoring strategies and supporting pest management programs against *H. halys* in Georgia (Sakartvelo).

Materials and Methods

Field experiments were conducted at three localities in Georgia (Sakartvelo) representing two geographic regions.

Two sites were located in western Georgia: Tkviri (Abasha) 42.16442682342438, 42.216076236934 and Kvaloni (Senaki) 42.27133061360895, 41.97921669959777 and one site was located in eastern Georgia, Lagodekhi 41.800066163863505, 46.267549725114506.

These localities were selected to assess the field performance of pheromone and trap-based monitoring systems under different regional and local conditions.

Sampling was carried out from late July to late October 2025, covering the main seasonal activity period of the target insect, one trap per treatment was placed at each site.

Traps were inspected at approximately two-week intervals on the following dates: 30 July, 14 August, 27 August, 10 September, 24 September, 8 October, and 22 October 2025.

The study evaluated two pheromone types (A-TRECE (Fig.1A) and B-AGROBEST(Fig.1B)) in combination with trap designs (sticky (Fig.1C) and rocket type (Fig.1D) as defined in the experimental setup).

At each sampling date, traps representing each pheromone–trap treatment were deployed at all three localities. Captures were recorded separately for each locality × treatment × date combination.

At each inspection, all insects captured in traps were collected and sorted by developmental stage into: Imago (adults) and Nymphs.

For each sampling date, locality, and treatment, the numbers of imago and nymphs were recorded. The total catch was calculated as the sum of both developmental stages. Each record in the dataset, therefore, included the following variables: sampling date, locality, treatment type (A or B), number of imago, number of nymphs, and total number of individuals.

Seasonal population dynamics were visualized using time-series line plots showing changes in total abundance (imago + nymphs) across the sampling period for each locality × treatment combination.

To assess differences in capture success among localities and treatments, total abundance was used as the response variable.

Separate two-way ANOVA analyses were performed for rocket and sticky traps to test the effects of locality and treatment (A vs B). Statistical significance was assessed at $p < 0.05$.

Because sampling was conducted repeatedly over time at the same localities, results are interpreted primarily to compare overall treatment performance and seasonal trends across regions rather than to model temporal dependence explicitly.

Results

To evaluate treatment effects, separate two-way ANOVA analyses were conducted for each trap type (rocket and sticky), testing the effects of locality and pheromone type. This approach allowed comparison of pheromone performance within each trap design independently.

Rocket traps (Chart 1).

Tkviri (Abasha) showed a consistently higher abundance than Lagodekhi throughout the sampling period. Population peaks were particularly pronounced in late August and September. This pattern suggests that Tkviri (Abasha) provides more favorable ecological conditions, potentially related to climate, host plant availability, habitat structure, or phenology.

Type A was consistently dominant in both localities, whereas Type B remained at low densities and was almost absent in Lagodekhi throughout the season.

Nymphal stages were most abundant in August and early September and disappeared completely by October, when captures were dominated by imago, indicating completion of development before late autumn.

Overall, population dynamics differed markedly between localities and pheromone types. Type A was dominant throughout the sampling period, with pronounced seasonal peaks in late August and September, particularly in Tkviri (Abasha). Type B occurred at consistently lower densities and was nearly absent in Lagodekhi.

A two-way ANOVA (Type II) revealed a significant effect of locality (F = 8.69, p = 0.007) and pheromone type (F = 15.90, p < 0.001) on total abundance. The interaction between locality and pheromone type was not statistically significant (F = 3.27, p = 0.083).

Thus, population abundance differed significantly between Tkviri (Abasha) and Lagodekhi, with consistently higher values observed in Tkviri, confirming a strong site effect likely reflecting ecological differences between localities.

Type A showed significantly higher abundance than Type B across the dataset, regardless of locality.

The non-significant interaction indicates that the magnitude of the Type effect was consistent across sites. Sticky traps (Chart 2).

In Lagodekhi, pheromone Type A exhibited an early and pronounced abundance peak in late August, followed by a gradual decline.

In contrast, in Kvaloni (Senaki), Type A reached its peak later, during September to early October. Thus, seasonal dynamics differed between localities, with Lagodekhi showing an earlier abundance peak compared to Kvaloni (Senaki).

In both localities, Type A was consistently more abundant than Type B, which remained at low densities throughout the sampling period.

Total abundance declined sharply toward late October at both sites, indicating completion of the main activity period.

Two-way ANOVA (Type II) showed no statistically significant effect of locality on total abundance (F = 2.70, p = 0.114). Although temporal trends differed visually between sites, overall abundance did not differ significantly when averaged across the season.

The effect of pheromone type was borderline significant (F = 4.25, p = 0.050), with Type A tending to be more abundant than Type B.

The interaction between locality and pheromone type was not significant (F = 0.001, p = 0.976), indicating that differences between Type A and Type B did not depend on locality but were primarily related to pheromone type.

Discussion and conclusion

The results demonstrate clear differences in capture efficiency between pheromone types, as well as locality-dependent variation in seasonal population dynamics.

Across all experiments, pheromone Type A consistently outperformed Type B, regardless of locality or trap design. This pattern was evident in both rocket and sticky traps and was supported statistically by two-way ANOVA, which revealed a significant or marginally significant effect of pheromone type on total abundance.

These findings indicate that pheromone Type A is more effective for monitoring *H. halys* populations under Georgian field conditions. The consistently low captures associated with Type B suggest lower attractiveness or reduced field stability of this pheromone formulation.

Locality effects were evident but varied between trap types. In the rocket trap experiment, Tkviri (Abasha) showed significantly higher population abundance than Lagodekhi, as confirmed by ANOVA.

This difference likely reflects ecological and climatic variation between western and eastern Georgia, including differences in humidity, host plant availability, and landscape structure, which are known to influence *H. halys* population development.

In contrast, for sticky traps, locality did not have a statistically significant effect on overall abundance, despite visible differences in seasonal dynamics. This suggests that trap design may mediate how locality-specific factors influence capture success.

Seasonal patterns observed in both trap types were consistent with the known phenology of *H. halys.* Nymphs were abundant mainly during August and early September and disappeared by October, while imago dominated late-season catches.

This indicates completion of development before late autumn and confirms that the July-October period effectively captures the full seasonal activity of the species in Georgia. Differences in the timing of peak abundance between western localities (Tkviri and Kvaloni) further highlight the importance of region-specific monitoring strategies.

The lack of a significant interaction between locality and pheromone type in both analyses indicates that the relative performance of pheromone Type A versus Type B was consistent across sites. This is an important practical outcome, as it suggests that pheromone Type A can be reliably applied for monitoring across different regions of Georgia without the need for locality-specific adjustments.

Although the analyses were based on repeated sampling over time, the results provide robust comparative insights into pheromone and trap performance. The study therefore contributes valuable applied information for optimizing pheromone-based monitoring of H. halys in Georgia and supports evidence-based decision-making in pest management programs.

This study demonstrates that pheromone Type A is consistently more effective than Type B for monitoring *Halyomorpha halys* populations across different trap designs and localities in Georgia (Sakartvelo). Seasonal population dynamics differed among localities, reflecting regional ecological variation, but the superiority of pheromone Type A remained stable across sites.

Population peaks occurred primarily in late August and September, with nymphal stages restricted to mid-season and adults dominating late-season catches.

These findings confirm that pheromone-based trapping from July to October provides reliable information on seasonal activity and population trends of *H. halys.*

Overall, the results support the use of pheromone Type A as a preferred tool for field monitoring of *H. halys* in Georgia.

The information generated by this study can contribute to the improvement of monitoring protocols and enhance the effectiveness of integrated pest management strategies targeting this invasive pest.

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Conflict of interest: The authors declare that they have no conflicts of interest.

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Fig. 1. Pheromone and Trap types: A – TRECE; B – AGROBEST;
C – Sticky; D – Rocket type.

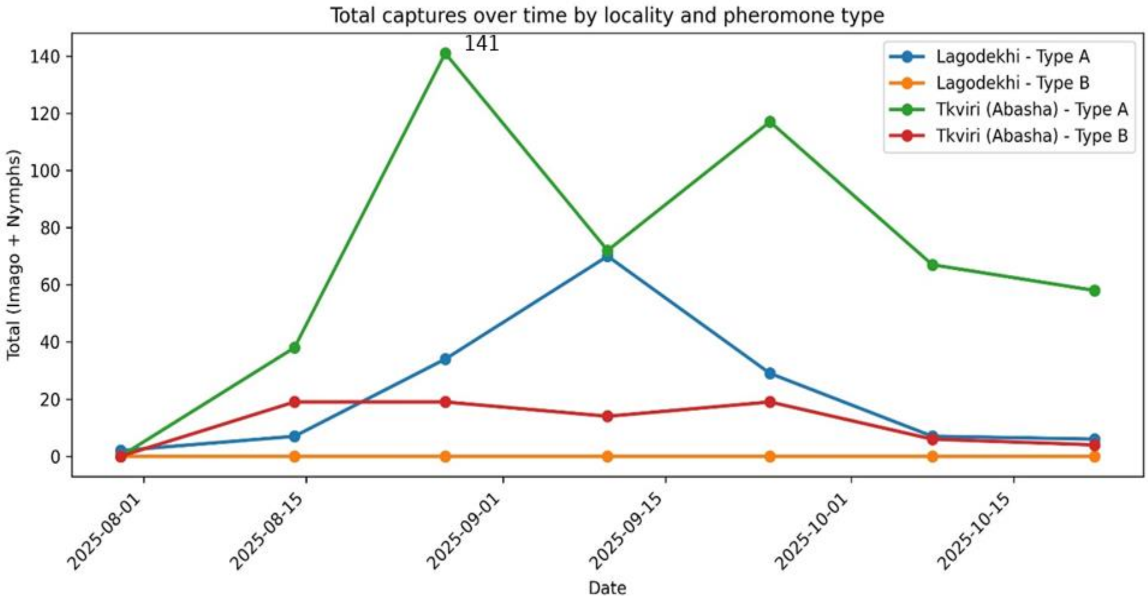

Fig. 2. Total captures by Rocket type trap.

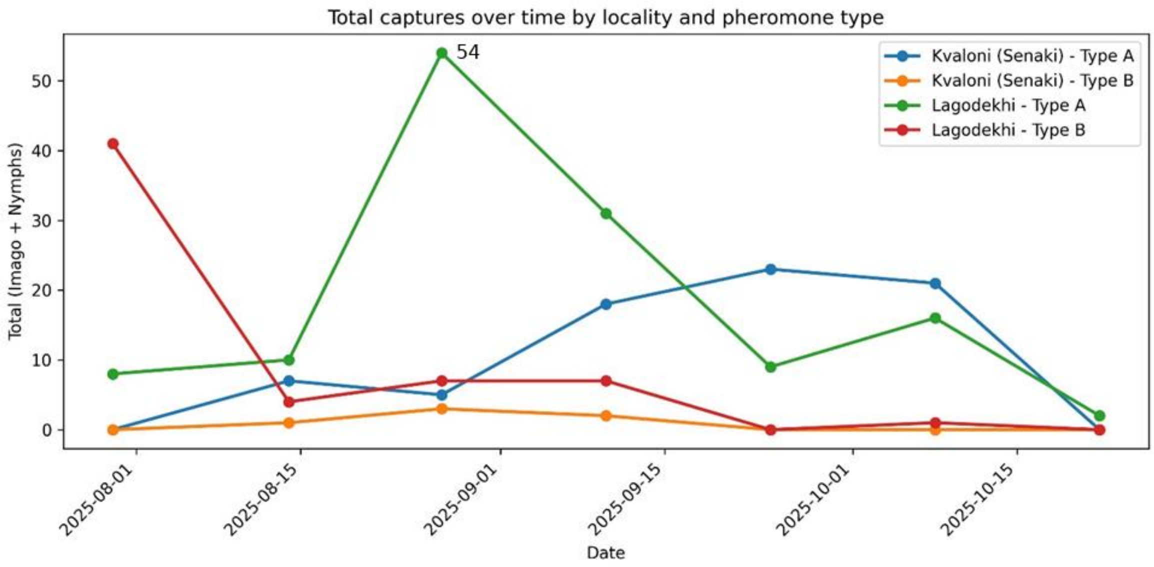

Fig. 3. Total capture by Sticky type trap.