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RESEARCH ARTICLE

Determination of the effect of yellow sticky traps on *Agonoscena pistaciae* (Hemiptera: Psyllidae) population density in pistachio orchards in Siirt, Türkiye

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ABSTRACT

Agonoscena pistaciae (Hemiptera: Psyllidae) is a significant pest in pistachio (*Pistacia vera* L.) orchards in Türkiye. This study aimed to evaluate the effectiveness of yellow sticky traps as an alternative method for controlling *A. pistaciae* populations in pistachio orchards. Conducted in late September and early October of 2021 and 2022, during peak pest activity, the experiment was carried out in Siirt, with three replicates following a randomized block design. Five traps were hung on all sides of each tree for sampling. Repeated measures ANOVA (repeated measures; general linear model) was used to observe changes over time. The results indicated that yellow sticky traps were highly effective in mass trapping adults, capturing an average maximum of 12 332.67 adults per trap. A significant decrease in the number of nymphs and eggs on the leaves was observed in the yellow sticky trap-treated trees compared to the control plots by mid-October ($P < 0.05$). Specifically, the average number of nymphs per composite leaf dropped from 24.95 to 11.23 in 2021, and from 145.18 to 27.29 in 2022. Similarly, the average number of eggs per composite leaf decreased from 61.18 to 2.29 in 2021, and from 73.56 to 3.64 in 2022. These findings suggest that yellow sticky traps can significantly reduce psyllid populations in pistachio orchards over the long term and can be an effective control method when used early in the vegetative period for low- to medium-sized psyllid populations.

Key words: Alternative control, mass trapping, *Pistacia vera*, pistachio psylla, population change.

INTRODUCTION

Pistachios (*Pistacia vera* L.) are among the most important agricultural products grown in Türkiye. Pistachios, which are produced in an area of 1046 thousand hectares worldwide as of 2023, were produced in 883 404.34 t in the same year. Pistachio cultivation is practiced in many provinces across Türkiye. According to FAO (2023), pistachio production covered an area of 390 000 ha in Türkiye. The common pistachio psylla *Agonoscena pistaciae* Burckhardt and Lauterer (Hemiptera: Psyllidae) cause significant losses in pistachios worldwide and in Türkiye by directly feeding on plants. Both nymphs and adults are damaged by sucking leaf sap. They also produce large amounts of sweet substances, leading to the formation of fumagine. By feeding directly on tree leaves, *A. pistaciae* causes loss of vigor in trees, stunting, bud drop, leaf shedding, and decreased yield.

Recent studies have reported that pistachio fields in Türkiye are suitable and optimal for *A. pistaciae* and cause serious yield losses (Dilmen and Özgökçe, 2020; Kaplan and Çiftçi, 2020; Sağıroğlu and Kaya, 2022; Usanmaz et al., 2022). As a matter of fact, it is possible to say that the complaints of producers about this pest have increased in the observations and interviews with farmers in Siirt Province. Therefore, it is very important to develop reliable methods that detect this insect in a timely manner and have a direct impact on the density of the pest. In this context, the use of yellow sticky traps is one of the most suitable strategies for decreasing pests. Growers mostly use chemical insecticides to control *A. pistaciae*. This may lead to resistance in the pest

and a decrease in the effectiveness of insecticides (Desneux et al., 2007). However, residue risk may occur and adversely affect non-target organisms. Moreover, pesticides that are not used at appropriate dosages negatively affect the environment and human health (Ansari et al., 2014; Singh et al., 2018). Although chemical pesticides are widely used in Siirt pistachio orchards, the population density of the pest is still high, and the existing natural enemy species are not sufficient to suppress the pest. To minimize agricultural production costs and reduce the ability of psyllids to develop resistance, it is extremely important to implement economically viable and effective methods within integrated pest management programs. Therefore, it is necessary to develop and adopt alternative methods for controlling *A. pistaciae*.

In this sense, it is highly important to investigate the use and effects of yellow sticky traps, which can be considered alternative methods for the control of harmful species. Yellow sticky traps are widely used for monitoring populations of many pests. Many studies have been conducted in this context (Shi et al., 2020; Zhang et al., 2020; Bozkurt and Uğur, 2022; Rubio-Aragón et al., 2023). However, to date, no study has been conducted to reveal in detail the effect of yellow sticky traps on the number of nymphs, adults, and parasitic nymphs of *A. pistaciae*. Furthermore, it has not been demonstrated whether yellow sticky traps can be used as a control method for *A. pistaciae*. In addition, because the above-mentioned studies were conducted in a single season, it has not been fully clarified whether these traps are effective in several seasons.

Therefore, the aim of this study was to determine the effect of yellow sticky traps on *A. pistaciae* population dynamics. In this study, the effects of yellow sticky traps on nymphs, eggs, and parasitic nymphal individuals of *A. pistaciae* were investigated during peak periods of infestation in pistachio orchards in Siirt. In addition, the benefits of using the yellow sticky trap method for controlling this pest have been revealed.

MATERIALS AND METHODS

The studies were conducted in fully productive 25-30-yr-old pistachio (*Pistacia vera* L.) orchards of the Siirt cultivar (Figure 1), planted at 8×4 m intervals from 2021-2022 in İkizbağlar Village (37°58'47.66'' N, 41°58'41.10'' E) in the Tillo district of Siirt Province (Figure 2). The experimental design followed a randomized block design with three replicates. Sampling began in late September, when the pest population density was at its highest, and was completed in early November

Figure 1. General view of the pistachio orchard where the study was conducted.

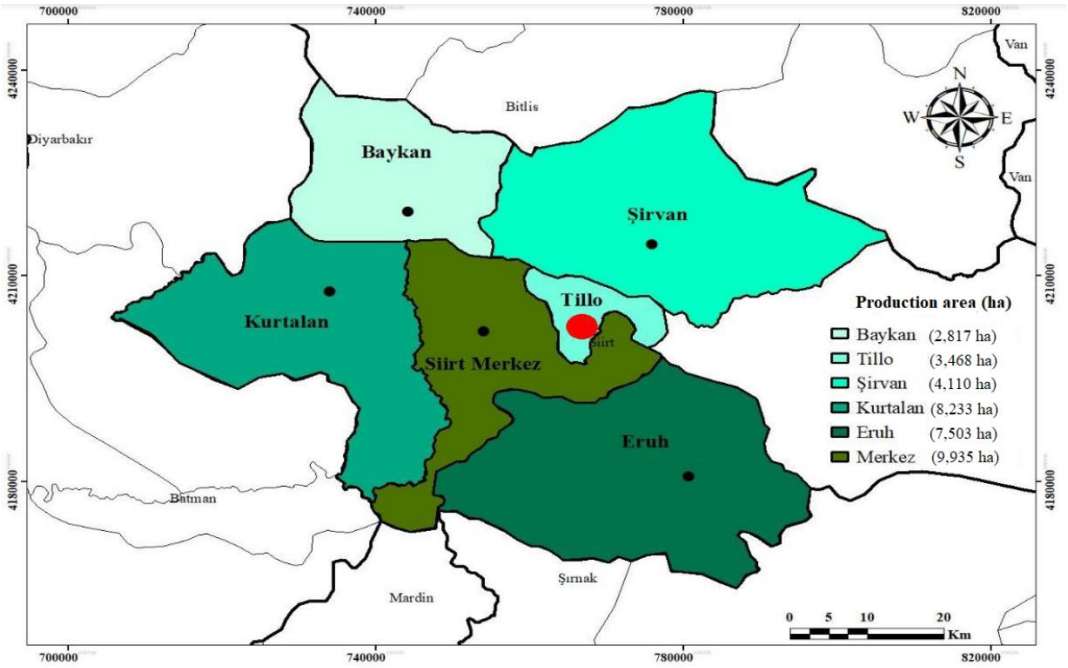

Figure 2. The studies were conducted in the Tillo district of Siirt Province (H. Dilmen, Original, Esri ArcGIS 10.2 program).

Field experiment

The experiment was structured using a randomized block design to account for any variability within the orchard and to ensure that the treatments were equally distributed across different environmental conditions. Each replicate consisted of a block of trees where five yellow sticky traps (measuring 20×25 cm) were hung on each tree at a height of 1.0-1.5 m. This height was chosen based on the typical flight height of *Agonoscena pistaciae* adults, ensuring maximum capture efficiency. The traps were replaced with new traps at 3 d intervals to maintain their adhesive efficacy and to ensure continuous monitoring of the pest population.

Sampling

Sampling involved both directly counting of pests on the traps and on leaves. The number of nymphs, eggs, and parasitized nymphs of the pest were counted on 25 leaves randomly collected from the same trees where the traps were hung. This dual approach allowed for a comprehensive assessment of both the adult and immature stages of *A. pistaciae*. Sampling at 3 d intervals ensured that the data captured the dynamics of the pest population accurately and provided sufficient temporal resolution to observe trends and changes over time.

Data analysis

Repeated measures ANOVA (repeated measurements; general linear model) was performed to determine changes in pest density over time ($p < 0.05$). This statistical method was chosen because it can handle the correlated nature of repeated observations from the same experimental units over time, thus providing a more accurate assessment of the effects of the yellow sticky traps.

Additionally, the nymphs, eggs, and parasitized nymphs of the pest detected on the leaves of the yellow sticky trap-treated trees and the control group trees were compared statistically at each sampling interval using the paired test (bootstrap, 100 000) with the Twosex MSChart (2024) package program (Chi, 2024). The use of bootstrap resampling provided a robust method to assess the significance of differences between treatments, especially in cases where the data might not follow a normal distribution.

In summary, the detailed experimental design and statistical analysis methods ensured robust and reliable evaluation of the effectiveness of yellow sticky traps in controlling *A. pistaciae* populations in pistachio orchards.

RESULTS AND DISCUSSION

It was determined that there was a significant decrease in population density in both years depending on the sampling intervals of all stages of *A. pistaciae*, except for parasitized nymphs, in the hung yellow sticky traps (YST) of the trees. The number of adults caught in the YST was quite high in both years. While 11 753 individuals per trap were detected on 23 September 2021, it was determined that the number of pests reached 12 333 individuals on the same date in 2022 (Figure 3). Similarly, the population density of the pest caught in the YST began to decrease significantly after the first 6 wk, starting on 7 October, in both years. Sampling continued until the period when the leaves turned yellow and fell in 2021 and 2022.

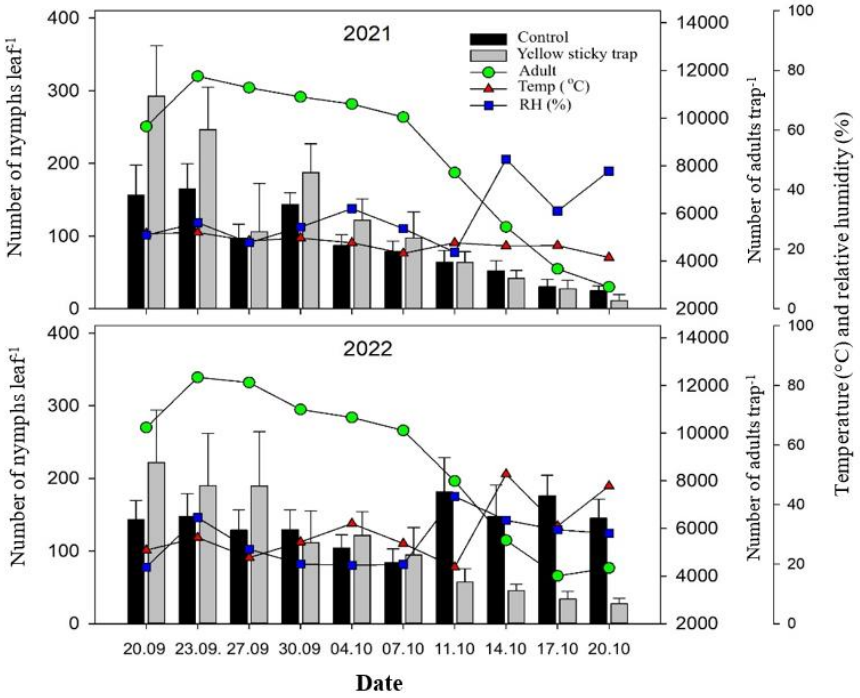

Figure 3. Number of adults caught with yellow sticky traps (YST) in 2021-2022 and the number of *Agonoscena pistaciae* nymphs determined in the leaves of the control group trees and YST-hanging trees.

The nymph density of the pest detected in the leaf samples taken from trees where YST was hung was significantly lower than that of the control group in the samples taken between 20 October 2021, and 11-20 October 2022 ($P < 0.05$) (Figure 3). While an average of 24.95 individuals per composite leaf was detected in the control trees on 20 October 2021, this number was 11.23 in the YST-treated trees and was found significant. Moreover, on the same date in 2022, an average of 145.18 nymphal individuals per composite leaf was detected in the control trees, whereas this number was 27.29 in the YST-treated trees ($P < 0.05$) (Figure 3).

In this study, the temperature readings during the September-October period of 2021 fluctuated between 30.2 and 17.2 °C. However, in 2022, temperatures during the same period ranged from 33.0 to 23.7 °C, surpassing those of 2021. Furthermore, starting in mid-October, the average relative humidity increased by 48.8% and 51.5%, respectively. Correspondingly, the densities of the adult, nymph, and egg stages of the pest increased in October 2022 (Figure 3). At temperatures higher than 23.7 °C, the density of *A. pistaciae* increased with increasing temperature. They reported that the optimal constant temperature for development was 30 °C; however, psyllid nymphs exhibited rapid development across a range of temperatures between 25.0 and 32.5 °C (Mehrnejad and

Copland, 2006). Moreover, Dilmen and Özgökçe (2020) showed that *A. pistaciae* is the main cause of damage during the autumn months when temperatures begin to decrease by creating a larger population.

Similar results were found for the number of harmful eggs detected in the leaves. In 2021, the number of eggs of the pest on the leaves was found to be significantly greater in the control group than in the control group among the five samples collected between 30 September and 14 October ($P < 0.05$) (Figure 3). On 30 September 2021, while the average number of eggs per composite leaf in the control trees was 61.18 the average number of eggs in the pistachio trees treated with YST was 2.29 (Figure 3). The same results were also found between 27 September and 11 October for 2022 ($P < 0.05$).

On 30 September 2022, similar to 2021, the average number of eggs per composite leaf in the control trees was 73.56, while in the YST-treated trees, the average number of eggs was 3.64. In general, the number of eggs from September 30 onward remained very low in trees treated with YST in both years (0.06-5.88) (Figure 4). Hanging yellow sticky traps on all sides of pistachio trees can decrease the potential for egg laying by capturing adult psyllids flying in their vicinity.

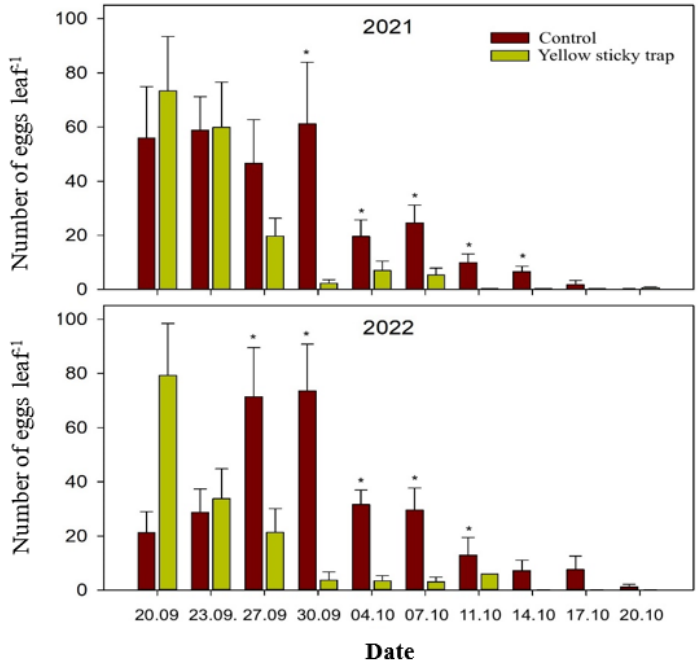

Figure 4. Number of *Agonoscena pistaciae* eggs in leaves of control group trees and yellow sticky traps hanging trees.

However, it was determined that the number of parasitized nymphs in the trees where YST was hung surpassed that of the control group in both years (Figure 5). In 2011, in a total of four samplings on 27 September, 4, 7, and 11 October and in 2022, in a total of six samplings between 27 September and 14 October, the number of parasitized nymphs was found to be greater on the trees where YST was hung ($P < 0.05$). On 7 October 2021, the average number of parasitoids per composite leaf was found to be at its highest level, reaching 4.72* in trees where yellow sticky traps were hung, while in control trees, this number was 0.23. Similarly, on 4 October 2022, in trees where yellow sticky traps were hung, the average number of parasitoids per composite leaf was found to be at its highest level, reaching 3.52, while in control trees, this number was 0.62. The reason for this is thought to be that YST may also be attractive to parasitoid adults. Parasitoids directed toward the trees with YST may have also attacked the nymphs of the pest present on those trees.

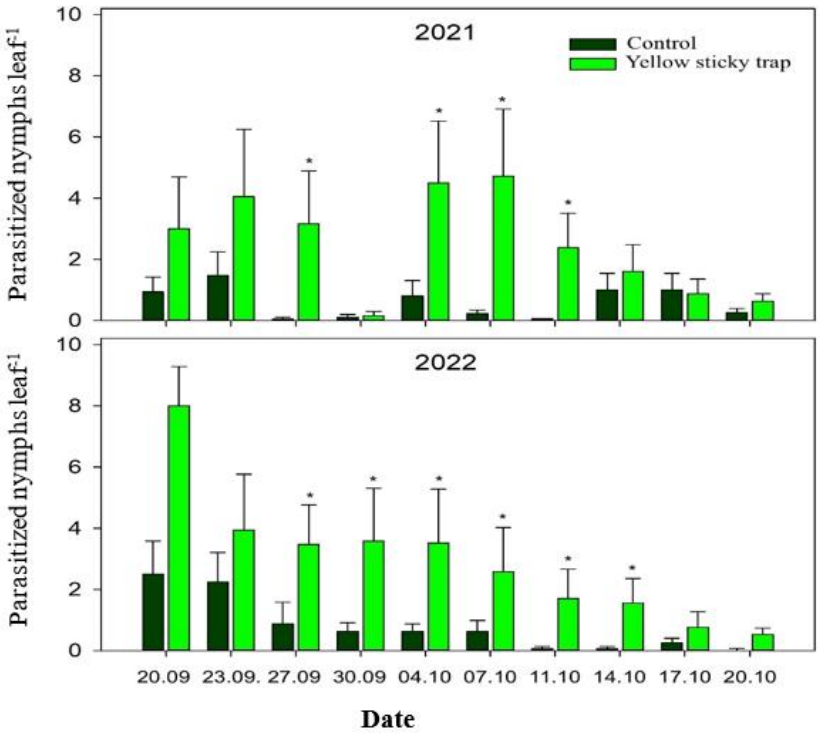

Figure 5. Number of *Agonoscena pistaciae*-parasitized nymphs on leaves of control group trees and yellow sticky traps hanging trees.

In both years of this study, the effects of YST activity on the populations of *A. pistaciae* were not significantly different ($P < 0.05$) on the first sampling date, which was 20 September. However, as a result of continuing the trapping activities in the same way at 3 d intervals, there was a significant difference in the number of live nymphs and eggs starting in mid-October. Furthermore, our study statistically proved that psyllid population levels in pistachios can be reliably estimated using YST. In recent decades, YST have been widely used to control harmful insect species. Studies on YST have primarily investigated their effects on populations of pests, especially psyllids, whiteflies, aphids, leafhoppers and fruit flies (Pinto-Zevallos and Vänninen, 2013; Toorani and Abbasipour, 2017; Salem et al., 2017; Shi et al., 2020; Özgen et al., 2020; Holthouse et al., 2021; Aragón et al., 2022; Bozkurt and Uğur, 2022; Rahman et al., 2023). In this context, when studies on psyllid species worldwide and in our country are examined, the data obtained in our research support these findings, indicating that YST are highly effective at attracting adult psyllids. Altun et al. (2024) highlights the potential of YST as an effective component of integrated pest management for controlling *Agonoscena pistaciae* in pistachio orchards, suggesting that they can significantly reduce psyllid populations when used in combination with other control methods. Furthermore, Özgen et al. (2020) used YST in eight different shades against *A. pistaciae* in a field experiment and reported that code 1016 attracted more psylla adults. Another study by Kosovaeri et al. (2014) revealed that YST were very effective at catching *Cacopsylla pyri* and *A. pistaciae* in Türkiye. Yellow sticky traps are highly effective at monitoring population fluctuations and reducing the population of *A. pistacaiae* in Iran (Fazeli et al., 2012). In a similar study, Seyedoleslami et al. (2002) reported that YST were highly effective in attracting *A. pistaciae*. Besides, in another study, it was concluded that the use of YST alone is not sufficient for the control of *C. pyri*. However, traps can be used as monitoring tools during the early spring period when overwintering *C. pyri* adults are present and beneficial populations are not active (Bozkurt and Uğur, 2022). Emami (2023) showed that the combination of 2% mineral oil with sticky traps was very effective in controlling *C. pyricola*. However, until now, no research has demonstrated the effects of using YST on *A. pistaciae* nymphs, eggs, or parasitoids. The data obtained from this field experiment showed that hanging YST on all sides of pistachio trees can help control psyllids. Particularly during the flowering period, when the initial population

density of psyllids increases, YST can be hung, and adults caught en masse can reduce the damage they will cause in later periods. Indeed, Horton (1999) stated that successful preflowering control of pear psylla is necessary to prevent problems during the next growing season. Furthermore, the fact that no natural enemy species were found stuck in the YST examined between 20 September and 20 October, when our study was conducted, is an encouraging finding.

CONCLUSIONS

Yellow sticky traps (YST) are a valuable tool for the control of for common pistachio psylla *Agonoscena pistaciae*. Our results indicate that the use of YST in pistachio orchards had a significant effect on both the number of nymphs and the number of eggs affected by the pest in the long term. Although YST were used in our study, the population density of the pest remained above the economic damage threshold. However, YST are effective at both tracking and catching the pest. Moreover, YST have been very successful at detecting the presence and population of psyllids in pistachio orchards. Early detection is crucial for timely control of this pest. As seen in our study, the mass capture of psyllids can be performed using YST. Especially in early spring, when adults first emerge, hanging YST on trees and capturing emerging adults en masse will significantly reduce the density of subsequent offspring. Again, in periods when the population density is high, a part of the pest population can be captured by strategically hanging enough traps in all orchards in a wide area or in villages at the same time; thus, the population density of the pest can generally decrease over time. In addition, when used in conjunction with other pest control methods, YST can help prevent pistachio psyllids from mating and reproducing. Thus, the number of eggs and subsequent offspring nymphs laid on pistachio trees can be reduced. On the other hand, when used as part of a comprehensive pest management strategy, YST can be valuable tools for controlling *A. pistaciae* and reducing damage to pistachio crops. Furthermore, it can complement integrated pest management strategies by offering an environmentally friendly and targeted approach to pest control, thereby reducing reliance on chemical pesticides. We believe that this approach will contribute to more sustainable and environmentally friendly pest control.

Author contribution

Conceptualization: H.D., M.S-Ö. Methodology: H.D., M.S-Ö. Validation: H.D., M.S-Ö., C.K. Formal analysis: H.D., M.S-Ö. Investigation: H.D., M.S-Ö., C.K. Resources: H.D. Sampling: H.D., C.K. Data curation: M.S-Ö. Writing-original draft: H.D., M.S-Ö. Writing-review & editing: H.D., M.S-Ö., C.K. Supervision: H.D., M.S-Ö., C.K. Project administration: H.D. Funding acquisition: H.D., M.S-Ö., C.K. All authors reviewed the final version and approved the manuscript before submission.

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