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Research Article

The Impact of Post-Harvest Removal of Vegetative Residues on the Adult Population Density of the Tomato Leaf Miner, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in Tomato-Growing Areas of Muğla

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ABSTRACT
This study investigated the effects of tomato plant residues that remained in the field after harvest on the population growth of adult *Tuta absoluta* in open-field tomato growing areas of Muğla province. The research was conducted in Çamköy (Milas, Muğla) and Kızlan (Datça, Muğla) between 2015 and 2017 in a total of four fields, including one field with field cleaning and tillage after harvest and one field without field cleaning and tillage in each location. Pheromone traps were used to determine the development of adult *T. absoluta* populations. During the studies, a total of 3.670 and 5.423 *T. absoluta* adults were captured in Çamköy in the fields with and without field cleaning and tillage, respectively. Based on these findings, the total mean number of *T. absoluta* adults was found to be 159.57 and 235.78, respectively. The difference between the two means was determined to be statistically significant. In Kızlan, another region where sampling was conducted, a total of 3.127 and 5.440 *T. absoluta* adults were captured in fields that underwent post-harvest field cleaning and tilling, respectively. The mean number of adults in these fields was 142.14 and 247.27, respectively, showing a statistically significant difference between the two means. These results indicate that cultural treatments aimed at reducing *T. absoluta* populations in post-harvest production areas effectively decreased pest population density in the following season.
Keywords: *Tuta absoluta*, population, vegetative residue, tomato, Muğla.

Muğla İli Açık Tarla Domates Üretim Alanlarında Hasat Sonrası Bitki Artıkları Temizliğinin Domates Yaprak Güvesi *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiiade)'nın Ergin Popülasyon Yoğunluğuna Etkisi

ÖZ
Bu çalışmada, Muğla ilinde açık alanda domates yetiştirilen alanlarda hasat sonrası tarlada kalan domates bitki artıkları ile yabancı otların ergin *Tuta absoluta* (Meyrick)'nın popülasyon gelişimi üzerine etkileri araştırılmıştır. Çalışmalar, 2015-2017 yılları arasında Çamköy (Milas, Muğla) ve Kızlan (Datça, Muğla)'da, hasat sonrası tarla temizliği ve toprak işlemesi yapılan bir tarla ile tarla temizliği ve toprak işlemesi yapılmayan bir tarla olmak üzere toplam dört tarlada yürütülmüştür. Ergin *T. absoluta* popülasyonlarının gelişimini belirlemek için feromon tuzakları kullanılmıştır. Çalışmalar sırasında Çamköy'de tarla temizliği ve toprak işlemesi yapılan ve yapılmayan tarlalarda sırasıyla toplam 3.670 ve 5.423 *T. absoluta* ergini yakalanmıştır. Bu bulgulara dayanarak, toplam ortalama *T. absoluta* ergin sayısı sırasıyla 159.57 ve 235.78 adet olarak bulunmuştur. İki ortalama arasındaki farkın istatistiksel olarak önemli olduğu belirlenmiştir. Örneklemenin yapıldığı bir diğer bölge olan Kızlan'da, hasat sonrası tarla temizliği ve toprak işleme yapılan ve yapılmayan tarlalarda sırasıyla toplam 3.127 ve 5.440 adet *T. absoluta* ergini yakalanmıştır. Bu tarlalardaki ortalama ergin sayısı sırasıyla 142.14 ve 247.27 adet olarak gerçekleşmiş ve iki ortalama arasındaki fark istatistiki olarak önemli bulunmuştur. Bu sonuçlar, hasat sonrası üretim alanlarında *T. absoluta* popülasyonlarını azaltmayı amaçlayan kültürel uygulamaların bir sonraki sezonda zararlı popülasyon yoğunluğunu azaltmada etkili olduğunu ortaya koymuştur.

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Anahtar kelimeler: *Tuta absoluta*, popülasyon, bitki artıkları, domates, Muğla.
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Introduction

The tomato leaf miner *Tuta absoluta* (Meyrick) is a major pest that poses a significant threat to tomato crops worldwide, including Turkey (Desneux et al., 2010; Silva et al., 2015; Nouri-Ganbalani et al., 2016). This pest can cause significant damage to both the yield and quality of tomatoes by tunnelling into leaves, stems and fruit, creating feeding galleries. These galleries can lead to secondary infections and significant economic losses (Harizanova et al., 2009; Cuthbertson et al., 2013, Aygel and Aslan, 2023). *T. absoluta* was first identified in Turkey from tomato plants in İzmir in 2009, and since then various studies have reported different levels of damage to tomatoes in almost all regions of the country (Kılıç, 2010; Erler et al., 2010; Karut et al., 2011).

Since the identification of *T. absoluta* in Turkey, intensive chemical control measures have been implemented to manage its population. Insecticide applications targeting this pest, which adversely affects both field and protected tomato production, were basis counted weekly and subsequently increased to every three days (Nouri-Ganbalani et al., 2016; Polat et al., 2016). Although these chemical methods demonstrate short-term efficacy in suppressing pests, their frequent use has resulted in several significant problems, including pesticide residues on crops, environmental pollution and the development of resistance in the pest to the insecticides used (Siqueira et al., 2000; Lietti et al., 2005; Desneux et al., 2010).

Several control methods can serve as alternatives to chemical control, one of which is cultural methods (Chhetri, 2018, Walgenbach, 2018). This approach involves the manipulation of artistic practices within the crop production process to reduce or eliminate pest arthropod populations. Cultural methods encompass a variety of strategies, ranging from straightforward interventions, such as adjusting sowing or planting dates to mitigate pest infestations, to more intricate approaches that involve reorganizing the spatial and temporal dimensions of an agroecosystem, as well as employing resistant crop varieties (EPPO, 2005; Silva et al., 2015).

An important cultural practice is the disposal of plant residues following the growing season, which role is critical in mitigating pest populations. This practice significantly aids in minimizing potential economic losses attributed to pests in subsequent growing seasons (Bashyal et al., 2022). By physically removing and appropriately disposing of infested plants, growers can effectively disrupt the pest's life cycle, consequently decreasing the number of overwintering stages that persist and reproduce. This disruption not only influences the reproductive cycle of the pest but also diminishes its population density, lowering the risk of future infestations (Cloyd and Herrick, 2022).

The effects of these preventive measures are often observed in the following growing season (Capinera 2001). By eliminating *T. absoluta*-infested plant material, growers can reduce the initial pest load, resulting in lower incidence rates and less damage to new crops. The effectiveness of this strategy is enhanced when combined with other control measures, such as biological control agents and targeted insecticides, creating a more robust and resilient pest management system. Consequently, the removal of infected plant material not only contributes to immediate pest control but also enhances the long-term sustainability of tomato production by minimizing the risk of recurrent infestations and supporting healthier crop development in the following season (Dara, 2019). In this context, the removal and destruction of pest-infested plant residues from the production area, along with deep tillage, play an important role in controlling *T. absoluta* (EPPO, 2005).

Due to its extensive host range, *T. absoluta* is capable of persisting in both natural and agricultural environments, even in the absence of

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specific host plants. In addition to its impact on cultivated species, this pest is also known to feed on various weeds (EPPO, 2009; Straten et al., 2011; Ögür et al., 2014; Polat et al., 2015). Moreover, the presence of plant residues remaining in production areas post-harvest plays a vital role in sustaining the pest's biology by offering essential habitats and protection from adverse climatic conditions (Tores et al., 2001). Furthermore, studies have shown that removing and properly disposing of leaves and other plant parts infested with *T. absoluta* can effectively reduce the incidence of damaged fruit (Estay, 2000; Illakwahhi and Sarivastava, 2017). Therefore, this study investigates the impact of plant residues left in the field after harvest in the tomato production areas of Muğla province on the adult population development of *T. absoluta*. The aim is to highlight the role of cultural practices in enhancing overall pest control efforts.

Material and Method

This study investigated the effects of tomato plant residues remaining in the field after harvest on the population growth of adult *T. absoluta* in open field tomato growing areas of Muğla province. The research was conducted in four different fields located in Çamköy (altitude: 177 m, 37.192312° N, 27.827447° E; altitude: 150 m, 37.195441° N, 27.795141° E, Milas, Muğla) and Kızlan (altitude: 20 m, 36.758438° N, 27.69291° E; altitude: 29 m, 36.761625° N, 27.678263° E, Datça, Muğla). Each study site included a tomato growing area with field cleaning, post-harvest tillage, and another area without these practices.

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In Çamköy, the treatments were applied on plots of 2 da each, while in Kızlan, they were used on plots of 7 da with cleaned crop residues and 10 da with uncleaned residues.

In the designated study areas, tomato seedlings were planted on 23.04.2015 in Çamköy and harvested between 2 July and 10 August 2015. In Kızlan, the seedlings were planted on 30.07.2016 and harvested between 18 October and 10 December 2016. The spatial distance between the fields for both treatments was 2 km in Çamköy and 6 km in Kızlan. All vegetation was retained throught the sampling period in fields where tomato plants and weeds were not removed after the harvest. In contrast, deep plowing was initially conducted in fields where vegetation was cleared post-hervest, followed by the collection and incineration of all remaining vegetation.

To follow *T. absoluta* adult population development, specially prepared 1 m long platforms were used in the middle of tomato growing areas; delta trap tables were placed 60 cm above the ground; 1 pheromone capsule (0.76 mg. E3, Z8, Z11-tetradecatrienyl acetate+0.04 mg E3, Z8-tetradecadienyl acetate, Chemtica Internacional, S.A., importer: SMC A.Ş., Turkey) were placed (Figure 1). According to the producer's recemmondation, pheromone capsules were replaced with new ones every eight weeks. The adults caught in the traps were counted weekly, the trap plate was cleaned and insect trapping gum (Polyisobutylene, SMC Blapi, Manufacturer: SMC İlaç Kimya Yapı San. ve Tic. A.Ş.) was applied.

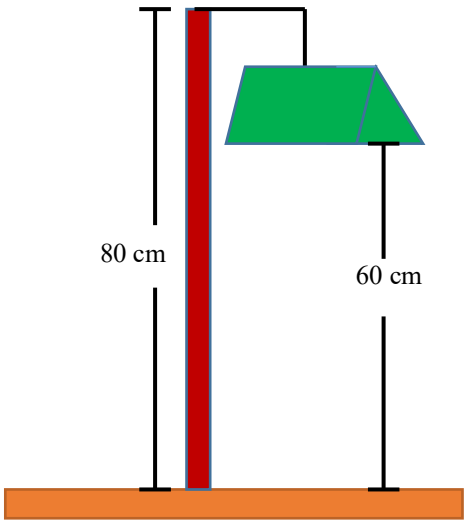

Figure 1. Trap used for monitoring *Tuta absoluta* adult population development

In Çamköy, traps were set on 26.10.2015 and adult sampling was carried out for 23 weeks. In Kızlan, traps were first set on 28.10.2016 and adult sampling was carried out for 22 weeks. The first sampling was carried out one week after trap installation (Çamköy: 2.11.2015, Kızlan: 3.11.2016) to monitor the development of the adult *T. absoluta* population. Trap counts were continued weekly and the number of adult individuals was recorded.

Data Analysis

A two-way factorial analysis of variance was conducted on the data, considering two factors: location (Çamköy and Kızlan) and treatment (with and without post-harvest cleaning). After the analysis of variance, if a statistical difference was identified between the factors, the difference between the means was assessed using an independent t-test. Logarithmic transformation was applied to the data before statical analysis, and the original data was presented in the evaluations.

Results and Discussion

The number of adult individuals of *T. absoluta* caught in pheromone traps were not statistically different between Çamköy and Kızlan (F: 0.903; df: 1; P: 0.345). However, the total mean number of *T. absoluta* in fields with and without post-harvest cleaning were statistically different (F: 9.371; df: 1; P: 0.003). The interaction between the two factors (location x treatment) was not statistically significant (F: 0.042; df: 1; P: 0.837). The population growth of adult *T. absoluta* caught in pheromone traps during the sampling periods of 2015-2016 in Çamköy and 2016-2017 in Kızlan is shown in Figures 2 and 3.

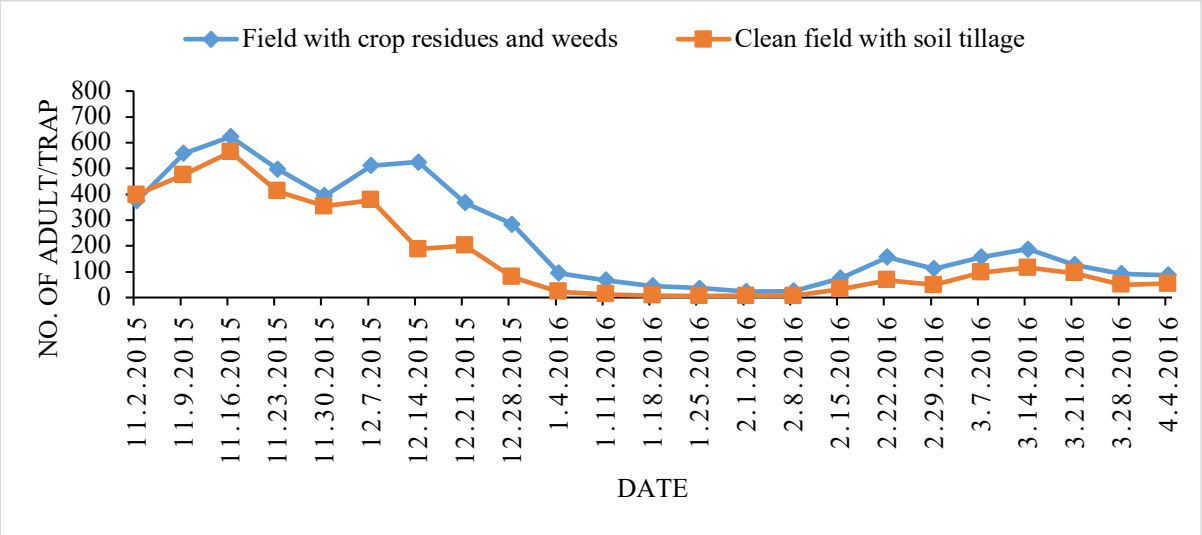

Figure 2. Population development of *Tuta absoluta* in a field with and without tomato plant residues and weeds in Çamköy (Milas, Muğla) between 2015 and 2016

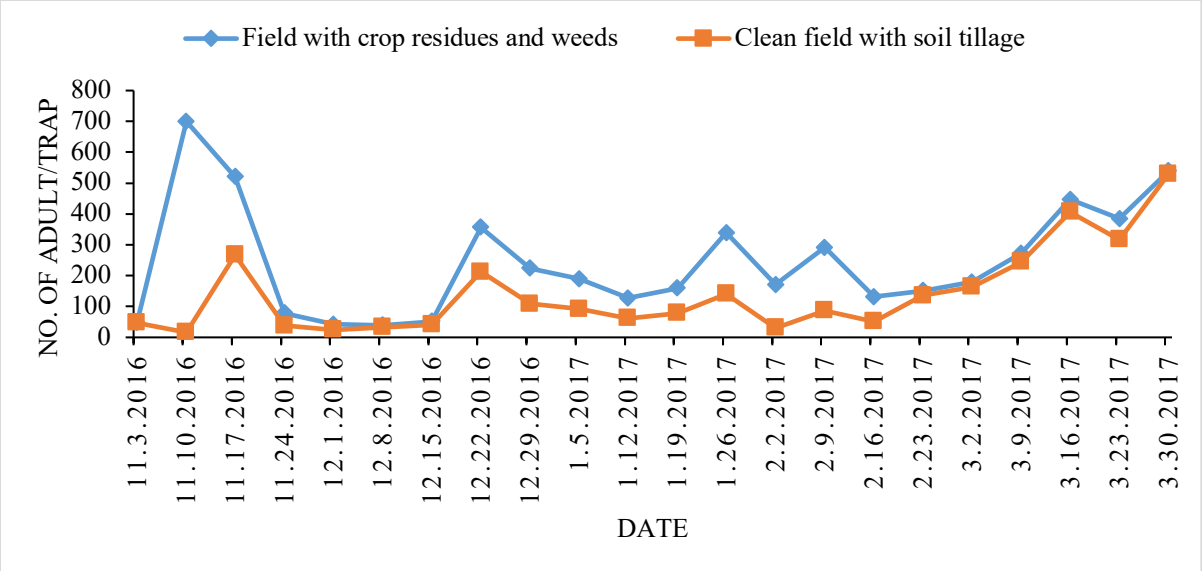

Figure 3. Population development of *Tuta absoluta* in a field with and without tomato plant residues and weeds in Kızlan (Datça, Muğla) between 2016-2017

Weekly sampling of adults trapped in the fields revealed that 3.670 *T. absoluta* adults were caught in Çamköy in fields with post-harvest cleaning and tillage, while 5.423 adults were captured in fields without these practices. Consequently, the total mean number of *T. absoluta* adults was 159.57 in the cleaned fields and 235.78 in the uncultivated fields. The difference between these means was statistically significant (t: 2.039; df: 44; P: 0.047).

In the field where cleaning and soil tillage were conducted after the harvest/production season, the lowest *T. absoluta* adult population was recorded at six adults/trap on 25.01.2016, and the highest adult population was recorded at 564 adults/trap on 16.11.2015. In the fields where no cleaning and tillage were performed after the harvest/production season, the lowest *T. absoluta* adult population was observed at 23 adults/trap on 01.02.2016 in Çamköy. In comprasion, the highest adult population was observed at 623 adults/trap on 16.11.2015 (Table 1).

Table 1. Highest and lowest *Tuta absoluta* adult densities and dates of occurrence in clean fields with harvest residues + weeds and tillage in Çamköy (Milas) and Kızlan (Datça)

Locations	Highest population				Lowest population			
	With harvest residue		Without harvest residue		With harvest residue		Without harvest residue	
	Date	No. of adults	Date	No. of adults	Date	No. of adults	Date	No. of adults
Çamköy	16.11.2015	623	16.11.2015	564	01.02.2016	23	25.01.2016	6
Kızlan	10.11.2016	700	30.3.2017	529	08.12.2016	39	10.11.2016	16

In Kızlan, another tomato growing area where sampling was conducted, a total of 3.127 and 5.440 *T. absoluta* adults were caught in the fields with and without post-harvest field cleaning and tillage, respectively. According to these results, the total mean number of adult individuals was 142.14 and 247.27, respectively, and the difference between the two means was statistically significant (t: 2.436; df: 42; P: 0.019). The lowest *T. absoluta* adult population was 16 adults/trap on 10.11.2016 and the highest adult population was 529 adults/trap on 30.3.2017. These tomato-growing areas were where field cleaning and tillage were done after the harvest/production season. In the growing areas where no field cleaning and tillage was done after the harvest/production season, the lowest *T. absoluta* adult population was 39 adults/trap on 08.12.2016 and the highest adult population was 700 adults/trap on 10.11.2016 (Table 1).

When evaluating the total *T. absoluta* population density in the context of fields with cleaned crop residues and fields with uncleaned crop residues, the statistical analysis revealed that the treatments in both locations showed similar results and were not statistically different based on location. When the treatments conducted in Çamköy and Kızlan were evaluated separately, the population density of adult *T. absoluta* was found to be statistically lower in the plots where crop residues had been removed. Based on these results, the population density of *T. absoluta* was found to be 47.77% and 73.97% higher in Çamköy and Kızlan, respectively, in the growing areas where field cleaning and tillage were not carried out during the production season/after

harvest than in the areas where cleaning and tillage were carried out.

In light of the findings from the study, a significant difference in *T. absoluta* population densities was observed between the two fields where post-harvest plant residues were removed and tillage practices were implemented, in contrast to the fields where these practices were not applied. Illakwahhi and Sarivastava (2017) reported that plant residues infested with *T. absoluta* in tomatos provide an important habitat for overwintering the pest and destroying.

These plant residues at the end of the cropping season have an important role in the control of *T. absoluta*. It has been reported that these processes can be executed through the incineration of plant residues, their burial in the soil, or by encasing them in an airtight manner using transparent plastic wrap, followed by exposure to elevated temperatures to facilitate their decomposition (Illakwahhi and Sarivastava (2017).

In the case of *Pectinophora gossypiella* (Saunders) (Lep.,: Gelechiidae), which shares similar biological characteristics with *T. absoluta* regarding overwintering, it was observed that removing plant stems and other residues after harvest in cotton production areas effectively reduced the pest population in the following season (Chu et al., 1996). Similarly, Attique et al. (2000) found that plowing post-harvest plant residues into cotton production areas reduced *P. gossypiella* adult population/emergence by 33% compared to leaving them on the soil surface. In addition to mixing the plant residues into the soil, it was reported that shredding them was more effective in reducing the adult population pest emergence. Estay (2000) reported that removing leaves infested with *T. absoluta* from the growing area greatly reducing the adult population.

Based on the results obtained from four relatively independent small tomato fields, it was concluded that removing and eradicating plant residues infested with *T. absoluta* significantly contributed to the reduction of the adult population of this pest in the subsequent growing season. It is hypothesized that a similar large-scale study focused on of removing plant residues across broader areas post-harvest will yield a comparable decrease in the adult population of *T. absoluta* in the following season. Furthermore, by integrating this method with other environmentally sustainable control strategies, it may be possible to achieve a more effective and sustainable management of *T. absoluta* (Başpınar et al., 2014).

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