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Research Article

Economic injury level and crop loss assessment of *Tuta absoluta* in open-field tomatoes in Western Iran

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Abstract: The tomato leafminer *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is an invasive pest of solanaceous crop plants, especially tomato, threatening worldwide tomato production. It has been a quarantine pest for Iran since 2010. However, it is now dispersed to all the main tomato production sites across the country. To assess crop loss and determine economic injury level (EIL), a field study was conducted in a 600 m^2 common research field for two consecutive years (2014-2015). Each tomato seedling (Super Strain B c.v.) was infested by different densities of the pest, including control, 1, 2, 4, and 8 tomato leafminer eggs in the first year and control, 2, 4, 8, and 16 leafminer eggs in the second year of study under cages. There was a significant relationship between the number of infested fruits and the number of leaf galleries made by tomato leafminer larvae. The EIL of tomato leafminer, according to the field experiments, was estimated to be 6.3 and 5.7 larvae/plant in 2014 and 2015, respectively. Evaluating the impact on crops and estimating the EIL are essential elements within a cost-efficient integrated pest management strategy, which provide practical tools for making informed decisions regarding the application of pesticides against *T. absoluta.*

Keywords: crop loss, decision making, tomato, South American tomato leafminer

Introduction

The South American tomato leafminer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae), has recently been regarded as one of the most damaging invasive pests of tomato plants around the world (Desneux *et al*., 2022). This species is deemed to have originated from South America (in 1964 from Chile; García and Espul, 1982), and it has now invaded more than 90 countries in the Afro-Euraisa continent (Mansour *et al*., 2018; Biondi *et al*., 2018; Han *et al*., 2019). Many of the main tomato production centers have also reported Tomato leafminer across more than twenty provinces of Iran (Baniameri and Cheraghian, 2012). This species has a short life cycle and high fecundity (about 60 to 200 eggs: Torres *et al*., 2001; Erdoghan and Babaroglu, 2014; Mohamed *et al*., 2022; Aslan and Birgucu, 2022); additionally, this pest produces as many as 260 eggs during increased

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female life span under favorable conditions (CABI, 2011). Tomato leafminer is a multivoltine species with nine generations reported in Italy (Sannino and Espinosa, 2010) and 13 per year in Spain (Aznar *et al*., 2010). However, different values have been reported for generation times depending on tomato cultivar and temperatures (Barrientos *et al*., 1998; Gharekhani and Salek-Ebrahimi, 2014; Rostami *et al*., 2017; Cherif and Verheggen, 2019; Poudel and Karuna, 2021; Kumari *et al*., 2021; Pandey *et al*., 2023).

The South American tomato leafminer strongly prefers tomato as a host plant. Although, this pest exhibits an expanded host range, encompassing secondary hosts such as eggplant, potato, pepper, tobacco, and even wild solanaceous plants (Vargas, 1970; García and Espul, 1982; Colomo *et al*., 2002; Pereyra and Sanchez, 2006; Desneux *et al*., 2010; Cuthbertson *et al*., 2013; Kalleshwaraswamy *et al*., 2015). Control of this pest primarily relies on chemical control; besides undesirable environmental hazards, it has recently developed a high resistance to the most commonly applied insecticides (Roditakis *et al*., 2018; Guedes *et al*., 2019). Therefore, it is recommended that the insecticides be utilized conscientiously as part of a holistic approach i.e. integrated pest management (IPM) (Mumford and Knight, 1997; Cuthbertson and Murchie, 2005; Cuthbertson, 2020). The keystone of a cost-effective IPM concept is reliable economic decision levels, which are an essential prerequisite for developing integrated control programs (Turnbull and Chant, 1961; Smith, 1969; Pedigo *et al*., 2021). Economic decision levels have been divided into economic (Action) threshold (ET) and economic injury levels (EIL) (Dent, 2000; Pedigo *et al*., 2021). EIL outlines the minimum number of pest individuals that will cause economic damage and is expressed as the number of insect pests per plant, sampling, or per area unit (Dent, 2000; Pedigo *et al*., 2021). The overall aim of developing economic decision levels is to reduce the number of pesticide applications.

Several studies have been carried out on the development of economic injury levels for various lepidopteran species (Tanskii *et al*., 1976; Hopkins *et al*., 1982; Rote *et al*., 1984; Bautista *et al*., 1984; Mamedova *et al*., 1990; Torres-vila *et al*., 2003; Zahid *et al*., 2008; Jaramillo-Barrios *et al*., 2020). However, few studies estimate decision-making levels for leaf mining pests, which may be assigned to their cryptic lifestyle and feeding habits. In Iran, Jemsi (2006) conducted a study in Khuzestan Province to determine the economic threshold of *Syringopais temperatella* Led (Lep.: Elachistidae), a pest that causes leaf mining damage on wheat. The study was conducted between 1999 and 2000 and between 2003 and 2004. A more closely related study investigated the yield loss of *T. absoluta* on six commercial potato cultivars in Ardabil province (Iran). Ghaderi *et al*. (2019) also estimated economic injury level and crop loss assessment for *T. absoluta* on different tomato cultivars.

To assess crop losses, different criteria, for example, the number of living galleries and larvae per plant, the number of galleries per leaf, the dry weight of aerial parts and tubers or fruits, and their percentage of dry weight loss can be used (Fathi and Behroo-Benamar, 2015). Considering the knowledge gap in this area, the current study aimed to establish a direct link between *T. absoluta* densities and damage caused in open-field tomato crops in a research station in Iran. This study will be the cornerstone for developing EIL and reducing unnecessary and excessive pesticide applications. It is crucial to emphasize that this study stands out as a pioneering field investigation in Iran (Fathi and Behroo-Benamar, 2015; Ghaderi *et al*., 2019). It encompasses a wide-ranging scope and employs a comprehensive methodology to assess the economic consequences stemming from the presence of the tomato minnow moth. Through previous research conducted in Iran, this study not only enhances our comprehension of the subject but also provides a significant background for future investigations into the economic ramifications caused by this specific pest. Moreover, it expands the existing knowledge base, paving the way for subsequent scholarly inquiries in this study area.

Materials and Methods

Experimental procedure

The study was conducted in the research field (ca. 600 m^2) of Bu-Ali Sina University, Hamedan Province, Iran (30.2" 01' 30° North and 42.7" 30' 48° East; 1730 meters above sea level) during two growing seasons of 2014 and 2015.

The experiment was carried out in a complete randomized block design with five treatments (different numbers) of *T. absoltua* eggs. Each treatment had four replicates (Rostami *et al*., 2021). The treatments included 0, 1, 2, 4, and 8 tomato leafminer eggs/host plant in the first year of study and 0, 2, 4, 8, and 16 eggs/tomato plant during the second year. Each plot consisted of three rows transplanted by six-host seedlings (Super Strain B c.v.) (Collectively 18 seedlings per plot). The distance between different tillage rows and between tomato seedlings on each row was set as 75 and 40 cm, respectively (The planting distances were set following recommended agricultural practices in the region). To prevent interplant movement of pest individuals, adjacent rows in each plot were separated by 1.5 m (The selected distance was chosen following the standard conditions of the region). All necessary farming practices, like plowing, seedlings, and weeding, were carried out according to the common practices of the local farmers. The amount of chemical fertilizer used was also determined according to preliminary soil fertility tests and local formal recommendations (Pooya Kesht Co®). Accordingly, NPK fertilizer (20-20-20) was applied (The timing and amount of fertilizer application followed the standard conditions of the region. NPK fertilizer was used after planting, before flowering, after flowering, and early during fruiting, 1-1.5 kg/1000 Lit water). No additional chemicals against any invertebrate pests or disease agents were applied.

Tomato seedlings (Super Strain B c.v.) were transplanted on the 21st of May in both years of study. After one month, the seedlings were confined in ventilated wooden cages (3 × 2 × 1.5 m, length × width × height), which excluded all other herbivores or natural enemies from entering (Rostami *et al*., 2021). Weeds were controlled mechanically every week as necessary. In both years, the artificial infestation was carried out on the 12th of July (50 days after transplanting the seedlings). To provide the cohort eggs, *T. absoluta* moths were reared on tomato (Super Strain B c.v.) seedlings in the growth chamber at 27 ± 1 °C, 70 ± 5% R. H. and 16L: 8D-h, then the eggs (12-16 h.), were collected, transferred to the field and were placed onto tomato leaves (top, middle and bottom leaves of the plant) at a defined rate of infestation using a fine camel hairbrush.

Following egg hatching and the appearance of larval feeding, the number of larval galleries created in each whole plant was counted at weekly intervals and recorded on each sampling date.

The number of larval galleries was recorded cumulatively on each sampling date. In this study, the size of the galleries was not recorded, and only their number was counted weekly.

Furthermore, ripened fruits were harvested and weighed using a scale (with a precision of 0.01 g) on each sampling date. Additionally, the length and width of fruits were measured using a caliper. The number of infested fruits (Showing symptoms of *T. absoulta* feeding) was recorded on each sampling date. Each plant and cage was labeled with a unique number, allowing us to track and record the quantity of fruit obtained from each plant and cage.

Data analysis

One-way analysis of variance (ANOVA) was used to test for significant differences in the number of feeding galleries among different *T. absoluta* egg densities (SAS Institute Inc. 2013). Shapiro-Wilk and Levene's tests were used to check residual normality and homogeneity of variance in the data. Different transformation methods (logarithmic, square-root conversion, adding constant, Box-Cox, Johnson conversion) were used whenever the normality assumption was unmet. The number of galleries was analyzed using a non-parametric Kruskal-Wallis test.

Regression analysis was used to establish the relationship between the number of larval galleries and yield. Finally, the regression coefficient with the highest value of R^2 was selected to calculate EIL. The EIL was computed using Equation 1 (Pedigo and Rice, 2015)

$$EIL = C/VbK \qquad \text{(Equation 1)}$$

Where C is the cost of control method (chemical control here, the Evisect selected as a common insecticide against tomato leafminer) per area unit, V is the market value of crop per unit of production, b is the yield loss/insect, and K is the efficiency of the control method or expected reduction in potential injury (Pedigo and Rice, 2015). Over both years, the sampling dates in which the number of zero data recorded was high were eliminated to prevent an adverse influence on the mean. Duncan's multiple test was used to find the mean differences among treatments.

Results

The number of galleries created

During feeding, larvae start to mine the leaves and create galleries between the upper and lower layers of the leaf epidermis. During both years of study (2014 and 2015), after egg hatch, the galleries made within the leaves were counted weekly. Because counting the number of active and inactive mines is complicated, the number of all galleries was recorded cumulatively.

In 2014, there was no change in the number of galleries in the first three weeks after infestation. In other words, after investigating the shrubs, it was found that no galleries were created due to the feeding of pest larvae. This period seems necessary for eggs to hatch and for emerging symptoms of larval feeding. However, four weeks following hatching, there was an increasing trend in the number of galleries (up to 800 per block) created, which could be assigned to adult emergence and the start of oviposition. The galleries reached 7,000 between the seventh and the eighth sampling dates. After the eighth sampling date, the increasing slope smoothed to a mild (gentle) trend again. Here, the sudden increase may have been due to the egg-laying of the first-generation females or early leading females of the second generation (Fig. 1).

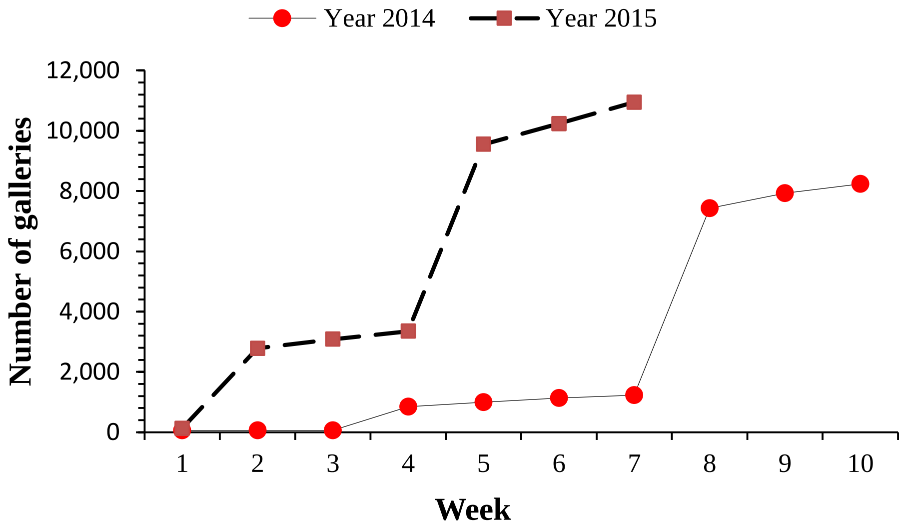

Figure 1 Fluctuations in *Tuta absoluta* on the number of galleries in 2014 and 2015. Date of infestation was 12th July in both years.

In the second year of study, the appearance pattern of galleries was the same as the previous year. However, considering the delay in starting the sampling compared with the year earlier, there was a sharp increase in pest density and number of galleries in the second week of sampling (22nd August 2015, about 2,700 galleries), but it was raised sharply between the 4th and 5th sampling dates with the number of galleries ranging from 3,300 to 9,500 (Fig. 1).

In both years, the effect of initial infestation levels on the number of galleries was significant (Kruskal-Wallis test, $P < 0.0001$) (Tables 1 and 2).

Table 1 The effect of initial pest density on the number of galleries in response to *Tuta absoluta* feeding (Year 2014).

Sampling date (Week)	Chi-Square	df	P-value
First	18.46	4	0.001
Second	18.46	4	0.001
Third	18.46	4	0.001
Fourth	18.42	4	0.001
Fifth	18.44	4	0.001
Sixth	18.42	4	0.001
Seventh	18.42	4	0.001
Eight	17.733	4	0.0014
Ninth	18.21	4	0.0011
Tenth	18.42	4	0.001

Table 2 The effect of initial pest density on the number of galleries in response to *Tuta absoluta* feeding (Year 2015).

Sampling date (Week)	Chi-Square	df	P-value
First	18.43	4	0.001
Second	18.42	4	0.001
Third	18.42	4	0.001
Fourth	18.42	4	0.001
Fifth	17.51	4	0.0015
Sixth	17.73	4	0.0014
Seventh	17.56	4	0.0015

The EIL of tomato leafminer according to the number, weight, and percentage of infested fruits

The relationship between the number of galleries as a criterion of larval injury and the weight of infested tomato fruits was not significantly regressed. Thus, we used other yield loss components instead. In both years of study, the effect of different infestation levels on the mean weight of infested fruits proved significant (Table 3).

To calculate an EIL, tomato leafminer densities were established as the independent variable, while the number and percentage of tomato fruits were considered as the dependent variable. As the number of tomato leafminer larvae could not be estimated accurately, the number of galleries made by *T. absoluta* larvae was selected instead as a criterion for estimating the number of larvae. Notably, each tomato larva mines two galleries during its premature life span (Rostami, *unpublished data*).

Accordingly, there was a significant regression between number of galleries and percentage of infested fruits in 2014 and 2015, and it was calculated as $Y = 0.002\ x + 12.113$ ($R^2 = 0.50$) and $Y = 0.002\ x + 13.158$ ($R^2 = 0.51$) respectively (Fig. 2).

According to Equation 1, to set up an economic injury level of tomato leafminer, it is necessary to estimate the cost of the management strategy first. As previously outlined, the major control methods used for *T. absoulta* are chemical-based and have highly variable costs, depending on the price of insecticides and associated labor costs. Considering the use of Evisect insecticide (50% suspension) in the region to deal with *T. absoulta*, its price was included as an evaluation factor in this research.

The cost of chemical control for each hectare of tomatoes includes the cost of pesticides at the recommended dose plus the cost of spraying (labor costs and spray equipment). The amount of insecticide used per hectare of tomato field was 800 g (the cost per 100 g of insecticide was \$8.5. The labor cost per person for an average working day is \$12 (on average, three persons are required to spray one hectare of tomato field). In addition, according to conventional sprayings, a 400-liter tank is necessary to spray a one-hectare tomato field, which costs approximately $9.5 as of 2016.

The denominator of EIL equation includes the market value, damage per insect, and the efficiency of the control method. The price of one kilogram of tomato in the wholesale market (fruit and berry field) in 2014 showed that each kilogram of high-quality tomato was $0.17 on average. It has been assumed that using chemicals reduced the damage by 90 percent, and therefore, K was set at 0.9 in Equation 1.

According to Equation 1, the EIL of tomato leafminer could be calculated as 371830.06 galleries per hectare based on the number of infested fruits in 2014. Considering that each tomato leafminer larvae during its larval period mined two galleries, the EIL in the year 2014 is 185915,03 larvae per hectare, and considering the average number of bushes per hectare (approximately 30,000 bushes), the EIL is calculated as 6.1 larvae/tomato host plant.

In 2015, tomatoes were reduced to $0.13 per kg, and the loss per insect coefficient was estimated at 0.003 (Fig. 2). In total, the EIL value was determined as 5.7 larvae /plant.

Table 3 Mean comparison (mean ± SE) of the weight of infested fruits (kg) of tomato in response to different *Tuta absoluta* egg densities (Years 2014 and 2015).

Treatment (egg density per plant) 2014	Weight of infested fruit (2014)	Treatment (egg density per plant) 2015	Weight of infested fruit (2015)
Control (0)	0 ^{d}	Control (0)	0 ^{d}
1	71.05 ± 3.37 ^{a}	2	34.41 ± 2.17 ^{c}
2	66.38 ± 4.49 ^{bc}	4	53.72 ± 3.61 ^{a}
4	67.97 ± 3.36 ^{ab}	8	44.79 ± 3.34 ^{b}
8	62.29 ± 2.88 ^{c}	16	41.81 ± 2.11 ^{bc}

Means with different letters in each column are significantly different, Duncan's Multiple Range Test ($P < 0.05$).

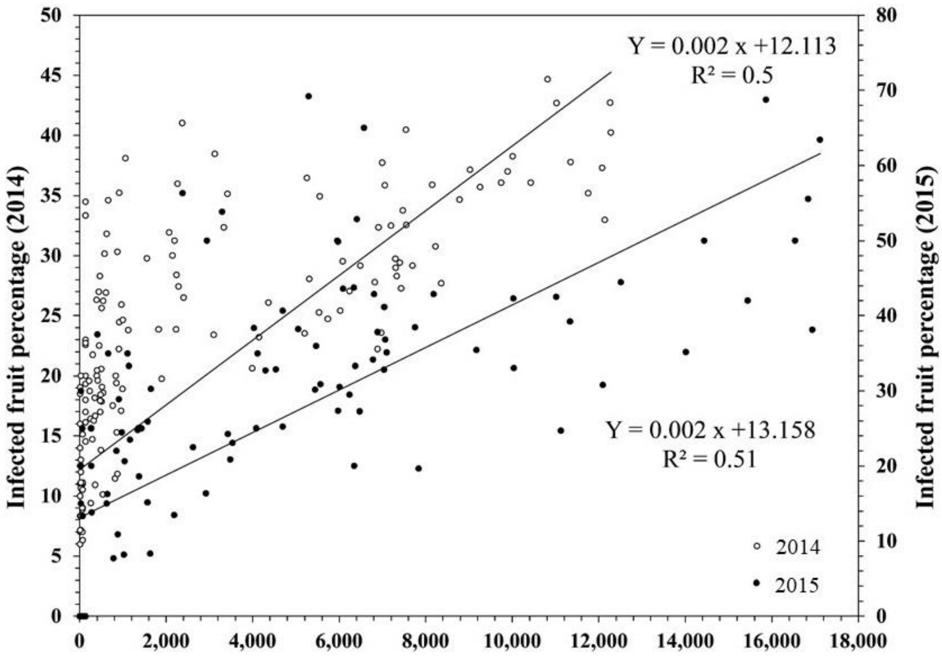

Figure 2 The regression relationship between the number of galleries and the percentage of infested fruits in 2014 and 2015.

As the yield loss per insect coefficient in terms of infested fruit percentage was the same as the number of infested fruits, the repetition of calculations was avoided.

$$\text{EIL} = \frac{C}{V.b.K}$$

$$\text{EIL} = \frac{68.57+35.71+9.5}{0.17\times0.002\times0.9}$$

EIL = 371830.06 number of galleries using the number of infested fruits in 2014

$$\text{EIL} = \frac{76.19+35.71+9.5}{0.13\times0.003\times0.9}$$

EIL = 345868.95 number of galleries using the number of infested fruits in 2015

Discussion

This study determined the economic injury level using the relation between the number of galleries as an index of pest density and the number of infested fruits in two consecutive years. Most studies have used the weight of infested fruits or yield loss to determine a yield loss-pest density relationship (Shiberu and Getu, 2018; Ghaderi *et al*., 2019). However, because *T. absoluta* reduces marketable yield and quality of harvestable products, it is possible to use other yield loss criteria significantly related to larval densities. Accordingly, the number and percentage of infested fruits were used to estimate the EIL. It has been shown to positively relate to the density of tomato leafminer galleries in both years.

Different EIL values have been estimated for *T. absoluta* on tomatoes, ranging from 3.82 larvae per plant (Shiberu and Getu, 2018) to 5.44 larvae/plant (Ghaderi *et al*., 2019), which are very similar to obtained results of the current study. However, Pena (1986) reported the EIL value of *T. absoluta* as less than one larvae per plant (0.67 larvae /plant).

Their inheritable traits determine the ability of plants to withstand insect infestations. These traits play a crucial role in implementing integrated pest management strategies as they help diminish the insect population and the damage they impose on crops (Williams *et al*., 2017; Guruswamy *et al*., 2023). Plants have displayed varying degrees of resistance to arthropods over time. Different plants have been known to employ four mechanisms to defend against these creatures: antixenosis, antibiosis, tolerance, and Escape (Williams *et al*., 2017; Guruswamy *et al*., 2023). Antixenosis resistance mechanism displayed as preventing and deterring herbivores from colonizing them by various strategies. These strategies can include the development of non-preferred colors, hair or bristles, fragrance, unappealing taste, and other deterrent factors. (Li *et al*., 2004). Antibiosis encompasses the hostile consequences inflicted by the host plant on the development and reproductive ability of insect pests, potentially culminating in the pests' fatality (Stout, 2013). The factors discussed can impact the economic injury level in various plant varieties.

The EIL values obtained in this research indicate that economic damage will occur under the conditions in our study in 2015 (including costs of chemical control, market value of tomatoes, and environmental factors) when the density of tomato leafminer goes beyond 5.7 larvae per plant. Therefore, management strategies should be implemented at this point.

It is obvious that EIL value is highly dynamic i.e. it is estimated under specific conditions of the given tomato production site. For example, in this study, Evisect was selected as the most common insecticide used against *T. absoluta* in the region. At the same time, other pesticides may be preferred or more readily available in other tomato production areas. In addition, market values, tomato varieties, climatic and agronomical conditions, pest strain and labor costs all influence decision levels.

Other studies investigating crop loss assessment and pest populations of South American tomato moth have shown that plants exposed to 6 to 10 insects were the most affected (27 to 43%), with the damage being estimated to be between 45% and 100%. The densities of 6 to 10 insects resulted in the loss of the plant buds compared to other pest densities. Plant height, number of internodes, number of leaves, and number of fruits in different densities showed that the leafminer significantly causes damage when the number of insects reaches more than two adults per plant (Cely *et al*., 2010). The highest leaf area loss was observed in the insect density treatments 10. The comparison of the number of internodes in the control treatment and treatment with the highest density was significantly different. However, there was no significant difference between the control treatment and the density of 10 insects regarding vegetative variables. In all treatments, larval feeding killed the terminal bud and increased the possibility of producing new inflorescences.

For this reason, densities of less than ten pest individuals were selected for further investigation (Cely *et al*., 2010). When the plant density is high, the stems and fruits will be attacked, along with damage to the leaves. More than 100 larvae per plant have been shown to increase the contamination of stems and fruits (Cely *et al*., 2010). The number of healthy fruits and fruits decreases with increasing pest density, so the highest number of infested fruits was observed at 6 to 10 adult females. At a high density of more than 100 larvae per plant, the damage rate was reported between 55 to 100%. Reducing the number of fruits due to pest infestation could be assigned to feeding larvae on flowering organs, reducing fruit and yield production. The larvae may also feed on ovaries, reducing the number of fruits. However, Marcano (1995) stated that heavy consumption of leaf mesophyll and vegetative tissue and the percentage removal of leaves are responsible for yield reduction incurred by *T. absoluta*.

To establish a relationship between the number of larvae on each host plant and the number of galleries counted, we should know the number of galleries made by each larva during its life span. As was noticed earlier, each tomato leafminer larva mines two galleries during the premature period. Furthermore, it has been stated that second-instar larvae of *T. absoluta* often move out of the corridors in the early morning hours and form new galleries (Coelho *et al*., 1984; Haji *et al*., 1988; Torres *et al.*, 2001).

Using tomato weight to estimate a pest population-yield loss relationship may create difficulties. For instance, in some cases, the weight or size of the fruit was acceptable, while a tiny hole created due to pest feeding opened the way for saprophytic rot fungi to invade and significantly reduce the marketable value of the product. Consequently, the critical value of more than two insects per plant can cause a great loss to the product, even if the fruit weight and plant growth characteristics are unchanged.

Other studies have considered the relationship between number of galleries made by tomato leafminer larvae and the number of damaged fruits (Balzan and Moonene, 2012). Here, it was demonstrated that the harvesting period and weather conditions are crucial for damage occurrence.

Regarding the feeding behavior and resulting damage, the level of economic damage by *T. absoluta* was evaluated based on the weight and number of infested fruits. The results of the number of infested fruits in evaluating economic injury level seem more logical because the pest damage did not significantly reduce the yield. Still, in marketing terms, even a small hole caused by larvae on the fruit leads to discarding the product and reducing its desirability.

Conclusion

In conclusion, this study provides valuable insights into the relationship between *T. absoluta* pest density and yield loss in open-field tomato production. The findings underscore the significance of proactive pest management strategies to mitigate yield losses and enhance crop productivity. By employing appropriate pest control measures and conducting further research, growers can effectively combat the detrimental effects of *T. absoluta* infestations and ensure sustainable tomato production.

Conflict of Interests

The Authors state that there is no conflict of interest.

Authors' Contributions
Elahe Rostami: Investigation, Data Curation, Visualization, Formal analysis, Writing-Original Draft
Hossein Madadi: Conceptualization, Resources, Writing-Review & Editing, Supervision, Project administration, Funding acquisition
Habib Abbasipour: Writing-Review & Editing, Project administration Peng Han: Writing-Review & Editing

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سطح زیان اقتصادی و ارزیابی خسارت شب‌پره مینوز گوجه‌فرنگي *Tuta absoluta* درشرایط صحرایی غرب ایران

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چکیده: شب‌پره مینوز گوجه‌فرنگي *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) یکي از آفات مخرب گوجه‌فرنگي و بومي آمریکاي جنوبي مي‌باشد که درحال حاضر تولید گوجه‌فرنگی در سراسر جهان را مورد تهدید جدی قرار داده است. *T. absoluta* در سال ۱۳۸۹ به‌عنوان یک آفت قرنطینه‌ای در ایران معرفی شد، اما اکنون در تمامی مراکز اصلی تولید گوجه‌فرنگی در سراسر کشور پراکنده شده است. به‌منظور ارزیابی خسارت و تعیین سطح زیان اقتصادي شب‌پره مینوز گوجه‌فرنگي مطالعه صحرایی در وسعتی حدود ۶۰۰ مترمربع در سال‌های ۱۳۹۳ و ۱۳۹۴ انجام شد. این آزمایش در قالب طرح بلوک کامل تصادفي با چهار تکرار و پنج تیمار شامل شاهد (بدون آلودگي تخم)، ۱، ۲، ۴ و ۸ تخم به‌ازاي هر بوته در سال اول و شاهد (بدون آلودگي تخم)، ۲،۴، ۸ و ۱۶ تخم به‌ازاي هر بوته در سال دوم در زیر قفس انجام شد. نتایج تجزیه‌وتحلیل رگرسیون خطی بین تعداد میوه‌های آلوده و تعداد دالان‌های ایجاد شده توسط آفت رابطه معنی‌داری را نشان داد. براساس نتایج به‌دست آمده سطح زیان اقتصادی محاسبه شده در دو سال متوالی به‌ترتیب ۶/۳ و ۵/۷ لارو به‌ازای هر بوته برآورد شد. ارزیابی اثر آفت روی عملکرد محصول و سطح زیان اقتصادی آفت، عناصر ضروری یک راهبرد مقرون به‌صرفه مدیریت تلفیقی آفات است. این یافته‌ها، فراهم‌کننده ابزار مؤثری برای تصمیم‌سازی زمان کاربرد آفت‌کش‌ها علیه شب‌پره مینوز گوجه‌فرنگی می‌تواند باشد.

واژگان کلیدی: کاهش عملکرد، تصمیم‌سازی، گوجه‌فرنگی، شب‌پره مینوز