Ukrainian Journal of Ecology

Ukrainian Journal of Ecology, 2021, 11(1), 409-414, doi: 10.15421/2021_59

ORIGINAL ARTICLE

Development, reproduction, and distribution of the South American tomato moth (*Tuta absoluta* Meyr.) in Ukraine

T.V. Bilousova[1], L.V. Humeniuk[1], M.M. Dolya[1], P.Yu. Drozd[1], S.V. Stankevych[2*], I.V. Zabrodina[2], A.V. Matsyura[3], L.V. Nemerytska[4], I.A. Zhuravska[4]

[1]National University of Life and Environmental Sciences of Ukraine, Kyiv, 03041, Ukraine
[2]V.V. Dokuchaiev Kharkiv National Agrarian University, v. Dokuchaevske, Kharkiv region, 62483, Ukraine
[3] Altai State University, Barnaul, Russian Federation
[4]Zhytomyr Agricultural College, Zhytomyr, 10031, Ukraine
**Corresponding author E-mail: sergejstankevich1986@gmail.com*
Received: 29.01.2021. Accepted 03.03.2021

Under current tomato cultivation conditions, measures aimed at preventing the development, reproduction, and distribution of the quarantine species of the South American tomato moth *Tuta absoluta* Meyr. in the steppe of Ukraine have been studied. Regional indicators on the distribution and peculiarities of biology and ecology of the South American tomato moth are estimated, both in importing tomatoes to Ukraine and in the use of modern technologies, mainly the range of insecticides, taking into account the organogenesis of cultivated plants. It specified the areas of new territories of moth reproduction by seasonal monitoring of the quarantine pest species development, considering the impact of globalization processes, changes in weather and climatic factors, and new ecosystems. We have determined biology and ecology indicators that affect the pest's acclimatization and occupation of new ecological niches in the structure of local species that affect tomatoes' yield and quality. Simultaneously, we have determined predictors for predicting the South American tomato moth's development and reproduction under the modern effectiveness of phytophage control measures at the species and population levels. The resistance of individual tomato varieties to *Tuta absoluta* was studied. The guidelines for determining the degree of phytophage colonization of tomatoes at the main stages of yield formation in vegetable crop rotations under relatively long reproduction and survival and a high pest population in the research region were developed. We have noted the importance of assessing the impact of rising air temperature on the duration of the autumn period of tomato growth and development and changes in moths' ecological optimum and pest spread in individual farms of the steppe zone. According to the population density indicators of this species, it was specified the mechanisms of tomato entomological community formation, taking into account the first years of localization of the South American moth foci. We have specified quarantine measures of phytophage control, both by the South American tomato moth phenology levels and the impact of agricultural background and weather fluctuations on moths number of generations, number, and survival rate these pests in the Ukrainian Steppe.
Key words: plant quarantine, South American tomato moth, monitoring, pheromones, number, generation, distribution, development, reproduction, varieties.

Introduction

The origin site of the tomato moth is South America. Today, it is widespread in many regions (Fig. 1).

For the first time in Ukraine, the South American tomato moth was discovered in 2010 in tomatoes from Turkey (most part) and Syria. So, foci of the pest were observed in the Autonomous Republic of Crimea and Odessa region. The colonized tomatoes' areas were in the open ground and greenhouse farms (Bashinska et al., 2009; Desneux et al., 2010).

In 2012, a quarantine moth was found in the Kherson region on 79 hectares, and in 2011 in the Mykolaiv region. In 2018, for the first time, the quarantine regime by the degree of discovering of the South American tomato moths was introduced in the Zaporizhzhia region in Huliaipole, Melitopol, and Kamenka-Dniprovsky districts on a total area of 52.7 hectares. In recent years, new pest foci have been identified in the Skadovsky district and for the first time in the Bilozersky and Holopristansky districts of the Kherson region. The quarantine regime has been introduced on 83.95 hectares. As of 01.01.2020, the total area of colonization was more than 1040 hectares (Fig. 2).

According to the State Service of Ukraine on Food Safety and Consumer Protection and monitored nightshade plantations concerning the pest, it was noted further spread of moths in Ukraine (Stankevych, 2017).

Fig. 1. The world's area of *Tuta absoluta*

Following the International standard for phytosanitary measures – International Financial Reporting Standards (IFRS) No. 8 "Determining the status of a harmful organism in the zone," the South American tomato moth meets the status of "present pest" by all criteria. The tomato moth is a quarantine species, which status is "Present: only in certain soil and climatic zones of Ukraine" and is assigned to the A-2 List of quarantine organisms that have limited spreading in Ukraine (Section "Insects"), List of regulated harmful organisms (Fedorenko et al., 2012; Stankevych & Zabrodina, 2016, 2020; Stankevych, 2020; Stankevych et al., 2020).

It is characteristic that the intensive distribution of this species in the steppe of Ukraine indicates a gradual "softening" of the climate, as well as the possible emergence of new pest generations that have adapted to the natural conditions of the south-eastern regions of Ukraine and morpho-physiological condition of zoned tomato varieties in the summer-autumn growing season.

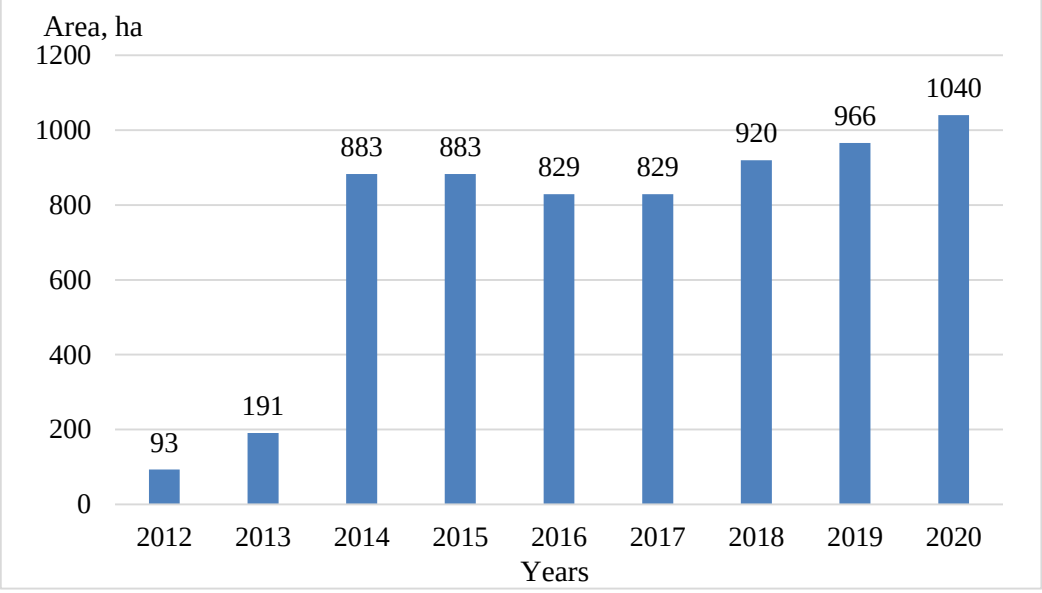

Fig. 2. Dynamics of distribution of the South American tomato moth (Ukraine, 2012-2020).

The primary host plants of the South American tomato moth (*Tuta absoluta* Meyr.) are tomatoes. In addition to them, the moth damages other plant species from the nightshade family (*Solanaceae*): eggplant, potatoes, peppers, tobacco, and wild nightshades such as datura, nightshade, and boxthorn (Stankevych et al., 2021).

It is characteristic that the pest can destroy from 60 % to 100 % of tomato yield quickly. In South America, it is considered one of the essential tomatoes' pests, both under field conditions and in greenhouses. In Spain, a year after the first detection (in 2007) due to damage caused by the caterpillars of *T. absoluta* Meyr. during the winter months, almost 100 % of tomato yield losses were recorded. The damage caused by caterpillars to tomato fruits resulting from pest feeding poses a potential threat to all tomatoes and other nightshades producers.

Material and methods

Observation of the nutrition features of the South American tomato moth on nightshade crops and development (from egg to imago) (fig. 2) was conducted on tomatoes in the village of Mygia, Pervomaisk district, Mykolaiv region in 2020 (Chernij & Chajka, 1987; Chernij, 1990; Chajka & Chernij, 1992; Chernij et al., 1996; Chernij, 2008).

A)  B) 

Fig. 3. South American tomato moth (*Tuta absoluta*). A) butterfly; B) damage to tomatoes by caterpillars (author's photo)

The analysis of the South American tomato moth's phytosanitary risk and the current state of its distribution in Ukraine and the world was carried out according to the State Service of Ukraine on Food Safety and Consumer Protection.
We used the pheromone traps for monitoring of the South American tomato moth according to generally accepted methods (table 2) (Chernij & Chajka, 1987; Quaqlia, 1988; Chernij, 1990; Chajka & Chernij, 1992; Chernij et al., 1996; Chernij, 2008; Melnichenko, Lazko, Korma & Krupenik, 2011; Mityushev, 2019).

Table 1. The technology of using pheromone traps to detect butterflies of the South American tomato moth

Foci detection			Ascertainment of foci boundaries			Terms of development observation
term	norms	selection order	term	norms	selection order	
the I decade of April-October	One trap per 1-5 ha – in the field; One1 trap per 250m^2 – greenhouse; male vacuum – 20-40 traps per ha, One trap per 50 ha – greenhouse	in 7–10 days	April – November, all year round	One trap at a distance of 100 m, up to 1 km from the foci	in 7–10 days	when the average daily temperature reaches + 10 °C

Results

We determined that the caterpillars of *Tuta absoluta* Meyr. feed on almost all parts of tomato plants (except underground) and damage plants at all stages of their growth. They form large passages-mines on the leaves, gnaw out long passages in the stems and shoots, green and ripe fruits. With significant damage, especially under closed space conditions, the leaves wither, then dry up and fall off. When the caterpillars damage fruits, pathogenic fungi quickly get into them, and tomatoes quickly lose their quality and marketable appearance according to the following signs (table 2).
It is noted that when there is a lack of food, the caterpillars fall into diapause. The moth pupates in cocoons on the surface of leaves or mines in the soil. They overwinter at the stage of egg, pupal, or adult insect.
Peculiarities of the South American tomato moth biology, as well as the ability to intensive reproduction and adaptation, indicates a significant threat of the phytophage, as well as its acclimatization in Ukraine and, in particular, in crop rotations of vegetable crops in Zaporizhzhia, Kherson, Mykolaiv, Odessa, and other regions. Greenhouse farms in all soil and climatic zones of Ukraine where nightshade crops are grown, especially those that do not form seedlings themselves, but import them, as well as those that use containers that were previously used to transport imported tomatoes, are also at risk.
In Ukraine, loads of fresh tomatoes, eggplants, peppers, and planting material of plant feeders (seedlings, ornamental Solanaceae in pots) of imported origin are the main ways of penetration of the South American tomato moth to different regions.

Table 2. Signs of damage to tomatoes by the South American moth caterpillars

Part of tomato plants	Signs of damage
Fruits	Irregular (ugly) shape, presence of excrement, as well as internal passages, visible outlet, premature defoliation, size less than standard
Growing points (apex of the shoots)	Dry pith, ugly shape, visible excrement, signs of internal feeding, general depression.
Inflorescence	Signs of external and internal feeding, visible excrement, complete defoliation, or dropping of petals.
Leaves	Bended shape, signs of external feeding, visible excrement, leaf blades rolled or folded, the presence of necrotic areas
Stems	- Dry brown pith, distortion (bending, abnormal shape), signs of internal feeding, visible excrement, wilting, significant branching
Plant	Dry pith, distortion (bending, abnormal shape), deformation, rosettes, visible excrement, signs of internal feeding, weakened or withered plant.

In the Netherlands, *Tuta absoluta* has migrated to greenhouse farms with infected packaging material and containers, which were later used for yield packaging. This indicates that the migration of this pest to greenhouses is possible with fruits of imported origin. However, in the greenhouse, in case of pest penetration, it can be destroyed in 1-2 years by the method of freezing and changing the crop, and in the open ground, this must be done using modern monitoring and control methodologies with highly effective means of controlling the phytophage. As for the countries from which the pest can enter, first of all, quarantine measures should take place on moth-infested cargo. In 2018, specialists of phytosanitary laboratories across the country identified the South American tomato moth in tomatoes from Turkey (17 cases) and Spain (2 cases). In recent years, transit and re-export vegetables have been subject to phytosanitary control by state phytosanitary inspectors with sampling and conducting appropriate entomological examinations. Only after carrying out all the necessary procedures and obtaining the conclusion of a phytosanitary examination on the cargo's condition, imported vegetable products are recommended for import to specific territories of Ukraine.

We registered that depending on the natural and climatic conditions, the development of one generation of *T. absoluta* lasts 24-38 days. The minimum temperature required for the beginning of insect development is + 9 °C. 10-12 generations of *T. absoluta* can develop per year (for example, in Argentina, up to five). Active imago flight is observed at night, and during the day, butterflies migrate between the leaves of forage plants. Externally, butterflies are relatively small, with a wingspan of up to 10 mm. The wings' overall color is brownish-grey, with dark spots and strokes without stripes on the forewings. The moth has a high reproductive capacity. On average, the female lays about 250-260 eggs on the leaves' surface and stems of plants, mainly on the underside. Eggs are 0.22 × 0.36 mm in size, cylindrical, milky white to yellow. The caterpillars hatch in 4-5 days and bite into the fruits, leaves, or tomatoes' stems. There are four age-related stages of caterpillars. The caterpillar is milky white with a dark head, after some time becomes yellow-green, at the first age it is 0.6-1.5 mm long, the fourth–7-8 mm. It is cylindrical and has a typical feature – a light anterior thoracic shield, the posterior edge of brown or dark brown to black.

Considering the peculiarities of development and reproduction, modern quarantine measures include the use of new mixtures of insecticides according to monitoring indicators for the detection and threat from this type of pest. Over the years of research, the high efficiency of a new generation of insecticides has been established and allows pest control under new quarantine systems. Simultaneously, the complex of measures provides for pest control by indicators of agrocenosis formation using measures to control the number of phytophages by the terms of trophic relationships on tomatoes.

We determined that this type of pest threatens tomatoes throughout the entire period of growth and development. All parts of plants are attacked, and the soil is also the habitat of insects. Seedlings of plants that form in early spring attract pests that migrate after overwintering in this field and from other reservations. Damaged young plants are affected by the pathogen agents, which leads to the liquefaction of tomato crops. As the crop grows, foci of pest reproduction appear with the spread of tomato diseases.

For effective prevention of product losses, it is necessary phase-by-phase planned management of tomato organogenesis according to the system of quarantine measures and consistent implementation of a complex of agrotechnical measures aimed at increasing the resistance and productivity of plants, taking into account their impact on harmful organisms when using unique chemical methods for controlling the phytophage at all stages of its development. The quarantine measures system's conceptual model should include monitoring and forecasting moth development and reproduction based on biology and ecology and trophic relationships' peculiarities. Indicators on the phytosanitary condition of tomatoes, particularly formations of population, are of primary importance. It allows determining the optimal terms of chemical treatments; implementing quarantine measures on varieties that have a relatively long period of morpho-physiological development and yield formation in relatively late autumn months.

We found that this phytophage colonized tomato varieties with a relatively long phase of active growth and formation of fruit ovaries and their ripening by 42–71 % more compared to varieties of medium and early yield formation. We also registered that the phase of active growth of more than 50 days to 72 days contributed to the formation of an additional one generation of the phytophages, and during the ripening period, an increase in the number of daily periods of organogenesis from 90 to 110 days contributed to the formation of two generations of the phytophages under conditions of the observation area (table 3).

Table 3. Colonization of tomato varieties by the South American tomato moth (Mykolaiv region, Pervomaisk district, Mygia village, 2020)

Variety	Terms of generative organs formation, days	Colonized, %	
		plants of	tomatoes
Mobil	110	48	26
Yana	72	21	14
Rio Grande	50	17	6

We determined that the periods of fruit formation correlate with caterpillars' development, the intensity of their passage from the first to the third ages, the variety and technology of growing tomatoes. The factors that contribute to the relatively long growth and formation of tomato yield are accompanied by relatively intensive reproduction and survival of 4 and 5 generations; in 2020, this was detected from May to October 22. Such peculiarities of biology and ecology indicate the need to apply special quarantine protective measures with phase –by- phase insecticides application according to the following scheme: active substance acetamiprid-thiamethoxam-imidacloprid and adding the surfactants when caterpillars of I age appear at the stages of tomato organogenesis.

Conclusions

1. With the help of a phytosanitary survey of tomatoes in the Mykolaiv region, we determined the presence of the South American tomato moth *T. absoluta* on a total area of 17 hectares, the phytophages reproduce according to seasonal regularities and mechanisms of trophic relationships on tomatoes.
2. Comprehensive consideration and control of the problems of interaction of tomatoes entomological community with the quarantine type of pest and plants justify the combination of tasks of phytosanitary monitoring with a short-term forecast of moth spread, prediction, and analysis of foci and degree of survival, as well as the growth in dynamic indicators of formation of this species generation and control measures at the main stages of its development.
3. The most suitable variety for tomato moth colonization was the "Mobil," with a relatively long period of formation of generative organs, which should be considered in quarantine measures for terms and multiplicity of applications of chemical measures to control the phytophages.
4. To eliminate foci of the South American tomato moth, it is necessary to apply insecticides taking into account the duration of tomato development, which in the context of climate change is crucial in controlling the phytophage and yield preserving.

References

Bashinska, O.V. et al. (2009). Ilyustrovanij dovidnik regulovanih shkidlivih organizmiv v Ukrayini. Kiyiv: Urozhaj (in Ukrainian).

Chajka, V.N. & Chernij, A.M. (1992). K razrabotke koncepcii monitoringa vrednyh cheshuekrylyh s pomoshyu feromonov. Entomologicheskoe obozrenie, 4(71), 741–751. (in Russian).

Chernij, A.M. & Chajka, V.N. (1987). Biologicheskoe obosnovanie primeneniya feromonov v zashite rastenij. Informacionnyj byuleten VPS MOBB, 20, 37–45. (in Russian).

Chernij, A.M. (1990). Feromony nasekomyh – dostizheniya i perspektivy ispolzovaniya. Zashita rastenij (in Russian).

Chernij, A.M. et al. (1996). Evaluation of population suppression by sterile Lepidoptera individuals in Ukraine. First research co-ordination meeting within FAO/IAEA. Evaluation of population suppression by irradiated Lepidoptera and their progeny. Jakarta, Indonezia, 16-28 April 1995. Reproduced by the IAEA, Vienna, Austria, 98–109.

Chernij, A.M.(2008). Regulyatori zhittyediyalnosti komah. Kyiv: Kolobig (in Ukrainian).

Chuzherodnye vidy na territorii Rossii. Available from: http://www.sevin.ru/invasive/ (in Russian).

Desneux, N. et al. (2010). Biological invasion of European tomato crops by *Tuta absoluta*: ecology, geographic expansion and prospects for biological control. J. Pest Sci., 83, 197–215. DOI 10.1007/s10340-010-0321-6

European and Mediterranean Plant Protection Organization. Organisation Europeenne et Mediterraneenne pour la Protection des Plantes. Available from: https://www.eppo.int

Fedorenko, V.P. et al. (2012). Strategiya i taktika zahistu roslin. Vol. I. Strategiya. Kyiv, Alfa-steviya (in Ukrainian).

Fitosanitarni principi karantinu ta zahistu roslin i zastosuvannya fitosanitarnih zahodiv v mizhnarodnij torgivli (2006). Sekretariat Mizhnarodnoyi konvenciyi iz zahistu roslin; Mizhnarodni standarti z fitosanitarnogo zahistu. Rim, FAO, 1, 19 (in Ukrainian).

Golovna derzhavna fitosanitarna inspekciya. Available from: http://www. http://karantin.gov.ua/. (in Ukrainian).

Hendrix, W.H. & Showers, W.B. (1990). Evawers Evaluation of differently colored buket traps for blach cutworm and armyworm (Lepidoptera, Noctuidae). Entomol, 83, 2.

Melnichenko, L.I., Lazko, M.M., Korma, O.M. & Krupenik, M.F. (2011). Metodichni rekomendaciyi z provedennya feromonnogo naglyadu za deyakimi vidami regulovanih shkidlivih organizmiv. Chernigiv, Derzhavna inspekciya z karantinu roslin po Chernigivskij oblasti (in Ukrainian).

Mityushev, I.M. (2015). Feromony nasekomyh i ih primenenie v zashite rastenij. Moscow. RGAU-MSHA imeni K.A. Timiryazeva, 124 (in Russian).

Mityushev, I.M. (2019). Integrirovannye sistemy zashity rastenij: feromony nasekomyh. Moscow: Yurajt (in Russian).

Pro karantin roslin: Zakon Ukrayini No 3369-IV. Vidomosti Verhovnoyi Radi Ukrayini, 19−20, 167 (in Ukrainian).
Quaqlia, F. (1988). L'impieqo delle trappole eromotropiche nella difesa integrate delle colture: stato attuali e prospettive. Inf. Fitopatol, 38, 12, 11–17.
Stankevych, S.V. & Zabrodina, I.V. (2016). Monitoryng shkidnykiv silskogospodarskyh kultur. Harkiv, FOP Brovin O.V. (in Ukrainian).
Stankevych, S.V. & Zabrodina, I.V. (2020). Zovnishnij i vnutrishnij karantyn roslyn: rekomendaciyi do vivchennya disciplini. Harkiv, HNAU im. V.V. Dokuchayeva (in Ukrainian).
Stankevych, S.V. (2015). Upravlinnya chyselnistyu komah-fitofagiv: navch. posib. Harkiv, FOP Brovin O.V. (in Ukrainian).
Stankevych, S.V. (2017). Metody oglyadu ta ekspertyzy pidkarantynnyh materialiv. Harkiv, FOP Brovin O.V. (in Ukrainian).
Stankevych, S.V. (2020). Nazvy karantynnyh shkidlivih organizmiv Harkiv, HNAU im. V.V. Dokuchayeva (in Ukrainian).
Stankevych, S.V. et al. (2021). Karantynni organizmy (z osnovamy ekspertyzi pidkarantynnyh materialiv). Harkiv, FOP Brovin O.V. (in Ukrainian).
Stankevych S.V. et al. (2020). Monitoryng shkidnykiv i hvorob silskogospodarskyh kultur. Harkiv: FOP Brovin O.V. (in Ukrainian).
Stankevych, S.V., Biletskyj, Ye.M. & Zabrodina, I.V. et al. (2020). Cycle populations dynamics of harmful insects. Ukrainian Journal of Ecology, 10(3), 147–161.
Stankevych, S.V., Biletskyj, Ye.M. & Zabrodina, I.V. et al. (2020). Prognostication algorithms and predictability ranges of mass reproduction of harmful insects according to the method of nonliner dynamics. Ukrainian Journal of Ecology, 10(1), 37–42.
Stankevych, S.V., Biletskyj, Ye.M. & Zabrodina, I.V., et al. (2020). Prognostication in plant protection. Review of the past, present and future of nonliner dynamics method. Ukrainian Journal of Ecology, 10(4), 225–234.
Stankevych, S.V, Biletskyj, Ye.M. & Golovan, L.V. (2020). Polycyclic character, synchronism and nonlinearity of insect population dynamics and prognostication problem: monograph. Kharkiv, Publishing House I. Ivanchenko (in Ukrainian).

Citation:
Bilousova, T.V., Humeniuk, L.V., Dolya, M.M., Drozd, P.Yu., Stankevych, S.V., Zabrodina, I.V., Matsyura, A.V., Nemerytska, L.V., Zhuravska, I.A. (2021). Development, reproduction, and distribution of the South American tomato moth (*Tuta absoluta* Meyr.) in Ukraine. *Ukrainian Journal of Ecology, 11* (1), 409-414.