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Tuta Absoluta: The Invasive South American Tomato Pinworm

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Introduction

Invasive species represent a major threat to both natural and managed agricultural systems (Asplen *et al.*, 2015). Biological invasions have occurred for millennia, but increasing globalisation in the recent decades has led to a drastic upsurge in the diversity and magnitude of invasions of new areas by alien species; this is particularly true for invasive exotic invertebrates (Roques *et al.*, 2009). Such invasive species can reduce yields, increase costs of cultivation and result in increased dependence on synthetic pesticides in agro-ecosystems (Palumbo *et al.*, 2016), which, in turn, may disrupt the pre-existing integrated pest management (IPM) programmes. Moreover, the establishment of invasive exotic species has the potential to cause cascading ecological impacts that may extend into natural systems as well.

The South American tomato pinworm, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae), has been a key pest of tomato in South America since the 1950s, causing drastic yield losses of up to 100%, owing to its leaf-mining activity and through fruit infestation in tomatoes in open as well as greenhouse conditions. The status of *T. absoluta* completely changed following its invasion in Spain in 2006 and the steady spread across the Afro-Eurasian supercontinent as it shifted from a pest restricted to South America toward a principal threat to global tomato production (Desneux *et al.*, 2010; Campos *et al.*, 2017).

Tomato is one of the most widely cultivated commodities. As major tomato-producing regions of the world—notably China, Mexico and the United States—are at high risk of being invaded by *T. absoluta*, this article provides a thorough overview of current knowledge on the

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ecology, worldwide spread and management status of this invasive pest.

Life cycle, host range and nature of damage

Solanaceous species are the main host plants of *T. absoluta*, with tomato, potato and European black nightshade (*Solanum nigrum*) being the most suitable ones (Desneux *et al.*, 2010; Abbes *et al.*, 2016). However, it can oviposit (lay eggs) and develop on several plants belonging to the Amaranthaceae, Convolvulaceae, Fabaceae and Malvaceae families (Bawin *et al.*, 2016).

Females use plant volatiles for orientation toward host plants, and leaf contact is a key component for inducing oviposition; the latter is currently the major drawback for developing effective plant-less rearing methods (Bajonero and Parra, 2017). Eggs are yellow and laid individually by females in upper plant parts on young leaves, stems, or sepals (Cocco *et al.*, 2015). The larva feeds by mining the leaf mesophyll, thus producing a thin 'leaf mine'. At high densities, larvae penetrate axillary buds of young stems and/or tomato fruits by mining below sepals (Desneux *et al.*, 2010). Mature larvae usually drop to the soil where they produce a thin, silky cocoon to transform into pre-pupae and pupae. Adults of both genders are sexually active by the first day of emergence and both sexes are polygamous.

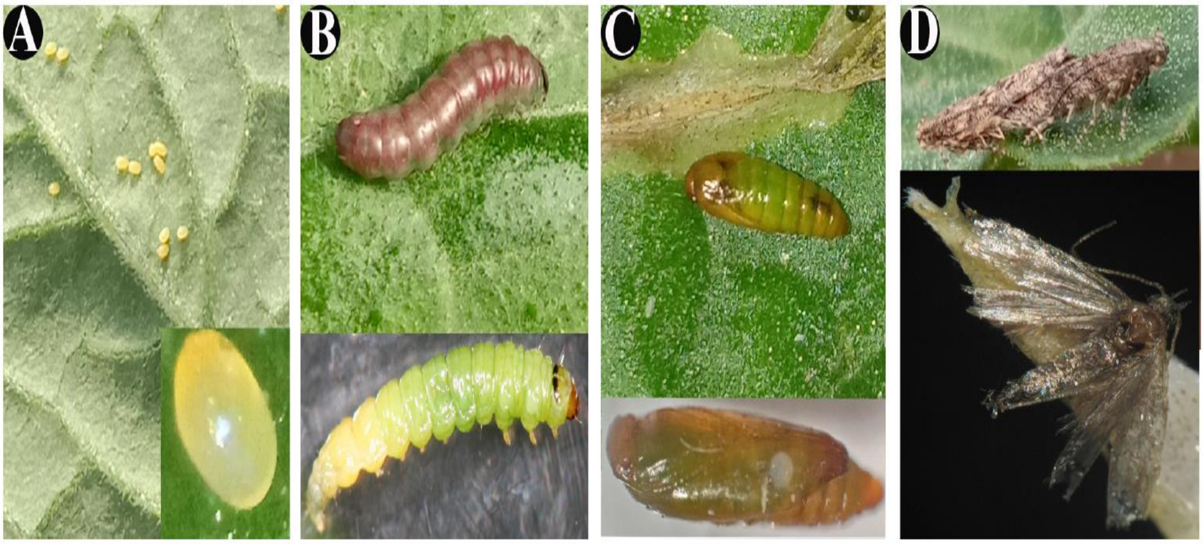

Fig. 1. Life stages of South American tomato pinworm (*Tuta absoluta*). A. Eggs, B. Larva, C. Pupa, D. Adult. (Source: Singh *et al.*, 2023)

The pest affects tomatoes produced for both fresh and processed markets, with larvae causing up to 100% losses in absence of implementation of management methods (Desneux *et* al., 2011). In addition, feeding activity on fruits directly affects the visual appeal of harvested products and increases costs of fruit post-harvest selection before marketing.

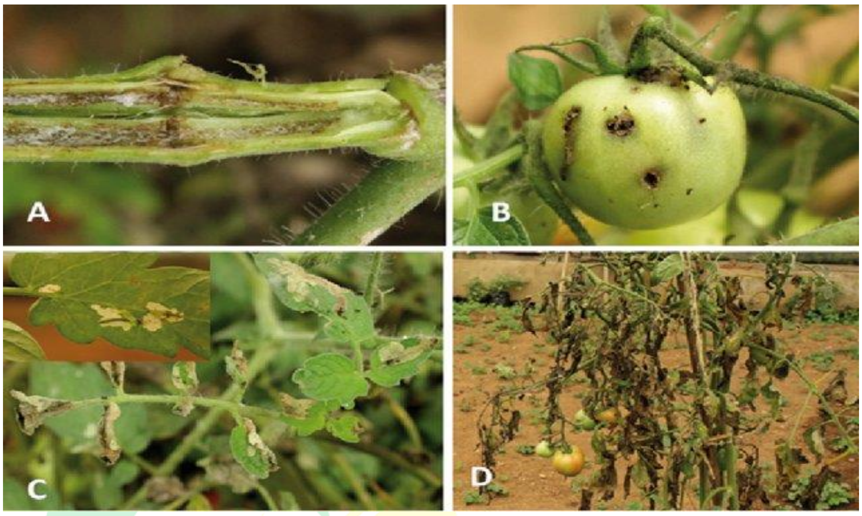

Fig. 2. Infestation of *Tuta absoluta* on tomato plants of the experimental farms at Umiam (Meghalaya state, India). A. Infested stem, B. Infested fruit, C. Infested leaves, D. Heavily infested plant. (Source: Sankarganesh *et al.*, 2017)

The optimal temperature for development of *T. absoluta* is 30°C and the duration of its life cycle varies from 26 to 75 days. Although no development or reproduction is reported to occur at low temperature (Cuthbertson *et al.*, 2013), *T. absoluta* shows cold tolerance, with 50% larval, pupal and adult survival at 0°C (for 11.1, 13.3 and 17.9 days, respectively) (Van Damme *et al.*, 2015).

Origin and spread of the pest

Tuta absoluta was initially described as native to the Central America, but recent hypotheses suggest that it originated in the Peruvian central highlands, spreading to the Latin American countries during the 1960s (Desneux *et al.*, 2011; Campos *et al.*, 2017). Being well-established as a key pest of tomato in South America for more than 50 years, *T. absoluta* was then detected in Spain in 2006 (138) and then rapidly spread across the Mediterranean coastal tomato-producing areas (Desneux *et al.*, 2010; Desneux *et al.*, 2011). Since then, the pest has spread at an average speed of 800 km per year, both eastward and southward.

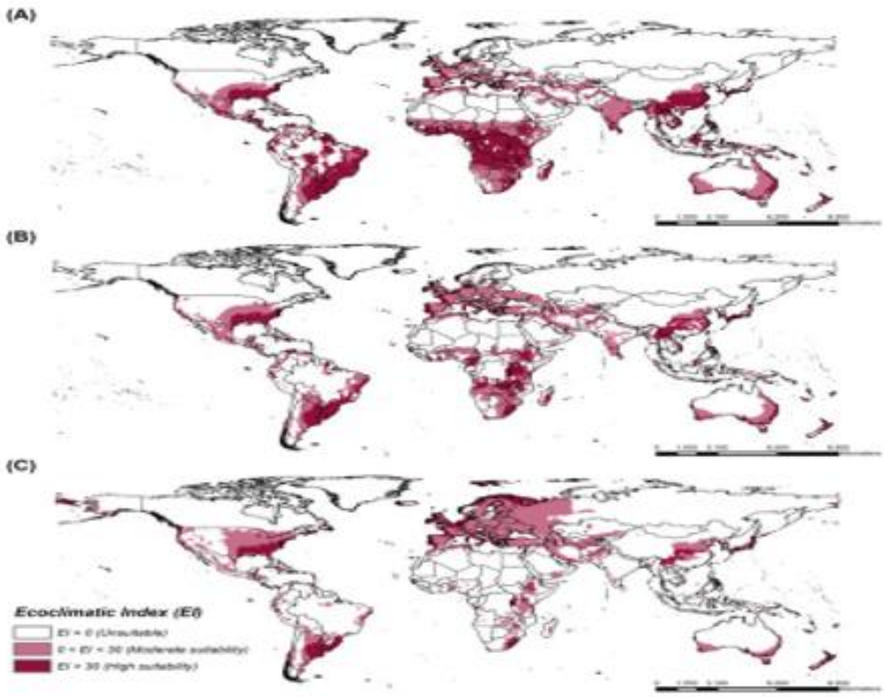

Fig. 3. The Ecoclimatic Index (EI) for *Tuta absoluta* modelled using CLIMEX in the (A) present time and CSIRO-Mk3.0 GCM running the SRES A2 scenario for (B) 2050 and (C) 2100. The projections show a decrease in suitability around the equator and an increase in suitability in northern Europe and Americas in 2050 and 2100. (Source: Santana *et al.*, 2019)

The rapid spread of *T. absoluta* over wide geographic areas may be a result of several factors such as its high biotic potential, the large range of its host plants (increasing its persistence in the cultivated areas and overwintering potential), the intra-continental dispersal facilitated by human transportation and the artificial selection of insecticide-resistant populations (Urbaneja *et al.*, 2012; Gontijo *et al.*, 2013; Campos *et al.*, 2015; Retta and Berhe, 2015). Furthermore, the absence of co-evolved natural enemies may elucidate why the pest population dynamics in the newly invaded areas are faster than in the native area, where natural enemies are more frequent (Desneux *et al.*, 2010).

Management of *Tuta absoluta*

The integrated pest management (IPM) strategies for the control of *T. absoluta* include the following:

a. ***Monitoring with pheromone traps:*** Pheromone traps can be used both for early

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detection and monitoring the infestation density of the pest. It can also help to reduce the population when used for mass trapping, in which case a higher number of traps need to be placed for higher captures. For monitoring purposes, the number of 10 traps per acre should be installed two weeks after transplanting, and the lures should be replaced at an interval of 30 days (Kumar *et al.*, 2020).

b. ***Biological control:*** *Nesidiocoris tenuis* (Miridae) is an efficient predator of eggs and small larvae of the pest. The application of *Trichogramma pretiosum*, an egg parasitoid, can reduce the population of *T. absoluta*, with a maximum control of 49% of the eggs. Therefore, it is suggested to combine with the application of a bio-insecticide based on *Bacillus thuringiensis*.

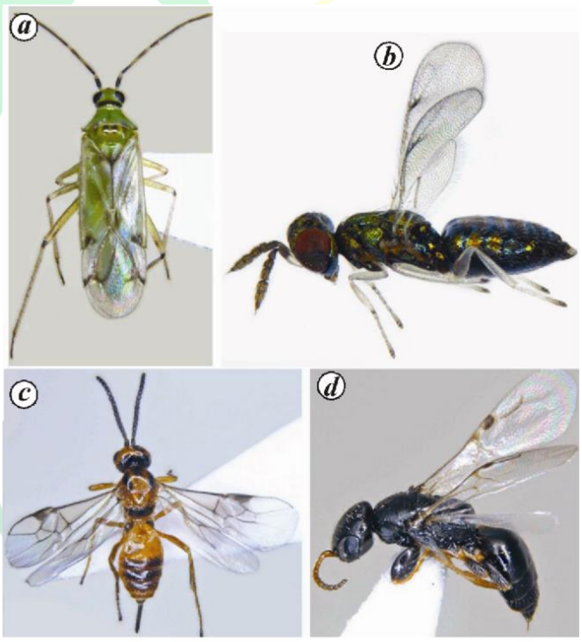

Fig. 4. Natural enemies of Tuta absoluta (Meyrick) a. Adult of *Nesidiocoris tenuis* Reuter, b. Female of *Neochrysocharis formosa* (Westwood), c. Female of *Habrobacon* sp., d. Female of *Goniozus* sp. (Source: Ballal *et al.*, 2016)

The use of neem oil (Azadirachtin 1500 ppm) @ 5 ml L^{-1} acts against low infestations of *Tuta absoluta* larva, when used on the tomato plant. The use of *Bacillus thuringensis* is recommended at low-medium infestation levels in combination with Azadirachtin. Spraying of *Bacillus thuringiensis kurstaki* @ 2 g L^{-1}, alternating with chemical insecticides, is recommended. Treatment module containing a combination of chemical insecticide and *Metarhizium anisopliae* @ 3 g L^{-1}, *i.e.*, 1×10^8 cfu/ g, has been proven beneficial in significantly reducing the percentage of mined leaves (Arpitha *et al.*, 2022).

c. ***Cultural practices:*** Good agricultural practices (GAPs) and IPM should always be part of a growers' practice for all types of pests and crops. GAPs for the control of *T. absoluta* include crop rotation with non-solanaceous crops (preferably cruciferous crops), summer ploughing, adequate irrigation and fertilisation, uprooting and destruction of infested plants, and complete removal of post-harvest plant debris and fruit. The removal of wild solanaceous host plants in the vicinity of the growing area is also encouraged, as these can host all stages of the pest which can then re-infect the growing crop.

d. ***Chemical control:*** The chemical control of the pest using pesticides is extremely difficult and quite challenging. Following reasons can be given to explain why their control using the chemical method is challenging:

i. The larvae show *entophytic feeding behaviour*, *i.e.*, they mine *within the plant tissue* (within stem, leaves and fruits) and are thus, protected from the contact insecticides (Öztemiz, 2013).

ii. The *large range of its host plants*, increasing its persistence in the cultivated areas and overwintering potential. Despite tomato being the primary host for *T. absoluta*, it has other hosts (cultivated and wild species of Solanaceae family).

iii. Their *ability to develop resistance towards insecticides* is another factor which makes their control quite challenging. Resistances of the pest to various chemical pesticides have been reported in Brazil, Chile and Argentina. The pest was reported to be resistant to dozens of insecticides including diamide insecticides like Chlorantraniliprole, Abamectin, Methamidophos and Permethricartap (Haddi *et al.*, 2012).

iv. They have *high reproduction potential*, *i.e.*, they are capable of producing 10 to 12 generations per year under favourable conditions. With such high reproduction potential, they are likely to undergo genetic changes (mutation) which, in turn, causes resistance to insecticides (Arnó and Gabarra, 2010).

Note: *The Insecticide Resistance Action Committee (IRAC) suggests that alternating insecticides by their mode of action (manner in which an insecticide kills an insect: effect on* *nervous system, stomach, respiration etc.) is more effective than alternating by active ingredient to delay the development of resistance.*

To control the pest effectively, it is essential to combine all the control measures available and not to rely only on insecticidal sprays. It is very important to pay attention to the side effects of insecticides on natural enemies, like predatory bugs, as they often have a slow establishment process. The insecticide(s) should be selected carefully, especially in the early growth stages of the crop. Need based application on novel insecticides like Cyzapyr 10 OD @ 1.8 ml L^{-1}, Rynaxpyr 20 SC @ 0.3 ml L^{-1}, Indoxacarb 14.5 SC @ 1 ml L^{-1}, Novaluron 10 EC @ 1.5 ml L^{-1} and λ-Cyhalothrin 2.5 EC @ 0.6 ml L^{-1} may be followed (Kumari *et al.*, 2021).

Conclusion

Tuta absoluta, native to the western Neotropics, is an invasive pest of the solanaceous plants. The pest incidence has increased from 3% to 60% of the worldwide tomato-cultivated

Fig. 5. Larva of *Tuta absoluta* inside tomato fruit. (Source: Hossain *et al.*, 2016)

area within only a decade, and currently represents the main long-term threat for the countries producing the most and third-most tomatoes (China and the United States, respectively) globally. Control strategies have historically relied on the widespread use of insecticides that have resulted in selection for insecticide resistance in many *T. absoluta* populations as well as in side effects on most of the non-target arthropods present in the tomato agro-ecosystems. Such increased insecticide use has disturbed pre-existing integrated pest management (IPM) programs in invaded areas, such as Europe. Biocontrol of *T. absoluta* has been developed, and it relies largely on the augmentation and conservation of predators and parasitoid complexes, and use of microbial organisms such as *Bacillus thuringiensis*. *Tuta absoluta* is involved in multiple direct and indirect (plant- and natural enemy-mediated) interactions with other insects and wild and cultivated plants, as well as endemic natural enemies. This highlights the need to revise the current control strategies in order to make them compatible with organic farming requirements and sustainable IPM modules.

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