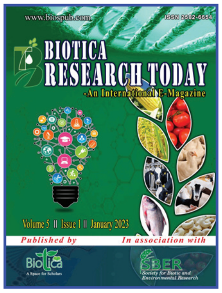

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Insecticidal Resistance Management Strategy of South American Tomato Pinworm, *Tuta absoluta* (Meyrick)

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Abstract

The South American tomato pinworm, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is difficult to manage this invasive pest. In particular in open field cultivation systems, insecticide treatment is still the most popular management strategy. As a result, both in South America and in Europe, pesticide resistance to several chemical types of insecticides has been documented. According to the chemical class, changed target-site sensitivity and/or increased detoxification are the key mechanisms causing the unusually quick development of pesticide resistance in this species. Low frequency resistance alleles are particularly concerning against newer chemistries since they have a propensity to spread along with invasions, making tomato pinworm very challenging to eradicate. To keep tomato pinworm infestations below economic damage thresholds and ensure sustainable yields, it is crucial to undertake integrated control programmes and suitable resistance management measures as part of such programmes.

Introduction

One of the most recent instances of such an invasive pest is the South American tomato pinworm, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae), which is of serious concern to tomato growers all over the world. According to initial descriptions from 1917, the native range of the tomato pinworm is the central highlands of Peru in western South America. Historically, only reports of tomato pinworm came from South America and Easter Island. Its current species designation of tomato pinworm is the result of a series of taxonomic modifications that occurred between the mid-1960 and the mid-1990. During this time, the species moved across South America, arriving in Brazil, the primary tomato-producing country in the area, in the early 1980. The pinworm, a species that is notoriously challenging to control, replaced other pest species of tomatoes in the area between the 1980 and the late 2000 (Biondi *et al.,* 2018).

The tomato pinworm infests young plants by tunneling its larvae into the buds of the plant stems. The leaf-mining larvae harm the leaves as the foliage expands, which impairs their capacity for photosynthesis. As the foliage grows, the leaf-mining larvae damage the leaves, reducing their ability to perform photosynthesis. Additionally, it has been documented that larvae attack tomato fruits, seriously reducing yields and crop grower. However, the only effective way of outbreak prevention was the application of insecticides. The performance of important chemical classes of insecticides was consequently impacted by the overuse of pesticides, which increased selection pressure. The tomato pinworm resistance monitoring demonstrated the fluidity of tomato pinworm resistance, altering with the insecticide use pattern. Resistance to organophosphate and pyrethroids pesticides was first discovered as a result of their early use, first in Chile and then in Brazil and Argentina. Pyrethroids resistance grew widespread at the beginning of the tomato pinworm invasion from South America and was probably transferred into Europe. Abamectin and cartap resistance was rapidly detected at low to moderate levels, and it gradually increased. While pyrethroids resistance fell to levels that were less than ten times as high. At the peak of their use in the mid-2000, field failure was caused by low-to-moderate levels of indoxacarb resistance as well as high resistance ratios to chitin biosynthesis inhibitors, according to later research. Spinosad was used more frequently and its resistance rose from low to high levels as a result of increased resistance to chitin biosynthesis inhibitors (Campos *et al.,* 2015). Therefore, it's essential to know the appropriate mechanism and effective management strategies of resistance against tomato pinworm.

Mechanisms of Insecticides Resistance

The most common mechanisms of insecticide resistance are as follows: (i) increased detoxification by metabolic enzymes like cytochrome P450s (CYP450), glutathione S-transferases, and esterases; (ii) target-site mutations by amino acid substitutions/ deletions leading to reduced sensitivity; and (iii) altered behavioural responses (iv) they reduced penetration, which are less common mechanisms (Feyereisen *et al.,* 2015). However, the most frequently observed defenses also present in tomato pinworm against a variety of chemical classes of pesticides are increased amounts of detoxification enzymes and changed target locations (Table 1).

Table 1: The major molecular mechanism of insecticides resistance authorized are listed here

IRAC MoA group	Mode of action	Chemical class or compound	Type of resistance	Major mechanism of resistance
1B	Acetylcholinesterase inhibitor	Organophosphates	Target-site mutation	A201S
			Metabolic	Esterase activity up
3A	Voltage-gated sodium channel modulator	Pyrethroids	Target-site mutation	M918T, T929I, L1014F
			Target-site mutation and Metabolic	M918T, T929I, L1014F
5	Nicotinic acetylcholine receptor modulator	Spinosyns	Metabolic	Esterase activity up
			Target-site mutation	G275E (α6-subunit)
			Target-site mutation	Exon deletion (α6-subunit)
6	Chloride channel activator	Avermectins	Unknown	Unknown
14	Nicotinic acetylcholine receptor blocker	Cartap	Unknown	Unknown
15	Chitin biosynthesis inhibitor	Benzoylureas	Unknown	Unknown
22A	Voltage-gated sodium channel blocker	Indoxacarb	Target-site mutation	F1845Y, V1848I
28	Ryanodine receptor modulator	Diamides	Target-site mutation	I4790 M/T, G4946E/V

Before the species was introduced to Europe, the first reports of pyrethroids resistance and control failure were noted in South America. Organophosphates were among the pesticides that failed to eliminate tomato pinwormin South America many years ago, but until this pest's invasion of Europe, the mechanisms giving resistance remained obscure. The acetylcholinesterase (ace1) gene's mutation A201S was found in two recent investigations on tomato pinworm resistance to organophosphates. Pyrethroids can also be broken down by detoxifying enzymes like esterases and CYP450s, although these processes don't seem to be very significant in tomato pinworm.

Insecticide Resistance Management (IRM) Strategy

Insecticide Resistance Management (IRM) approach needs to be proactive because if nothing is done to stop it, resistance is likely to emerge. The two components that make up the foundation of an IRM strategy are one that is more broadly intended to lessen selection pressure and one that is more specifically intended to prevent the selection of resistance mechanisms. The continued use of the same chemicals with the same modes of action over several generations selects for insecticide resistance.

Therefore, by reducing pest populations and maximizing insecticide use, the first element of an IRM approach is to lessen the selection pressure. Recommendations made by the Insecticide Resistance Action Committee (IRAC) for managing tomato pinworm resistance in a sustainable and efficient manner (IRAC, 2014). Major integrated control measures are mentioned here.

1. Prophylactic Measures

• To avoid pest carryover from previous crops, give as least six weeks between crop destruction and planting the following crop.

• Between planting cycles, cultivate the soil and solarize it or cover it with plastic mulch.

• Manage weeds to stop them from growing in other weed hosts (especially *Solanum*, *Datura*, and *Nicotiana*).

• Use transplants free of pests.

• Cover greenhouse with tomato pinworm appropriate, high-quality nets.

• Dispose of the damaged plant components.

2. Behaviour-based Measures

• Sticky traps should be installed before transplanting.

• Set up pheromone-baited traps to keep track of all tomato production phases, including nurseries, farms, packaging, processing, and distribution facilities, and begin keeping track two weeks prior to planting.

• Start mass moth trapping as soon as more than 3-4 moths trap^{-1} are caught each week.

• Use sticky traps or water + oil traps (20-40 traps ha^{-1}) baited with pheromone for moth mass capture.

• Following the removal of the crop, continue employing pheromone traps for at least 3 weeks to catch any surviving male moths.

3. Biological Measures

• Establish populations of effective biological control agents (*e.g.*, *Nesidiocoris tenuis*, *Necremnus*, *Trichogramma*, *Macrolophus*, *Pseudoapanteles*, *Podisus*, and *Nabis*/ *Metarhizium*).

• Optimizing the usage of insecticides. Check the crop for early indications of damage.

• Set up local thresholds to start pesticide spraying.

• Insecticides should be chosen based on their established local efficacy and selectivity.

• Use only pesticides approved for controlling tomato pinworm and always abide by the usage instructions provided on the product label.

• Keep population growth below the economic threshold.

Conclusion

The use of insecticides, and insecticide resistance as one of its principal effects, plays a significant role in determining the setting of communities and their organizational patterns. One of the potential effects of community stress brought on by insecticide use and resistance is bug outbreaks, especially secondary pest outbreaks. Curiously, the topic continues to be largely ignored, with the emphasis being placed on natural adversary assemblages while ignoring even their linked host complex. Finally, the development of the first resistance management programmes was made possible by the key facts on species genetics, population structure, and patterns and mechanisms of pesticide resistance. These programmes now need to be regionally tailored by local specialists. Therefore, the above mentioned information is useful to control the tomato pinworm effectively.

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