BREEDING FOR INSECT RESISTANCE IN TOMATO WITH REFERENCE TO *Tuta absoluta*

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Abstract

The tomato is susceptible to pest attacks that can lead to damages throughout the crop cycle. Pest control is carried out, mainly, by insecticide and chemical acaricide spraying. However, the use of chemical pest control can cause severe damage to the environment, biological imbalances and deleterious effects on farmers and consumer health, as well as increased production costs. An interesting alternative to minimizing the problems arising from the agrochemical application and maintaining pest populations below the economic damage level is the development of tomato plants displaying resistance to insect and arachnid pests. In this context, the main purpose of this chapter is to provide a review of the techniques applied in this regard, major progresses to date and future prospects for tomato pest-resistance breeding. This chapter is divided into five sections: (1) wild pest resistant tomato species, (2) Wild genotypes of tomato trichomes (3) allelochemicals that confer pest resistance, (4) Leaf trichomes (5) overview, problem and future thrust for pest-resistant tomato breeding

Introduction

Tuta absoluta (Lepidoptera: Gelechiidae) is an emerging pest on tomato in different countries causing up to 100% crop loss (Desneux et al., 2010; Sridhar et al., 2015). Total reliance on insecticides for its management results in resistance development apart from residues (Rakha et al., 2017). Wild relatives of tomato are known for insect resistance source (Oliveira et al., 2009) and generally associated with the presence of different trichome types and densities (Tissier, 2012). Glandular trichomes (GT) synthesize and store secondary metabolites (Schilmiller et al., 2010). The diversity of trichome types and chemical composition among tomato species respond differently against herbivore attack in conferring resistance (Rakha et al., 2017) to *T. absoluta*. The objective of this study is to assess cultivated and wild tomato genotypes for resistance to *T. absoluta* and identification of mechanism involved

In tomato plants, the female adults lay eggs on all above ground part of the plant (leaves, shoots and flowers as well on the fruits). Despite the clear preference of this insect on tomato species, it also affects common bean, potato, egg plant and tobacco. It also has been using weeds as an alternative host such as; *Lycium chilense, Solanum nigrum* and *Datura stramonium ; Datura ferox* and *Nicotiana glauca.* Tomato leaf minor is one of the major devastating pests of processing and fresh tomatoes, both in greenhouse and open field. *Tuta absoluta* larvae can absolutely destroy the tomato canopy by excavating the leaves, stems and buds; and burrows into fruits causing the quality decline of fresh tomato and yield loss that range from 50% to 100%. Because of its biology and behaviour this insect is hard to control. Chemical control methods have been trusted, but the feeding habits of the larvae, the increasing number of resistant strains of this pest, together with the negative impact of the chemical into the environment makes the chemical control method not sustainable.

METHODOLOGY

To identify the relevant scientific literature related to *Tuta absoluta* host plant suitability, all terms potentially related to these words were listed. These terms were then included in a single query, as follows: ("*Tuta absoluta*" "*Phthorimaea absoluta*" "*Gnorimoschema absoluta*" "*Scrobipalpula absoluta*" "*Scrobipalpuloides absoluta*" "tomato leafminer" "tomato borer" "tomato pinworm" "tomato leaf miner" "South American tomato pinworm") and (plant / variety / cultivar) and (oviposition/ location / development / life cycle / fitness/ life history trait). The composed terms were placed between quotation marks so that the entire term was considered.

HOST PLANT SUITABILITY

The main host of *T. absoluta* is cultivated tomato: the global fitness of this insect species is higher on this particular host compared to other plant species, according to all laboratory experiments performed to date (Negi et al., 2018; Cherif et al., 2019). Nevertheless, many Solanaceae species allow *T. absoluta* feeding, development and reproduction. Numerous studies highlighted the suitability of potato (*S. tuberosum*), eggplant (*S. melongena*), and pepino (*S. muricatum*) for *T. absoluta* development.

Garcia & Espul (1982) showed that *T. absoluta* was able to complete its development on some wild Solanaceae species including *S. nigrum, S. elaeagnifolium, Lycopersicum puberulum, Datura ferox, D. stramonium* and *Nicotiana glauca*. In particular, the tomato leafminer showed the ability to overwinter, yet at low population density, on winter potato and *S. nigrum* (Cocco et al., 2015).

Pest-resistant wild tomato species

The cultivated tomato *Solanum lycopersicum* L. comprises several wild species, with which it has greater or less inter specific cross-compatibility These species are native to regions located along the western South America coast, encompassing mainly the Andes in Ecuador, Peru and northern Chile, as well as the Galapagos Islands. Thus, these are species that have developed in a variety of habitats, from 2 Recent Advances in Tomato Breeding and Production sea level in the Pacific Coast to 3300 m of altitude in the Andean mountains of Ecuador, in climates that range from arid to rainy. Genetic diversity between species is expressed through different morphological, physiological and sexual characteristics. It is very probable that Andean geography, with its diverse ecological habitats and different climates, contributed significantly to tomato diversity. Wild tomato species are valued for use in breeding programs because they present resistance genes to pests, phytopathogens and abiotic stresses, as well as higher nutritional quality. During evolution, wild plants underwent selection pressure in order to survive and guarantee their reproduction in their center of origin conditions, developing resistance mechanisms against the most adverse conditions present in their natural environment. The following wild species display resistance to pest insects and arachnids: *S. pennellii*, *S. habrochaites* var. *hirsutum* e var. *glabratum*, *S. galapagense*, *S. peruvianum*, *S. pimpinellifolium*, *S. cheesmaniae* and *S. chmielewskii*. Research has demonstrated the efficiency of these species in the transmission of genes that express certain desirable characteristics, such as the production of glandular trichomes that, in most cases, exude chemical compounds, called allelochemicals.

Significant Role of Wild Genotypes of Tomato Trichomes for *Tuta Absoluta* Resistance

The objective of this resistance was to screen wild tomato accession and identify resistance mechanism against *T. absoluta.* Sixteen wild tomato accessions from six species were tested in two experiments. The tested parameters were damaged leaf area, oviposition rate, emerged larvae, adult and larvae survival, larvae and adult preference.

Those parameters were correlated with the density of each trichome type and with LC-MS data. From no-choice test parameters accession LA1777, LA1718 and LA716 were the most resistant and LA1401 and LA1139 were the most susceptible, and all *S. lycopersicum* accessions were susceptible. From choice test, the accessions G1.1561, LA1718, LA716, LA1645, LA0483 and LA1408 were not preferred by the larvae, and the accessions LA1777 and G1.1561 were the least preferred by the adults. The accession LA1777 and LA716 were out of the most resistance. The resistance of this genotype was related to the presence of trichome Type I and IV.

Allelochemicals

Allelochemicals are natural chemicals mainly present in higher plants that act as nutritional, antinutritional, herbal, medicinal and pest- and disease-resistance factors. The chemical substances responsible for plant resistance to pest insects and arachnids can be classified into three categories: substances that act on pest behavior (glycosides, alkaloids, terpenes, phenols and essential oils); those that act on pest metabolism, such as secondary metabolites (including some alkaloids and quinones, among others); and antimetabolites, which make essential nutrients unavailable to pests, causing nutritional imbalances. The most important allelochemicals found in wild tomato species are acyl sugars, sesquiterpenes and methyl ketones. Acyl sugars (AA), such as acylglycosis and acylsucrose are found in *S. pennellii* and *S. galapagense* accession leaf trichomes. Sesquiterpenes, mainly zingiberene (ZGB), are found in *S. habrochaites* var. *hirsutum* accessions, while methyl ketone, 2-tridecanone (2-TD), is found in *S. habrochaites* var. *glabratum* accessions.

Leaf trichomes

The *Solanum* genus presents seven types of trichomes. Their classification is based on the length of the trichome, the presence or absence of the gland at the apical end and the number of cells that make up the gland, when present. Trichomes are classified into two types, non glandular trichomes (II, III, V), which are quite similar to each other, differing only in length, and glandular trichomes (I, IV, VI, VII), capitated, with the head, in most cases acting as the allelochemical secretory region. Wild tomato accessions display an abundance of type I, IV and VI trichomes. In contrast, cultivated tomato display mostly type V trichomes, with the rare presence of types I and VI. On the other hand, types I, IV and VI, due to the presence of allelochemicals, are considered to be of major importance in pest resistance. Trichomes, besides acting as chemical barriers, can also act as physical barriers, limiting pest insect and arachnid access to the plant surface, due to trichome density and length.

Importance of tomato trichomes for *T. absoluta* resistance

Correlation between trichomes I, IV and V with resistance (oviposition rate and larva survival) was noticed. Trichomes are epidermal structures that originate from the epidermal cells of above ground plant tissue, have been implicated in protection against various biotic and biotic attacks, extreme temperature and excessive light. As well, the glandular trichomes are an important source of essential oils, i.e., natural fragrance or products that can be used by the pharmaceutical industry and most of these substances involved in plant defence to herbivorous. The diversity of trichome types and chemical composition among tomato species made different species of tomato respond in a different way against herbivore attack. For instance, it was reported that wild tomato accessions with a high density

of trichome type IV (*i.e. S. habrochaites, S. pennellii, S. galapagense*) are resistant to silver leaf whitefly. Glandular trichomes are the major sites of different phytochemical production that prevents herbivore attack than non-glandular trichromes. Although a negative correlation between glandular trichome Type, I and IV with the oviposition rate and the larva survival was observed, not all the accessions with trichomes type IV, or I was resistant

Problems in breeding for *Tuta absoluta* resistance

- It is a long term process.
- Sometimes, breeding for resistance to one pest leads to the susceptibility to another pest.
- Chances of linkage between desirable & undesirable genes.
- It is the expensive and difficult method.
- In some cases resistant variety has lower yield and poor quality.

Future thrust

- Need to identify the mechanism of resistance to *Tuta absoluta* other than the trichome densities and secondary metabolites.
- There is need to Identify novel genes with different mechanisms of resistance and pyramid such genes to get resistance
- Have to use the advanced breeding methodology to identify the mechanism of insect resistance.

Conclusion

The devastating invasion of *Tuta absoluta* represents a significant biosecurity threat that affects majority of livelihoods dependent on agriculture. The adoption of genetically resistant plant materials is one of the main strategies for pest management in sustainable tomato crops, in which the use of pesticides should be reduced or mitigated due to their adverse effects on environment and human health. A large number of biochemical and morphological characteristics have been related to tomato resistance to several key and secondary pests. The introgression of genes from wild species has shown to be the main strategy for tomato breeding programmes.

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