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Review Article

Updated List of Host Plants of *Tuta absoluta* (Meyrick, 1917) (Lepidoptera: Gelechiidae) with Reference to Romania

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Abstract: The tomato leafminer *Tuta absoluta* is one of the worst invaders affecting vegetable crops. This pest initially fed only on tomato, but since the species started to spread into new territories, new hosts have been reported. Our work summarises the recent accessible published data and presents lists of the host plant species of *T. absoluta* worldwide, identifying potential hosts for Romania. In total, plants belonging to 11 families, 27 genera and 64 species, including one species of Monocots clade, were found as hosts of *T. absoluta* in the available literature. Most of those species (40) are weeds and/ or wild plants. Of all plant species reported in literature, 33 are found in Romania. Of them, 16 are cultivated plants and 17 are wild plants. Our results indicate that all these plants may serve as potential hosts of *T. absoluta* in Romania. Updated knowledge about this new host range of *T. absoluta* is crucial for the plant phytosanitary key actors to organise better the national inspections and surveys and to provide accurate information about the cultural control recommendations to farmers.

Key words: *Tuta absoluta*, host plants, wild plants, biodiversity, Romania.

Introduction

New alien pests have spread rapidly in Europe, causing losses of billion euros (BRADSHAW et al. 2016). The rate of establishment of alien insects has doubled in the last decades, reaching 19.6 species per year for 2000–2008 (ROQUES et al. 2010). The tomato leafminer *Tuta absoluta* (Meyrick, 1917) (Lepidoptera: Gelechiidae) is considered today one of the worst arthropod invasive species, with huge impact on tomato production worldwide (DESNEUX et al. 2010, 2011, CAMPOS et al. 2017, BIONDI et al. 2018). The larvae attack the tomato plants during all growth stages; immediately after hatching, the young larvae feed mainly on leaf mesophyll but also

on plant axillary buds, young shoots, new growths, as well as on developing and mature fruits (DESNEUX et al. 2010, CHERIF & VERHEGGEN 2019).

The pest attacks all tomato varieties but some cultivars tend to be less attractive (PROFFIT et al. 2011, CHERIF & VERHEGGEN 2019). Some alternative host plants allow *T. absoluta* to survive in many habitats in the absence of tomato crops, due to its high ecological plasticity and demonstrated high reproductive fitness (ABBES et al. 2016). This fact is important both for the improvement of the control methods and for the pest eradication. It is expected that the number of plant species as alternative hosts will increase in the near future (PORTAKALDALI et al. 2013, CHERIF & VERHEGGEN 2019). Due to the

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high economic importance, the intensive research has resulted in quick development of alternative control methods and successful integrated pest management schemes for the tomato and some other crops belonging to the family Solanaceae, especially the indoor crops (FERRACINI et al. 2012, OUARDI et al. 2012, CAMPOS et al. 2017, BIONDI et al. 2018, HOGEA 2020).

In the context of climate changes, the biodiversity implications of the presence and spread of *T. absoluta* is still unknown. GALARZA (1984) was one of the first authors who tested 15 species of the family Solanaceae and found out that *T. absoluta* may develop on alternative hosts. Of those, at that time, *T. absoluta* did not lay eggs on six species – *Salpichroa origanifolia*, *Datura ferox*, *Physalis viscosa*, *Portulaca oleracea*, *Chenopodium album* and *Amaranthus quitensis*. However, 30 years later, some of these species have been documented as host plants (GARCIA & ESPUL 1982, PORTAKALDALI et al. 2013, SALAS GERVAISSIO et al. 2016). The larvae of *T. absoluta* are able to complete their development to the adult stage on the other nine species mentioned by GALARZA (1984): the tomato, potato, eggplants, tobacco, *Solanum gracilius*, *S. bonariense*, *S. elaeagnifolium*, *S. sisymbriifolium* and *S. pseudocapsicum*. Currently, on the EPPO Global Database website, 24 host plants are listed, of which one is considered as a major host, nine as minor hosts and 14 are weeds (EPPO 2020). A recent review on *T. absoluta* has assessed the host suitability of 26 species of the family Solanaceae and showed that there is no oviposition on 14 of them. The same study has evaluated 18 plant species belonging to eight other families; on four of them, no oviposition has been observed (CHERIF & VERHEGGEN 2019).

In Romania, the available data on *T. absoluta* is extremely poor. The first occurrence of this pest dated back to 2009 and reported from Botoşani and Maramureş counties by LEAOTĂ (2009), and from Bihor, Arad, Ilfov and Mureş counties by CEAN & DOBRIN (2009). All reports of the pest species were exclusively on tomatoes in protected areas. Eggplants were mentioned as hosts by BĂEŢAN et al. (2013) and confirmed by HOGEA (2020), while the only record of the sweet pepper as a host of *T. absoluta* was published by CICEOI et al. (2018).

As new information has become available and has filled the knowledge gaps about the host plant spectrum evolution, our work summarises the recent accessible published data and presents lists of the host plant species of *T. absoluta* worldwide, identifying potential hosts for Romania.

Materials and Methods

The literature survey was conducted mainly through the online databases, using different combinations of key words related to *T. absoluta* and its hosts plants. More than 200 articles were downloaded directly from the publisher sites or other databases and repositories, such as the Web of Science, Scopus, SpringerLink, CAB abstracts, CABI, Google Scholar and Research Gate. When references were inaccessible, direct requests were sent to either the authors or repositories, as was the case with some old references from South America (SIDALC). All trustable materials were considered for the analysis and often their references were cross-checked. A large database with information from each source was prepared. The following information was analysed and presented for the purposes of this review: taxonomic status, type of host plant, location (country and region), testing method, main observations/ results and references. The type of host plants was classified as follows: major or minor, weeds, wild plants, incidental and artificial.

Results

In total, plants belonging to 11 families, 27 genera and 64 species, including one species of Monocots clade, were found as hosts of *T. absoluta* in the available literature. Most of those species (40) are weeds and/ or wild plants.

A total of 23 host plant species of *T. absoluta* belong to 10 families other than Solanaceae, as follows: Amaranthaceae, Asteraceae, Brassicaceae, Convolvulaceae, Cucurbitaceae, Euphorbiaceae, Fabaceae, Malvaceae, Geraniaceae and Poaceae (Table 1). Out of those 23 species, seven host plant species have not been reported in the most recent review of CHERIF & VERHEGGEN (2019).

In addition to the three major host plant species of *T. absoluta* belonging to the genus *Solanum*, the tomato (*S. lycopersicum*), potato (*S. tuberosum*) and eggplant (*S. melongena*), other species of the family Solanaceae are also very sensitive to this pest. Fifteen species of the following 10 genera were found to be reported as hosts in the reviewed literature: *Atropa*, *Brugmansia*, *Capsicum*, *Datura*, *Lycium*, *Lycopersicon*, *Nicotiana*, *Physalis* and *Salpichroa* (Table 2). Of those host plants, eight species have not been listed in the review of CHERIF & VERHEGGEN (2019).

Most of the host plant species of *Tuta absoluta* belongs to the genus *Solanum*. We found information about 23 species listed in Table 3. The results on *S.*

Table 1. Host plants of *Tuta absoluta*, excluding the species of the family Solanaceae. The species marked with an asterisk (*) are those included in the EPPO Global Database (2020).

| Family | Plant species | Host type | Country/ Region | Testing method | Results | References | |
|---|---|--|--|--|---|---------------------------------------|---------------------------|
| Amaranthaceae | <i>Amaranthus spinosus</i> L. (spiny amaranth) * | wild | Sudan / Khartoum, Gezira, Kassala, Sennar, Northern States regions | monitoring, pheromone traps (2011–2014) | first report as a host plant | MOHAMED et al. (2015) | |
| | <i>Amaranthus viridis</i> L. (slender amaranth) | wild | Turkey / Southeast Anatolia Region | monthly surveys, open fields | first report as a host plant for Turkey | BAYRAM et al. (2015) | |
| | <i>Beta vulgaris</i> L. (sugar beet) * | minor | Algeria / Biskra Region | monitoring, pheromone traps (2009–2011) | first report as a host plant | DROUAI et al. (2016) | |
| | <i>Chenopodium album</i> L. (lamb's-quarters) | wild | Argentina / Buenos Aires Province | greenhouse tests, plants were artificially infested with eggs | no oviposition observed | GALARZA (1984) | |
| | | wild | Turkey / Adana, Osmaniye, Mersin, Hatay, Gaziantep | surveys (2010–2011), weekly sampling, open fields, greenhouses | first report as a host plant (miles away from tomatoes) | PORTAKALDALI et al. (2013) | |
| | Brassicaceae | <i>Chenopodium bonus-henricus</i> L. (m.as <i>Blitum bonus-henricus</i> (L.) Rehb) * | wild; incidental | Turkey / Konya | filed monitoring (2013) | first report as a host plant | ÖGÜR et al. (2014) |
| | | | wild; incidental | Algeria / Biskra Region | monitoring, pheromone traps (2009–2011) | first report as a host plant | DROUAI et al. (2016) |
| | | <i>Chenopodium rubrum</i> L. (red goosefoot) * | wild; incidental | Algeria / Biskra Region | monitoring, pheromone traps (2009–2011) | first report as a host plant | DROUAI et al. (2016) |
| | | <i>Spinacia oleracea</i> L. (spinach) * | minor; incidental | Algeria / Biskra Region | monitoring, pheromone traps (2009–2011) | first report as a host plant | DROUAI et al. (2016) |
| | | <i>Raphanus raphanistrum</i> L. (wild radish) | wild; incidental | Iraq / Najaf Province | survey, five tomato farms | first report as a host plant for Iraq | ABDUL-RIDHA et al. (2012) |
| <i>Sinapis arvensis</i> L. (wild mustard) | | wild | Turkey / Çanakkale Province | survey, tomato and weeds (2012–2013) | infestation rate = 1.6%; first report as a host plant | POLAT et al. (2015) | |
| Asteraceae | <i>Xanthium brasiliicum</i> Vell. (ramtoug) | wild | Sudan / Khartoum, Gezira, Kassala, Sennar, Northern States regions | monitoring, pheromone traps (2011–2014) | first report as a host plant | MOHAMED et al. (2015) | |
| | <i>Xanthium strumarium</i> L. (rough cocklebur) * | wild | Turkey / Southeast Anatolia Region | monthly surveys, open tomato fields | first report as a host plant for Turkey | BAYRAM et al. (2015) | |
| Convolvulaceae | <i>Sonchus oleraceus</i> (L.) L. (sow thistle) | wild | Turkey / Çanakkale Province | survey, tomato and weeds (2012–2013) | infestation rate = 1.6%; first record | POLAT (2014), POLAT et al. (2015) | |
| | | wild | Turkey / Adana, Mersin, Osmaniye, Hatay, Gaziantep | survey (2010–2011), weekly sampling, open fields and greenhouses | found miles away from tomato crops | PORTAKALDALI et al. (2013) | |
| | <i>Convolvulus arvensis</i> L. (field bindweed) | wild | Egypt | survey, greenhouse (2015) | heavy infestation, tomato seedlings in proximity | SABRY & RAGAEI (2015) | |
| | | | Turkey / Çanakkale Province | survey, tomato and weeds (2012–2013) | infestation rate = 1.6% | POLAT et al. (2015) | |

Table 1. Continuation.

| Family | Plant species | Host type | Country / Region | Testing method | Results | References |
|---------------|--|-----------------------|--|--|---|---------------------------|
| Cucurbitaceae | <i>Citrullus lanatus</i> L. (watermelon)* | minor | Sudan / Khartoum, Gezira, Kassala, Sennar, Northern States regions | monitoring, pheromone traps (2011–2014) | first report as a host plant | MOHAMED et al. (2015) |
| | <i>Cucurbita pepo</i> L. (field pumpkin)* | minor | Italy / Piedmont | laboratory assay, cv Nero di Milano | 6 / 392 eggs hatched; no larvae developed | INGEGNO et al. (2017) |
| Euphorbiaceae | <i>Jatropha curcas</i> L. (physic nut)* | minor | Sudan / Khartoum, Gezira, Kassala, Sennar, Northern States regions | open field and greenhouse surveys (2011–2014) | first report as a host plant for Kassala | MOHAMED et al. (2015) |
| | <i>Medicago sativa</i> L. (alfalfa)* | minor; incidental | Iraq / Baghdad Province | identification of infested alfalfa plants in the fields | adults emerged from alfalfa infested leaves in laboratory | ABDUL-RASSOUL (2014) |
| Fabaceae | <i>Phaseolus vulgaris</i> L. (common bean)* | incidental | Sudan / Khartoum, Gezira, Kassala, Sennar, Northern States regions | open field and greenhouse surveys (2011–2014) | found in Khartoum and Northern States | MOHAMED et al. (2015) |
| | | minor | Algeria; Biskra Region | monitoring, pheromone traps (2009–2011) | both in greenhouse and field | DROUAI et al. (2016) |
| | minor; incidental | Italy, Sicily | NPPO announcement (2009) | occasional damages | EPP0 (2009) | |
| | minor; incidental | Italy, Lazio | two greenhouse surveys (2009) | 24% and 66% infested leaves per plant | SPERANZA & SANNINO (2012) | |
| | artificial | Sudan / six states | field surveys at 38 sites (2014–2016) | no attack in the field; in non-choice-test, larvae died after mining into French bean leaves | IBRISS et al. (2020) | |
| | minor; incidental | Iraq / Najaf Province | survey in five tomato farms | first record for Iraq | ABDUL-RIDHA et al. (2012) | |
| Geraniaceae | <i>Vicia faba</i> L. (broad bean) | artificial | Belgium / Gembloux | artificial infestation | 18% eggs viability | BAWIN et al. (2016) |
| | | minor | Sudan / Khartoum, Gezira, Kassala, Sennar, Northern States regions | open field and greenhouse surveys (2011–2014) | found in Halfa and Northern States regions in Sudan | MOHAMED et al. (2015) |
| Malvaceae | <i>Vigna unguiculata</i> (L.) Walp. (cowpea) | minor; incidental | Iraq / Najaf Province | survey in five tomato farms | first record for Iraq | ABDUL-RIDHA et al. (2012) |
| | | artificial | Italy / Piedmont | laboratory assay | eggs laid; no larvae developed | INGEGNO et al. (2017) |
| Poaceae | <i>Geranium robertianum</i> L. (scots geranium) | artificial | Belgium / Gembloux | artificial infestation | eggs laid; no larvae developed | BAWIN et al. (2016) |
| | | incidental | Turkey / Southeast Anatolia Region | monthly surveys, open tomato fields | first record for Turkey | BAYRAM et al. (2015) |

Table 2. Plant species tested and confirmed as host plants of *Tuta absoluta*, belonging to the family Solanaceae, excluding the genus *Solanum*. The species marked with an asterisk (*) are those included in the EPPO Global Database (2020).

| Host species name | Host type | Country / area | Testing method | Results | References |
|--|------------------------|--|--|---|----------------------------|
| <i>Atropa belladonna</i> L. (deadly nightshade) | artificial | France / Saint-Andiol (collection) | behavioral assays, flying tunnels, greenhouse collected adults | larval survival rate 50%; development time egg – adult = 24.7 days; survival rate=39%; adult longevity = 15 days | BAWIN et al. (2015) |
| <i>Brugmansia arborea</i> (L.) Steud. (angel's trumpet) | incidental; artificial | Chile | tests, laboratory conditions, artificial infestation | found infesting the plants grown in the wild | VARGAS (1970) |
| <i>Capsicum annuum</i> L. (sweet pepper) | minor | Turkey/ Çanakkale Province | survey, tomato and weeds (2012–2013) | infestation rate 2.7% | POLAT et al. (2015) |
| | | Turkey / Adana, Mersin, Osmaniye, Hatay, Kilis, Gaziantep, Kahramanmaraş | weekly surveys (2010–2011) | found in cultivated and non-cultivated plants, including miles away from tomato crops | PORTAKALDALI et al. (2013) |
| <i>Capsicum</i> sp. | artificial | Turkey / Southeast Anatolia Region | monthly surveys, open tomato fields | found in all surveyed regions | BAYRAM et al. (2015) |
| | | Chile | tests, laboratory conditions, artificial infestation | artificial infestation not successful, tomato leafminer does not develop | VARGAS (1970) |
| <i>Datura ferox</i> L. (long spined thorn apple) * | artificial | Argentina / Buenos Aires | artificial infestation | no oviposition observed | GALARZA (1984) |
| | wild | Argentina / Mendoza | field survey | able to complete its development | GARCIA & ESPUL (1982) |
| | artificial | Tunisia | artificial infestation | no oviposition and development observed | ABBES et al. (2016) |
| <i>Datura stramonium</i> L. (Jimson weed) | artificial | France / Saint-Andiol (collection) | behavioral assays, flying tunnels, greenhouse collected adults | larval survival rate 20%; development time egg – adult = 24.4 days; survival rate 9%; only males emerged from pupae | BAWIN et al. (2015) |
| | artificial | Tunisia | artificial infestation | no oviposition and development observed | ABBES et al. (2016) |
| | wild | Argentina / Mendoza | field survey | able to complete its development | GARCIA & ESPUL (1982) |
| | wild; incidental | Chile / Azapa and Lluta valley | survey on the wild flora | found as host in the wild | VARGAS (1970) |
| | wild; incidental | Algeria / Biskra Region | monitoring, pheromone traps (2009–2011) | host plant very rare in Biskra Region | DROUAI et al. (2016) |
| <i>Lycium chilense</i> Miers ex Bertero * | wild | Sudan / Khartoum, Gezira, Kassala, Sennar and Northern States regions | monitoring using pheromone traps (2011–2014) | present only in Khartoum and Gezira regions | MOHAMED et al. (2015) |
| <i>Lycium halimifolium</i> L. (Himalayan goji) | wild | no data | no data | no data | EPPO (2020) |
| | artificial | Belgium / Gembloux | artificial infestation | egg lay occurred, egg viability 73%; larvae survival 73%; only males emerged from pupae | BAWIN et al. (2016) |

Table 2. Continuation.

| Host species name | Host type | Country / area | Testing method | Results | References |
|--|------------------|------------------------------------|---|----------------------------------|-------------------------------|
| <i>Lycopersicon hirsutum</i> Dunal <i>f. glabratum</i> | artificial | Brazil / Vicosia | artificial infestation | 0.14 eggs/ leaf | LETTE et al. (1995) |
| <i>Lycopersicon puberulum</i> Phil. | wild; incidental | Argentina / Mendoza | field survey | able to complete its development | GARCIA & ESPUL (1982) |
| <i>Nicotiana physalodes</i> (L.) Gaertn. | artificial | Chile / Azapa and Lluta valley | survey on the wild flora | found as host in the wild | VARGAS (1970) |
| <i>Nicotiana glauca</i> Graham (tree tobacco) * | wild | Belgium / Gembloux | artificial infestation | no oviposition observed | BAWIN et al. (2016) |
| <i>Nicotiana rustica</i> L. (Aztec tobacco) | artificial | Argentina / Mendoza | field survey | able to complete life cycle | GARCIA & ESPUL (1982) |
| <i>Nicotiana tabacum</i> L. (tobacco) | minor | Argentina/ Buenos Aires Province | seven tomato farms, monthly surveys (2013–2015) | relative abundance 99% | SALAS GERVASSIO et al. (2016) |
| <i>Nicotiana tabacum</i> L. (tobacco) | artificial | Belgium / Gembloux | artificial infestation | egg = >adult survival 9% | BAWIN et al. (2016) |
| <i>Nicotiana tabacum</i> var. <i>virginica</i> Comes | minor | Argentina | greenhouse tests, plants were artificially infested with eggs | – | GALARZA (1984) |
| <i>Physalis angulata</i> L. (cutleaf groundcherry) | minor | Turkey / Southeast Anatolia Region | survey | – | SYLLA et al. (2019) |
| <i>Physalis peruviana</i> L. (cape gooseberry) | minor | Italy / Sicily | monthly surveys, open tomato fields | new host plant record for Turkey | BAYRAM et al. (2015) |
| <i>Physalis viscosa</i> L. | minor | Argentina / Buenos Aires Province | detection, greenhouses (2009) | – | TROPEA GARZIA (2009) |
| <i>Salpichroa origanifolia</i> (Lam.) Baill. (lily of the valley vine) | wild | Argentina/Buenos Aires Province | greenhouse tests, plants were artificially infested with eggs | no oviposition observed | GALARZA (1984) |
| | | Argentina/Buenos Aires Province | seven tomato farms, monthly surveys (2013–2015) | relative abundance 100% | SALAS GERVASSIO et al. (2016) |
| | | Argentina / Buenos Aires Province | greenhouse tests, plants were artificially infested with eggs | no oviposition observed | GALARZA (1984) |

Table 3. Host plants of *Tuta absoluta* belonging to the genus *Solanum*, excluding its main hosts (*Solanum lycopersicum*, *Solanum melongena* and *Solanum tuberosum*). The species marked with an asterisk (*) are those included in the EPPO Global Database (2020).

| Host species name | Host type | Country / area | Testing method | Results | References |
|--|------------|--|---|--|-------------------------------|
| <i>Solanum aculeatissimum</i> (Jacq.) | wild | Botswana / 67 sites | surveys, pheromone traps | only found in Kgatleng district | MACHEKANO et al. (2018) |
| <i>Solanum aethiopicum</i> L. (African eggplant) | major | Senegal / 50 tomato fields | extensive surveys (2012–2013) | observed | BREVAULT et al. (2014) |
| | | Sub-saharan Africa | direct observation | observed | WYCHUYS et al. (2013) |
| <i>Solanum americanum</i> Mill. (american black nightshade) | wild | Tanzania / Arumeru, Lushoto, Kilolo, Mvomero | surveys in fields, 15 villages | mines/leaf = 0.02 ± 0.03 | SMITH et al. (2018) |
| | | Argentina / Buenos Aires Province | seven tomato farms, monthly surveys (2013–2015) | relative abundance 100% | SALAS GERVASSIO et al. (2016) |
| <i>Solanum bonariense</i> L. | artificial | Argentina / Buenos Aires Province | artificial infestation | complete lifecycle in less than 8.5% of individuals | GALARZA (1984) |
| <i>Solanum chenopodioides</i> Lam. (mentioned as <i>Solanum graecilius</i>) | artificial | Argentina / Buenos Aires Province | artificial infestation | Egg to adult survival – 12% | GALARZA (1984) |
| <i>Solanum chmielewskii</i> (C.M.Rick et al.) D.M.Spooner et al. | artificial | Turkey | artificial infestation | egg/leaf = 2,60±0,6; larvae/leaf = 9,00±1,1 | KAYAHAN et al. (2018) |
| <i>Solanum coccineum</i> (Jacq.) | wild | Botswana / 67 sites | surveys, pheromone traps | considered as an important host | MACHEKANO et al. (2018) |
| <i>Solanum dubium</i> L. (gubbain) | minor | Sudan / Khartoum, Gezira, Kassala, Sennar, Northern States regions | monitoring using pheromone traps (2011–2014) | most preferred alternative host plant, severe infestation on leaves and fruits | MOHAMED et al. (2015) |
| | | Belgium / Gembloux | artificial infestation | 84% of viable eggs, 36% complete development | BAWIN et al. (2016) |
| <i>Solanum elaeagnifolium</i> Cav. (silver-leaved nightshade) * | wild | Argentina / Mendoza | field survey | able to complete its development | GARCIA & ESPUL (1982) |
| | | Argentina / Buenos Aires | artificial infestation | complete lifecycle in less than 8.5% of individuals | GALARZA (1984) |
| <i>Solanum habrochaites</i> Knapp & D. M. (spooner) * | wild | Algeria / Biskra Region | pheromone traps | leaves and fruits seriously damaged | DROUAI et al. (2016) |
| | | no data | no data | no data | EPPO (2020) |
| <i>Solanum hirsutum</i> L. | artificial | Turkey | artificial infestation | egg/leaf = 2,90±0,8; larvae/leaf = 1,60±0,4 | KAYAHAN et al. (2018) |
| | | no data | no data | no data | EPPO (2020) |
| <i>Solanum lyratum</i> Thunberg * | wild | no data | no data | no data | EPPO (2020) |

Table 3. Continuation.

| Host species name | Host type | Country / area | Testing method | Results | References |
|---|------------------|--|---|--|----------------------------|
| <i>Solanum muricatum</i> Ait. (sweet pepino) * | minor | Turkey / Adana, Mersin, Osmaniye, Hatay, Gaziantep, Kahramanmaraş, Kilis | weekly surveys (2010–2011) | the pest was found miles away from tomato crops | PORTAKALDALI et al. (2013) |
| | | India / Himachal Pradesh | artificial infestation | mean development time 47.73 days, weekly multiplication rate 1.36 | NEGI et al. (2018) |
| <i>Solanum neorickii</i> D.M. Spooner, G.J. Anderson & R.K. Jansen. | artificial | Turkey | artificial infestation | egg/leaf = 2.20±0.7; larvae/leaf = 6.00±0.9 | KAYAHAN et al. (2018) |
| | | France / Saint-Andriol (collection) | behavioural assays, flying tunnels, greenhouse collected adults | larval survival rate - 79 %; development time egg - adult =22.9 d; survival rate=45% | BAWIN et al. (2015) |
| | | Tunisia | artificial infestation | female fecundity - 20.86 egg/f; adult survival = 5.86 d. | ABBES et al. (2016) |
| | artificial | Italy | greenhouse test, 27± 3°C and 55±23% RH | 26.12 days developmental time; 44.4% emergence rate | INGEGNO et al. (2017) |
| | | Spain / Barcelona | greenhouse and laboratory experiments | total survival from egg to adult between 22 and 24% | ARNÓ et al., (2019) |
| | | Argentina / Mendoza | field survey | complete development | GARCIA & ESPUL (1982) |
| <i>Solanum nigrum</i> L. (black nightshade) * | wild; incidental | Chile / Azapa and Lluta valley | survey on the wild flora | found as host in the wild | VARGAS (1970) |
| | | Tanzania / Arumeru, Lushoto, Kilolo, Mvomero | sampling fields, 15 villages | mines/leaf =0.02 ± 0.03 | SMITH et al. (2018) |
| | | Turkey / Adana, Mersin, Osmaniye, Hatay, Gaziantep, Kahramanmaraş, Kilis | weekly surveys (2010–2011) | the pest was found miles away from tomato crops | PORTAKALDALI et al. (2013) |
| | | Algeria / Biskra Region | monitoring, pheromone traps (2009–2011) | detected | DROUAI et al. (2016) |
| | artificial | Turkey / Southeast Anatolia Region | monthly surveys, open tomato fields | detected | BAYRAM et al. (2015) |
| | | Turkey / Çanakkale Province | survey on tomato fields and weeds around (2012–2013) | infestation rate = 4.8% | POLAT et al. (2015) |
| | | China / four locations in Xinjiang provinces | monitoring, pheromone traps (2017) | 100% infested plants, 30% of the leaf areas mined-and-fed | ZHANG et al. (2020) |
| | | Sudan / six states | field surveys at 38 sites (2014–2016) | detected and sampled for laboratory tests | IDRISS et al. (2020) |
| <i>Solanum peruvianum</i> L. | artificial | Brazil / Vicosa | artificial infestation | eggs/leaf - 0.22 | LETTE et al. (1995) |

Table 3. Continuation.

| Host species name | Host type | Country / area | Testing method | Results | References |
|---|------------------|------------------------------------|--|---|-------------------------------|
| <i>Solanum pimpinellifolium</i> L. | artificial | Turkey | artificial infestation | egg/leaf = $1,90 \pm 0,4$; larvae/leaf = $4,90 \pm 1,0$ | KAYAHAN et al. (2018) |
| <i>Solanum pseudocapsicum</i> L. | artificial | Argentina / Buenos Aires Province | greenhouse tests, plants artificially infested with eggs | complete lifecycle in less than 8.5% of individuals | GALARZA (1984) |
| <i>Solanum sarrachoides</i> Sendtn. * | artificial | Spain / Barcelona | greenhouse and laboratory experiments | total survival from egg to adult between 22 and 24% | ARNÓ et al., (2019) |
| <i>Solanum sisymbriifolium</i> Lam. (litchi tomato) | artificial | Argentina/Buenos Aires Province | greenhouse tests, plants artificially infested with eggs | complete lifecycle in less than 8.5% of individuals | GALARZA (1984) |
| | wild | Argentina / Buenos Aires Province | seven tomato farms, monthly surveys (2013–2015) | relative abundance 69.17% (<i>Phthorimaea operculella</i> 25%) | SALAS GERVASSIO et al. (2016) |
| <i>Solanum</i> sp. | wild; incidental | Chile / Azapa and Lluta valley | survey on the wild flora | found as host in the wild | VARGAS (1970) |
| <i>Solanum supinum</i> (Dunal) | wild | Botswana / 67 sites | surveys, pheromone traps | 187.4 ± 12.21 moths/trap/month, most widely distributed | MACHEKANO et al. (2018) |
| <i>Solanum wononowii</i> Pojark. | wild | Turkey / Southeast Anatolia Region | monthly surveys, open tomato fields | New host plant record for Turkey | BAYRAM et al. (2015) |

lycopersicum, *S. melongena* and *S. tuberosum* are not presented, as these three main cultivated host species have been subject of numerous studies. Thirteen of the species are not included in the precedent review of CHERIF & VERHEGGEN (2019).

Out of all 64 plant species reported in literature as hosts of *T. absoluta*, 33 plant species are found also in the Romanian flora and have the potential to become a host of this pest in the future (Table 4). Of them, 16 species are cultivated plants and 17 are wild plants. Our results indicate that all these plants may serve as potential reservoir of *T. absoluta* in Romania, considering the current climate changes and the pressure put on the pest by the chemical treatment in vegetable farms. Some reports show that *T. absoluta* has been found in open field (TLPLUS 2016, NICA 2018) and research needs to be carried out on its biological features in the new conditions.

Discussion

The first study on the host plants of *T. absoluta* is that of MENDES (1939) who reported as hosts in the state of Sao Paulo, Brazil, the tobacco (*Nicotiana tabacum*) and 11 other species of the genus *Nicotiana*, potato (*S. tuberosum*) and other species of the genus *Solanum*, including the eggplant (*S. melongena*), and two species of *Physalis*. VARGAS (1970) mentioned that in Chile it is impossible to have an artificial inoculation of *T. absoluta* on *Physalis peruviana* and that, in the wild, the pest develops on the sweet cucumber (*S. variegatum*), tobacco (*N. tabacum*) and pepper (*Capsicum annuum*).

GALARZA (1984) is one of the first authors to signal that *T. absoluta* may develop on alternative hosts. Recently, reports on new host plants come mainly from surveys and monitoring activities that also include the wild vegetation around the tomato, eggplant and potato crops. During a two-year survey (2009–2011) in Biskra Region, Algeria, five wild species and five cultivated species, belonging to Solanaceae, Amaranthaceae and Fabaceae have been found as hosts of *T. absoluta*. Of those, two wild species *Chenopodium rubrum* and *C. bonus-henricus*, and two cultivated species, *Spinacia oleracea* and *Beta vulgaris*, were recorded as hosts for the first time (DROUAI et al. 2016).

The status of some plants as hosts has changed recently. For example, the eggplants may be severely affected by *T. absoluta* under certain conditions (MOHAMED et al. 2015). However, the previous reports have shown no oviposition or incomplete development of larvae on the eggplant leaves, as well as the eggplants grown in *Tuta*-infested greenhouses

Table 4. Potential host plants of *Tuta absoluta* in Romania. Bold letters indicate the plant species mentioned worldwide as hosts of *T. absoluta* that belong to the wild flora, while normal characters indicate the cultivated species. The ‘plus’ (+) shows that the respective plant species are present in the Romanian flora, while the ‘minus’ (–) shows plant species that are absent from Romanian flora.

| Host plant species | Presence in Romania | Host plant species | Presence in Romania |
|--|---------------------|--|---------------------|
| <i>Amaranthus spinosus</i> L. * | - | <i>Solanum aculeatissimum</i> (Jacq.) | - |
| <i>Amaranthus viridis</i> L. | + | <i>Solanum aethiopicum</i> L. | - |
| <i>Atropa belladonna</i> L. | + | <i>Solanum americanum</i> Mill. | - |
| <i>Beta vulgaris</i> L. | + | <i>Solanum bonariense</i> L. | - |
| <i>Brugmansia arborea</i> (L.) Steud. | - | <i>Solanum chenopodioides</i> Lam. | - |
| <i>Capsicum annuum</i> L. | + | <i>Solanum chmielewskii</i> (C. M. Rick et al.) D. M. Spooner et al. | - |
| <i>Capsicum</i> sp. | + | <i>Solanum coccineum</i> (Jacq.) | - |
| <i>Chenopodium album</i> L. | + | <i>Solanum dubium</i> L. | - |
| <i>Chenopodium bonus-henricus</i> L. | + | <i>Solanum dulcamara</i> L. | + |
| <i>Chenopodium rubrum</i> L. | + | <i>Solanum elaeagnifolium</i> Cav. | - |
| <i>Citrullus lanatus</i> L. | + | <i>Solanum habrochaites</i> Knapp & D. M. | - |
| <i>Convolvulus arvensis</i> L. | + | <i>Solanum hirsutum</i> L. | - |
| <i>Cucurbita pepo</i> L. | + | <i>Solanum lycopersicum</i> L. | + |
| <i>Datura ferox</i> L. | - | <i>Solanum lyratum</i> Thunberg | |
| <i>Datura stramonium</i> L. | + | <i>Solanum melongena</i> L. | + |
| <i>Geranium robertianum</i> L. | + | <i>Solanum muricatum</i> Ait. | - |
| <i>Jatropha curcas</i> L. | - | <i>Solanum neorickii</i> D. M. Spooner, G. J. Anderson & R. K. Jansen | - |
| <i>Lycium chilense</i> Miers ex Bertero | - | <i>Solanum nigrum</i> L. | + |
| <i>Lycium halimifolium</i> L. | + | <i>Solanum peruvianum</i> L. | - |
| <i>Lycopersicon puberulum</i> Phil. | - | <i>Solanum pimpinellifolium</i> L. | - |
| <i>Lycopersicon hirsutum</i> Dunal f. <i>glabratum</i> | - | <i>Solanum pseudocapsicum</i> L. | - |
| <i>Malva sylvestris</i> L. | + | <i>Solanum sarrachoides</i> Sendtn. | - |
| <i>Medicago sativa</i> L. | + | <i>Solanum sisymbriifolium</i> Lam. | - |
| <i>Nicotiana glauca</i> Graham | + | <i>Solanum</i> sp. <i>tomatillo</i> | - |
| <i>Nicotiana rustica</i> L. | + | <i>Solanum supinum</i> (Dunal) | - |
| <i>Nicotiana tabacum</i> L. | + | <i>Solanum tuberosum</i> L. | + |
| <i>Phaseolus vulgaris</i> L. | + | <i>Solanum woronowii</i> Pojark. | - |
| <i>Physalis angulata</i> L. | - | <i>Sonchus oleraceus</i> (L.) L. | + |
| <i>Physalis peruviana</i> L. | + | <i>Sorghum halepense</i> (L.) Pers. | + |
| <i>Physalis viscosa</i> L. | - | <i>Spinacia oleracea</i> L. | + |
| <i>Raphanus raphanistrum</i> L. | + | <i>Vicia faba</i> L. | + |
| <i>Salpichroa origanifolia</i> (Lam.) Baill. | - | <i>Vigna unguiculata</i> (L.) Walp. | + |
| <i>Sinapis arvensis</i> L. | + | <i>Xanthium brasiliicum</i> Vell. | - |
| <i>Solanum aculeatissimum</i> (Jacq.). | - | <i>Xanthium strumarium</i> L. | + |

have demonstrated no symptoms of damages (MOHAMED et al. 2012). As one of the most important crops, the suitability of potato and its cultivars as a host plant of *T. absoluta* has been extensively studied (CAPARROS MEGIDO et al. 2013, YOUNES et al. 2018, KANLE SATISHCHANDRA et al. 2019)

The family Fabaceae has become the second preferred host-group, following Solanaceae. During some surveys in 2010 in Bagdad Region, Iraq, it has been proven that *T. absoluta* can develop to the adult stage on alfalfa (ABDUL-RASSOUL 2014). The studies of BAYRAM et al. (2015) demonstrate that *T. absoluta* can also find shelter on monocotyledon weeds as *Sorghum halepense*, a common weed and, therefore, may spread much faster and adapt quicker to new environmental conditions. According to BAJRACHARYA et al. (2016), this pest can spread even into new locations, where tomato is not cultivated, and even in the absence of solanaceous plants, due to its already enlarged plant host spectrum, which includes commonly-found weeds. Other extensive studies show that only few of the above-mentioned host plants are true host plants and their use depends on location, local conditions, cultural practices and many other factors. An extensive survey on fifty-three potential host plant species in Sudan reveals that only tomato, eggplant, black nightshade and gubbain are suitable host plants for *T. absoluta* (IDRISS et al. 2020).

Recent comprehensive studies about host preferences of *T. absoluta* have been performed by CAPARROS MEGIDO et al. (2014), showing that the tomato-reared females are more attracted to tomato compared to potato plants and concluding that the larval experience has an impact on the host finding behaviour of the subsequent adults. The same observations are made by OLSSON et al. (2006) and MOREAU et al. (2008) on *Lobesia botrana*, *Ephesthia cautella* and *Plodia interpunctella*. Recent studies in chemical ecology demonstrate that the attraction and oviposition of *T. absoluta* females are mediated by the volatile signature of their host plant. It is reported that the tomato leaf odours, including volatile terpenoid compounds, favour the upwind orientation flight of females followed by landing and egg-laying (PROFFIT et al. 2011). Extensive description of tomato and potato volatiles is made by CAPARROS MEGIDO et al. (2014) and PROFFIT et al. (2011). Despite the extensive studies, the reports about the host plants of *T. absoluta* are inconsistent, most possibly varying with the geographical and meteorological conditions.

In Romania very few studies on the host plants of *T. absoluta* have been conducted. For the moment

there is no written report for the development of this species on wild plants. The tomato, eggplants and sweet pepper are the confirmed hosts, while the spinach was mentioned as a host plant in one farmers' survey, but there was no evidence if *T. absoluta* used the species as shelter or fed and completed its life cycle on it (CICEOI et al. 2018). Some reports about the spread of the pest are available in an online video-sharing platform or in farmer forums (TLPLUS 2016, NICA 2018), without any data on the wild hosts. In August 2018, the Ministry of Agriculture has acknowledged the spread of *T. absoluta* in the country and asked farmers to take control actions, following the massive damages in Olt, Buzau, Galati and Ialomita counties (NICA 2018).

Conclusions

Our work documented that 67% (40 out of 60 species) of the host plant species of *T. absoluta* are weeds or wild plants. Updated knowledge about this new host range is crucial for the plant phytosanitary key actors to organise better the national inspections and surveys and to provide accurate information about the cultural control recommendations to farmers. Almost all the reported wild host plants of *T. absoluta* are very common in the Northern Hemisphere. Therefore, it is important to find a balance in the agricultural practice between the keeping of weeds to enhance the biodiversity and natural biocontrol mechanisms and the weeding as a measure to isolate certain agrosystems from others. Still, for the biodiversity and environment, the impact of the expanding host plant range of *T. absoluta* is unforeseen and it should receive more attention from the plant health practitioners.

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