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Tuta absoluta (Meyrick) an invasive insect pest on Tomato in Narmadapuram (Hoshangabad) district of Madhya Pradesh

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Abstract
Tomato is a cash crop, mostly grown by small and marginal farmers in Central India. Incidence of an unfamiliar invasive insect pest *Tuta absoluta* (Meyrick), created unrest among tomato growers for being unsuccessful in its management. This happened before they could recover from the recent financial shock due to the wide spread havoc incidence of Fall army worm on their maize crop. The incidence of *T. absoluta* was observed in field of all the 54 tomato growers surveyed. The yield loss varied from 48.40 to 100 percent. Pheromone and light traps installed in the farmers' field helped to disrupt its mating and monitoring of the pest followed by application of contact insecticides. Field sanitation by collection and burning of infested fruits and plants also helped in managing the pest. The learning from the field was shared as advisory through social digital platform for faster and deeper penetration of the management strategy among the farming communities.

Keywords: Invasive pest, *Tuta absoluta*, farmer, management, pheromone

Introduction
Tomato leaf miner *T. absoluta* (Meyrick), belonging to Lepidoptera: Gelechiidae, is a serious pest of tomato (*Solanum lycopersicum* L.; Solanales: Solanaceae), *S. melongena*, *S. tuberosum*, *Capsicum annuum*, *Nicotiana tabacum* and *Phaseolus vulgaris*. It is an invasive insect pest (Biondi *et al.*, 2018, Desneux *et al.*, 2011) [3, 12]. *T. absoluta* is originally from South America. It was described in Peruas early as in 1917 as *Phthorimaea absoluta* by Meyrick in 1917 (Desneux *et al.*, 2010) [13].
Invasive insect pests cost the global economy (70 billion dollars) and human health (6.9 billion dollars) each year (Bradstraw *et al*., 2016) [5]. *T absoluta*'s yield loss in tomato is caused by leaf-mining activity and fruit infestation (Biondi *et al*., 2018; Desneux *et al*., 2010) [3, 13]. Invasive pests have become more common in recent years, with around a third of all cases occurring in the last four decades (Seabens *et al*., 2017) [20]. International commerce and climate change (Bellard *et al*., 2013) [1] are two major contributors to these occurrences.
The problem of an unknown insect pest destroying tomatoes in villages of Bankhedi and Sohagpur block of Hoshangabad district was first noted in March 2019 by us. Tomato is grown in Hoshangabad district in the area of 1960 ha by 1155 farmers. The annual production of tomato in the district is about 50,060 metric ton. *T. absoluta* has a tremendous reproduction rate, with up to 10–12 cycles per year and 24–76 days per generation dependent on favorable weather conditions. The larvae develop on tomato plants, creating enormous passageways in the leaves, penetrating into stalks, and eating both apical buds and fruits. The eggs hatch on mesophyll tissue of leaves, making asymmetrical leaf mines that eventually turn fatal. This, in turn, allows secondary pathogens to infiltrate, resulting in fruit rot. Additionally, if timely control measures are not done, this invasive pest can damage tomato plants at any stage of their growth, resulting in up to 100% losses. It has also been observed attacking various cultivated Solanaceous and non-Solanaceae crops, as well as non-cultivated weeds.
T. absoluta is making modest but steady development in India's northern and north-eastern areas. For rapid relief against *T. absoluta*, farmers are mostly reliant on chemical pesticides. In India, Sridhar *et al*. (2016) tested eleven pesticides against *T. absoluta* and discovered Spinetoram, Cyantraniliprole, Flubendiamide, and Spinosad to be the most effective.

According to a following investigation, the insecticides cyazypyr, Rynaxypyr, and Indoxacarb caused the least fruit damage.So far, very few research studies in India have focused on the bio-control options against this invasive pest. Application of *Bacillus thuringiensis*, *Nomuraea rileyi*, *Beauveria bassiana*, and *Metarhizium anisopliae* formulations led to 70–81% reduction in *T. absoluta* larvae, whereas Azadirachtin 5% EC reduced 70% of the live mines of *T. absoluta* on tomato in Karnataka, India. Studies on integrated management options for this invasive pest was lacking in Madhya Pradesh. Hence, an intensive survey was carried out in the seven major tomato growing villages in the district to confirm the infestation, nature and extent of damage as well as a possible solution for its management.

Materials and Method

Description of the study locations

T. absoluta is an invasive insect pest and a survey on its incidence was carried out to gather the knowledge on

1. Nature of damage
2. Peak time of the incidence
3. Farmers coping mechanism
4. Economic losses due the incidence

The survey on the incidence of *T. absoluta* was conducted in the seven prominent tomato growing villages of the district Hoshangabad (Fig 1). The district is agro-climatically located in the 'Central Narmada Valley Zone' of Madhya Pradesh, Geographically it lies between 3°24′38.9″ E longitude and 36°39′37.1 N latitude at 309 m above mean sea level. The 1,36,223 farmers in the district is distributed in its seven development Blocks. About 50,060 metric ton of Tomato is produced annually in the district by just 1155 farmers from their 1960 ha of land. Almost all the tomato growers are small and marginal farmers.

Sampling, data collection and identification

Tomato growers fields (Fig. 1) in seven villages of Bankhedi (6 villages) and Sohagpur (1 village) development Blocks were surveyed (Table-1). The larval infested tomato fruits, leaves, other infested plant parts and debris were collected for the study. The specimens of adult and larva of *T. absoluta* was preserved in 96% Ethanol and sent to the Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur for its molecular identification.

Observation of the infected plants was recorded to study the nature of damage of the pest in the field. Data on yield loss, decay percent, normal yield, average cost of cultivation etc. were collected from tomato growers for the study of above objectives (ii to iv). The field visits were conducted during early morning and evening hours. Visit to the market was planned between 10 am to 12 noon, when farmers bought their produce to the traders for sale.

The details of the villages surveyed for *T. absoluta,* number of farmers and the GPS coordinate of their fields are mentioned in Table-1.

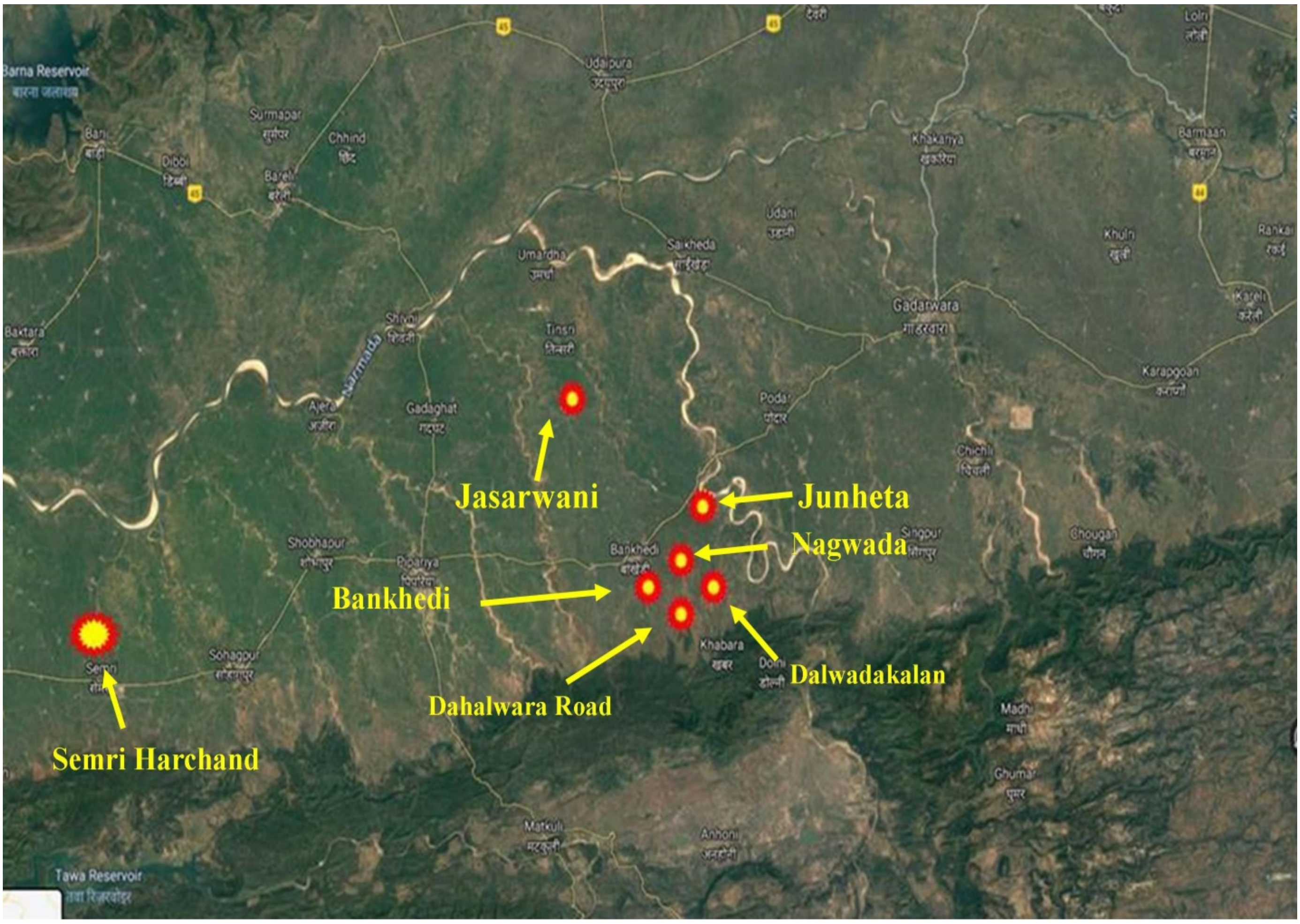

Fig 1: Tomato growers

Molecular identification
DNA extraction
Genomic DNA was extracted from two adult abdomens (two individuals from each location monitored; Table 1) using DNeasy Blood and Tissue Kit (QIAGEN), following the manufacturer's instructions.

PCR analysis
The mitochondrial cytochrome oxidase subunit I (COI) gene proved suitable for PCR because of its good genetic resolution, which is ideal for differentiation at the species level. Therefore, primers amplifying mtCOI fragments were employed for the PCR analyses. Amplification of the COI gene was performed with LCO1490 (5'-GGTCAACAAATCATAAAGATATTGG-3') and HCO2198 (5'-TAAACTTCAGGCTGACCAAAAAATCA-3') primers (Table 2). PCR was set up in 20 µL lanif volume and the master mix contained: High Yield Reaction Buffer A with $MgCl_2$, 0.6 mM of each dNTP, 0.5 µM of each primer and 0.1U/µl of *Taq* and polymerase. Amplification was performed in a Thermal Cycler 2720 (Applied Biosystems) and the temperature profile for the amplification in the reaction with LCO1490/HCO2198 primers was: 5 min at 95 °C (initial denaturation) followed by 1 min at 95 ºC, 1 min at 54 ºC, 30 sec at 72 ºC for 35 cycles, with a final extension at 72 ºC for 7 min and storage at 4 ºC. The final PCR products were electrophoresed on 2% agarose gel at 100 V for 1 hour. The gel was stained with a 0.05% solution of ethidium bromide. After electrophoresis, the gel was visualized under gel documentation system.

Sequencing and data analysis
Amplified products were sent for sequencing. BLAST analysis (Basic Local Alignment Search Tool; http://blast.ncbi.nlm.nih.gov/Blast.cgi) was used to compare the sequences obtained with those from the GenBank.

Results and Discussion
Morphological identification
Identification of *T. absoluta* was based on morphological characters of the infested leaves. Tomato fruits were dissected to obtain different larval instars for identification. The fruit damage had characteristic holes in the fruit surface, while leaves on the mesophyll tissues were mined between the upper and lower epidermis. The larvae from the dissected tomatoes and leaves were creamy-white in the early instars while green or pinkish with dark brown head in later instars. The moth were small (less than 7 mm), had grey to brown scales and black spots on anterior wings. It has filiform (bead like) antennae as well as on the shape of the uncus, digitate, setosevalvae and the well-developed vinculum and phallus of the male genitalia. Incidence of *T absoluta*was devastating, as none of the tomato growers, traders, pesticide dealers and extension workers knew about this pest and management tactics. The incidence was noticed in Hoshangabad district for the first time in March 2019 by the KVK scientist during their routine development work. As the symptoms did not match that of the major insect pests of tomato is the area, an intensive survey and in-depth study of the pest was undertaken among the most affected 54 tomato growers.

Majority of the tomato growers affected by the *T. absoluta* were small and marginal farmers. The commonly grown tomato varieties were Abhilash, 3001, 3003, Rashi, Karina, 2103 and 1403. All the varieties were found susceptible to *T. absoluta.* There were 13 farmers having holdings between 0.25 to 0.9 acre, 22 farmers had 1.0 acre while 9 farmers had land holding between 1.5 to 4.0 acres (Table-2).

Molecular identification was performed on the basis of PCR amplification of mitochondrial gene COI.The amplified products with targeted markers were sent for sequencing and obtained sequences was used for BLAST analysis. The alignment results showed 100 percent similarity with other sequences of *T. absoluta* already present in NCBI. The same method for the identification of insects has been adopted previously by Cifuentes *et al.,* (2009) and Kambhampti and Smith (1995).

Nature of damage
The larvae of *T. absoluta* mine the leaves by feeding on the mesophyll, leaving the epidermis intact. Tunnels created by larvae while feeding on the leaf (mines) reduce the photosynthetic surface area of the leaves. In extreme cases, leaf mining caused early drying of leaves and eventual death of the plant. The third and fourth instar larvae were found to abandon the mines in the leaves to bore into stalks, apical buds and fruits. Pupation was observed in the mines of fresh leaves, fallen and dried leaves as well as in soil. The holes on the fruits were minute, bearing black spots with a small encircle of yellow line. Usually, there were 2-4 holes per fruit. The larvae was creamy-white in the early stage (early instar) that turned to green or pinkish with dark brown head in later instars.

Peak period of incidence
The incidence in the field was observed in the month of March 2019 and it attained a peak (in terms of infestation) during first fortnight of April 2019. The population appeared to decline after the 14th April 2019 as the level of infestation was reduced. The reduction may be due to indiscriminate use of pesticides by farmers to control the pest or unavailability of the host due to death of tomato plants in the field.

Farmers coping mechanism
Unfamiliar with the symptoms of damage observed by the tomato growers, they applied insecticides suggested by the local pesticide dealers. It was common among majority of the panic striven tomato growers. Increasing the dose and application frequency of the insecticides increased the cost of production. Pesticide residue load on the tomato fruit sold cannot be ruled out.

During normal years tomato growers in the area follow 7 to 10 spray schedule of insecticides, to manage insect pest complex (sucking insects, borers and leaf miners). The mean cost of a single spay of insecticide application on tomato varied from INR 650 to INR 6,500 depending on the land holding. Thus the total cost of insecticide application during the entire tomato cropping season varied from INR 4550 to INR 65,000 per farmer depending on the number of sprays and land holding (Table-2).

In the year 2019, when there was an outbreak of *T. absoluta* on tomato crop, the farmers had to increase the schedule and frequency of insecticide spray. Thus there were 4 to 6 more spray of insecticides which were in addition to their normal schedule of insecticide sprays. The additional cost burden due to additional applications of insecticide varied from INR 2,600 to INR 39,000 per farmer depending on the number of sprays and land holding. Thus, due to the outbreak of *T. absoluta* on tomato crop, the additional cost of insecticide application increased from 57.14 to 60.00 percent during 2019.

However, out of the 54 tomato growers, only four of them agreed to install light trap with local arrangement and five installed pheromone traps, bought for them from neighbouring Bhopal district. These nine farmers saw the collection of adults and saw a subsequent decline in fresh infestation in their field.

Losses due to outbreak of *T. absoluta*

Losses to the tomato growers due to outbreak of *T. obsoluta* can be stratified into three types.

a. Economical
b. Social
c. Environmental

Economical losses

The economical losses due to outbreak of *T. absoluta* was because of

1. Increase in the production cost due to additional spray of insecticides
2. Decrease in marketable yield

In the absence of a concrete management strategy and lack of knowledge of *T. obsoluta* there was panic among the tomato growers in the area (Fig. 1). The panicked farmers on the advice of the local pesticide dealers went for additional spray schedule of insecticides to reduce the incidence of the new and unknown pest on the cash crop. Majority of the farmers purchase insecticides on credit and pay back after the sale of their produce. Under this condition they often get insecticides on a higher price and also substitutes of branded company. The increase in the cost of insecticide went up varying from 57.14 to 60.00 percent during 2019 in comparison to previous year.

Even after of an increased application of insecticides, tomato growers suffered economic losses due to reduction in marketable yield of tomato, especially when the tomato was traded at higher price of INR 900 per quintal in April 2019. During normal years, the mean yield of tomato of the farmers under study varied from 73q to 876q, again depending on their land holding (Table-2). During the 2019, due to the outbreak of *T. obsoluta,* the infected tomato fruits either had holes in the fruit rendering it unmarketable and there was decay of fruits in the field. The fruits with holes varied from 47.49 to 95.96 percent among the farmers, while that of decay was 0.91 to 6.85 percent.

Finally the marketable tomato fruits left with the growers varied from 27q to 431.75q depending on the land holding. The yield loss suffered by the farmers under study due to the outbreak of *T. obsoluta* varied from 48.40 to 100 percent when compared to their previous year yield.

Social losses

Generally, crop losses due to pest incidences or natural calamities are assessed in terms of economical losses. But it is a fact that when such incidences occurs, there occurs distress in the affected farmer, disturbance in the family, loss of appetite, fear of loss and debit burden. During our interview and discussion most of the tomato farmers under the study agreed to have been under tremendous distress, disturbance in the family, loss of appetite, fear of loss and debit burden. One more factor which they expressed which generally went unnoticed by an outsider. There is a competition among neighbouring farmers in terms of production, productivity and profitability (3Ps). Any incidences that affect the 3Ps also bring down the morale of the farmers affected in their society.

Environmental losses

As our study, could not measure the environmental factors for calculating the losses, but we could foresee the impact of the pesticide treadmill to manage the outbreak of *T obsoluta*. However, it was visible during the trade of tomato. The outbreak of *T obsoluta* and indiscriminate use of insecticides for its management was very much in public domain due to publicity in local newspapers and social media. The tomato from the affected villages was less preferred and fetched lesser price in whole sale market.

In the present study, both light trap and pheromone traps were employed to monitor the moths of *T. absoluta.* Traps are very useful for monitoring insects. Malaise trap (Sheikh *et al.*, 2016a) [21] pitfal trap (Sheikh *et al.*, 2018) [24], light trap (Sheikh *et al.*, 2016c; Kurmi *et al.*, 2019) [23, 18] sweep net trap (Sheikh *et al.,* 2016c) [23] and pheromone trap (Ferrara *et al.,* 2001) are a few types of traps used very effectively in the past. In the present case both light and pheromone traps used were very helpful in monitoring the pest.

Earlier workers also have reported that the *T. absoluta* caused losses in Tomato varying from 30 percent in greenhouses (Chermiti *et al.*, 2009) [8] to nearly 100 percent losses in field condition (EPPO 2005; Viggniani *et al*., 2009, Desneux *et al.*, 2010; Chidege *et al.*, 2016) [14, 13, 27, 9]. Levy (2010) [19] observed that *T. absoluta*moths can cover a few kilometres by flying and in a year can often be carried more than 1000 km on the wind. They can spread locally from one plant to another or neighboring fields or globally through trans-border trade (Toševski *et al.*, 2011; Bettaibi *et al.*, 2012) [26, 2].

The larvae mine into the leaves of tomato plants and later tunnels into the fruits making it unmarketable. Similar observation was also reported by Viggniani *et al.,* (2009) [27]. Among the integrated it was suggested management strategy for biological control (Biondi *et al.*, 2018) [3], essential oils with insecticidal activity (Compolo *et al.*, 2017, Soares *et al.*, 2019) [11, 25] and even optimized nutrient application (Blazheyski *et al.*, 2018 [4], Han *et al.*, 2018) [16] are suggested against *T. absoluta*. In the present study a combination of Pheromone and light traps, field sanitization and application of contact insecticides were the management strategy implemented to manage *T. absoluta.*

Table 1: Geographical locations of Hoshangabad district

Block	Locality/village	No. of growers	GPS coordinates
Bankhedi	Bankhedi	8	E 58.3896 '31 °78 and N "16.59 '46 °22
	Junheta	8	E "42.552 '36 °78 and N "31.8444 '47 °22
	Jasartwani	10	E "4.6056 '31 °78 and N "17.6436 '51 °22
	Dahalwara Road	1	E "53.2464 '35 °78 and N "59.9076 '45 °22
	Nagwada	2	E "12.1776 '35 °78 and N "33.2976 '46 °22
	Dalwadakalan	1	E "50.8176 '33 °78 and N "10.6308 '45 °22
Sohagpur		24	E 0.378 '45 °77 and N "1.368 '45 °22

Table 2: Economics of *Tuta absoluta* incidence in tomato crop

Land holding of farmers (ha.)	No. of farmers	No. of insecticide spray			Cost (INR)				Normal yield (q/ha)	Yield loss q/ha. due to *Tutaab soluta*				Average marketable yield (q/ha)	Income (INR)		B:C Ratio
		Routine	Additional	Total	Per Spray	Total spray	Average cost of cultivation	Total		Average loss	Average decay	Total	Loss %		Gross income	Net income	
0.1	2	7	4	11	650	7150	16000	23150	73	41	5	46	63.014	27	24300	1150	1.05
0.2	18	7	5	12	1350	16200	31000	47200	146.8	89.4	8.2	97.6	66.485	49.2	44280	-2920	0.938
0.28	1	8	5	13	1850	24050	42000	66050	198	190	8	198	100	0	0	-66050	0
0.3	1	8	5	13	1850	24050	45000	69050	208	140	5	145	69.712	63	56700	-12350	0.821
0.36	1	8	5	13	2200	28600	55000	83600	268	205	9	214	79.851	54	48600	-35000	0.581
0.4	22	9	5	14	2500	35000	65000	100000	290.12	178.81	10	188.81	65.08	101.31	91179	-8821	0.912
0.6	3	9	6	15	3750	56250	90000	146250	438.66	290.66	8	298.66	68.085	140	126000	-20250	0.862
0.8	4	10	5	15	5000	75000	128000	203000	586.75	419.25	12.5	431.75	73.583	155	139500	-63500	0.687
1	1	10	6	16	6000	96000	150000	246000	745	373	9	382	51.275	363	326700	80700	1.328
1.2	1	10	6	16	6650	106400	190000	296400	876	416	8	424	48.402	452	406800	110400	1.372

Conclusions

Open trade and related transits have increased chances of introduction of invasive pests. Identification and monitoring as well as developing an acceptable management strategy is the key to keep the pest under EIL. Use of social media is effective to share the information for the management of pests.

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References

1. Bellard C, Thuiller W, Leroy B, Genovesi P. Will climate change promote future invasions? Global Change Biology. 2013,19: 3740-3748
2. Bettaibi A, Mezghani-Khemakhem M, Bouktila D, Makni H, Makni M. Genetic variability of the Tomato Leaf Miner (*Tuta absoluta* Meyrick; Lepidoptera: Gelechiidae) in Tunisia, inferred from RAPD-PCR. Chilean J Agri Res. 2012;72(2):212-216
3. Biondi A, Guedes RNC, Wan FH, Desneux N. Ecology, worldwide spread and management of the invasive South American tomato pinworm, *Tuta absoluta*: past, present and future. Ann RevEntomol. 2018;63:239-258
4. Blazheyski S, Kalaitzaki AP, Tsagkarakis AE, Impact of nitrogen and potassium fertilization regimes on the biology of the tomato leaf miner *Tuta absoluta*. Entomol Gen. 2018;37:157-174
5. Bradshaw CJ, Leroy B, Bellard C, Roiz D. Massive yet grossly underestimated global costs of invasive insects, Nat Comm. 2016;7:12986
6. Campolo O, Cherif A, Ricupero M, Siscaro G, Grissa-Lebdi K, Russo A, *et al*: Citrus peel essential oil nanoformulations to control the tomato borer, *Tuta absoluta*: Chemical properties and biological activity. Scientific Rep, 7, 1-10.
7. Campos MR, Biondi A, Adiga A, Guedes RNC, Desneux N. From the Western Palaearctic region to beyond: *Tuta absoluta* 10 years after invading Europe. J Pest Sci, 90, 787–796
8. Chermiti B, Abbes K, Aoun M, Ben S, Ouhibi M, Gamoon W, Kacem S. First estimate of the damage of *Tuta absoluta* (Povolny) (Lepidoptera: Gelechiidae) and Evaluation of the efficiency of sex pheromone traps in greenhouses of tomato crops in the Bekalta Region, Tunisia. The African J Plant Sci Biotechnol. 2009;3:49-52
9. Chidege M, Al-Zaidi S, Hassan N, Julie A, Kaaya E, Mrogoro S. First record of tomato leaf miner *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in Tanzania. Agri Food Sec. 2016;5:1-7
10. Cifuentes D, Chynoweth R, Bielza P. Genetic study of Mediterranean and South American populations of tomato leafminer *Tuta absoluta* (Povolny, 1994) (Lepidoptera: Gelechiidae) using ribosomal and mitochondrial markers Pest Manag Sci. 2011;67:1155-1162.
11. Campolo O, Cherif A, Ricupero M, Siscaro G, Lebdi K, Russo A, *et al*: Citrus peel essential oil nano formulations to control the tomato borer, *Tuta absoluta*: Chemical properties and biological activity. Scientific Rep. 2017;7:13036
12. Desneux N, Luna MG, Guillemaud T, Urbaneja A: The invasive South American tomato pinworm, *Tuta absoluta*, continues to spread in Afro-Eurasia and beyond: the new threat to tomato world production. J Pest Sci. 2011;84:403-408
13. Desneux N, Wajnberg E, Wyckhuys K, Burgio G, Arpaia S, Narváez-Vasquez CA, *et al*. Biological invasion of European tomato crops by *Tuta absoluta*: Ecology, geographic expansion and prospects for biological control. J Pest Sci. 2010;83:197-215
14. EPPO: Data sheets on quarantine pests: *Tuta absoluta* - EPPO Bullet. 2005;35:434-435
15. Ferrara AAF, Vilela EF, Jham NG, Eiras ÁE, Picanco MC, Attygalle AB. Evaluation of the synthetic major component of the sex pheromone of *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) J Chem Ecol, 2001:27(5):907-917.
16. Han P, Desneux N, Becker C, Larbat R, Le Bot J, Adamowicz S, *et al*. Bottom-up effects of irrigation, fertilization and plant resistance on *Tuta absoluta*: Implications for Integrated Pest Management J Pest Sci. 2018;92:1359-1370.
17. Kambhampati S, Black WC, Rai KS. Random amplified polymorphic DNA of mosquito species and populations: techniques, statistical analysis and applications. J MedEntomol. 1992;29:939-945.
18. Kurmi A, Pachori R, Bhowmick AK, Sharma AK, Thomas M, Sharma HL. Bio-diversity of photo-tactic hemipteran insects in the rice ecosystems Jabalpur district, Madhya Pradesh, India. J Entomol Zool Stud. 2019;7(3):1359-1362.
19. Levy D. Meet the *Tuta absoluta* Tomato News. 2010;6:7-10.
20. Seebens H, Blackburn TM, Dyer EE, Genovesi P. No saturation in the accumulation of alien species worldwide. Nat Commun. 2017;8:14435.
21. Sheikh AH, Thomas M, Bhandari R, Meshram H. Malaise trap and insect sampling: Mini Review. Biol Bullet. 2016a;2(2):35-40.
22. Sheikh AH, Thomas M, Bhandari R, Bunkar K. Light trap and insect sampling: an overview. Int J Curr Res. 2016b;8(11):40868-40873.
23. Sheikh AH, Kumar G, Thomas M, Bhandari R. Taxonomic studies on vespid wasps (hymenoptera: vespoidea: vespidae) of Dumna Nature Park, Jabalpur, Madhya Pradesh. The Rec Zool Sur India. 2016c;117(3):198-213.
24. Sheikh AH, Ganaie GA, Thomas M, Bhandari R, Rather YA. Ant pitfall trap sampling: An overview. J Entomol Res. 2018;42(3):421-436.
25. Soares MA, Campos MR, Passos LC, Carvalho GA, Haro MM, *et al*. Botanical insecticide and natural enemies: A potential combination for pest management against *Tuta absoluta*.J Pest Sci. 2019;92:1433-1443.
26. Toševski I, Jović J, Mitrovizć M, Cvrković T, Krstić O, Krnjajić S. *Tuta absoluta* (Meyrick, 1917) (Lepidoptera, Gelechiidae): a New Pest of Tomato in Serbia. Pesticides Phytomed. 2011;26(3):197-204.
27. Viggiani G, Filella F, Delrio G, Ramassini W, Foxi C. *Tuta absoluta*, a new Lepidoptera now reported in Italy. Inform Agrar. 2009;65:66-68.