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Bioscience Research

https://dspace.nm-aist.ac.tz/handle/20.500.12479/1042

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**Article** *in* Bioscience Research · September 2020



Never Zekeya
The Nelson Mandela African Institute of Science and Technology


Musa Chacha
The Nelson Mandela African Institute of Science and Technology


Ernest Mbega
The Nelson Mandela African Institutation of Science and Technology

Available online freely at www.isisn.org

**Bioscience Research**

**Print ISSN: 1811-9506 Online ISSN: 2218-3973**

*Journal by Innovative Scientific Information & Services Network*

**RESEARCH ARTICLE** BIOSCIENCE RESEARCH, 2020 17(2): 874-880. **OPEN ACCESS**

# Understanding factors influencing distribution and density of a micro-Lepidoptera moth, *Tuta absoluta* (Gelechiidae) and its impact in tomato agroecological zones of Tanzania

**Never Zekeya[1], Johnson Ouma[2], Musa Chacha[1], Humphrey Ndossi[3] and Ernest Rashi Mbega[1]**

[1]Department of Sustainable Agriculture and Biodiversity Conservation, School of Life Science and Bioengineering, Nelson Mandela African Institution of Science and Technology P.O. Box 447, Arusha, **Tanzania**
[2]Africa Technical Research Centre, Vector Health International Ltd, P.O. Box 15500, Arusha, **Tanzania**
[3]Tanzania Industrial Research and Development Organization, P. O. Box 23235, Dar es salaam, **Tanzania**

***Correspondence:** neverz@nm-aist.ac.tz **Received 09-03-2020, Revised: 17-05-2020, Accepted: 19-05-2020 e-Published: 07-06-2020**

Field survey was conducted from August to November 2016 and repeated from January to April 2017 to study population, distribution and damage by tomato leaf miner (TLM) (*Tuta absoluta* Meyrick 1977) in 156 farms in agroecological zones of Tanzania. A pheromone trap/farm was deployed in tomato or other Solanaceae's crops for examining moth of *T. absoluta* stuck in each trap and to determine damage by TLM. Results indicated that TLM is present in 13 regions with the highest population in Southern zone (Iringa), Northern zone (Arusha) and East-Central (Morogoro) with catches averaging 357.8±25.5, 279.9±12.1, 298.7±11.4 and 173.1±10.1 moths/trap in dry season respectively whereas lowest count amounting 13.3±1.0moths/trap was observed in western zone (Mwanza) during rainy season. Tomato was the most damaged crop with high mines averaging 90.0 ± 0.0% damage in Iringa and the low of 30.0±5.7 % realized in Mwanza. *Tuta absoluta* was found attacking 10 more plant species besides tomato with damage incidence averaging 83.3 ± 3.7% in *Solanum lycopersicum*, 60.0±0.0% in *Solanum tuberosum*, 30.0±0.0% damage in weed (*Solanum incanum)* and the lowest damage averaging 0.0±0.0% was observed in *capsicum annuum*. Based on these findings, it is evident that, *T. absoluta* is expanding its geographical range and hosts resulting into high damage and yield loss affecting farmers' livelihood in Tanzania. This study informs farmers on the proper use of pheromone traps for early detection, scouting, weeding, crop rotation, use of biological control agents for effective management of the pest to reduce losses and environmental impact due to extensive use of synthetic pesticides.

**Keywords: Crop damage; Economic loss; host range; Invasive *Tuta absoluta;* small holder farmers**

## INTRODUCTION

*Tuta absoluta* (Gelechiidae), commonly known as tomato leaf miner (TLM) is a micro-lepidopteran insect (Lepidoptera: Gelechiidae) native to South America (Desneux, Luna, Guillemaud, and Urbaneja, 2011; Urbaneja, González-Cabrera, Arnó, and Gabarra, 2012). The pest is currently invasive to many European, Asian and African countries leading to deterioration and losses of its preferred tomato host (Arnó et al., 2009; Urbaneja et al., 2012; Zappala et al., 2013). Other threatened hosts include potato (*Solanum tuberosum*) (Pereyra and Sánchez, 2006) and eggplant *Solanum melongena*) (Dandria & Catania, 2009) and night shades (*Solanum nigrum*) and weeds such as *Nicotiana glauca* and *Datura stramonium* (Desneux et al., 2010; Polaszek et al., 2012).Tomato leaf miner is characterized by a high reproduction rate as female TLM can lay about 300 to 350 eggs which may result into similar number of offspring in leading up 10-12 generations per year (Derbalah, Morsey, and El-Samahy, 2012). Due to its aggressive nature, TLM has become a key pest of concern in many countries in Tanzania. Tomato leaf miner was reported for the first time in 2014 in northern regions of Tanzania in tomato plantations leading to yield losses of up to 100% (Chidege et al., 2016). Management of TLM is challenging due to its high reproduction potential (Abd El-Ghany et al., 2016) and to concealed larval feeding nature that occurs within hidden plant parts include stem, fruit or under leaf and this forfends it from contact managements (Zekeya et al., 2016) growth in different locations, for instance, while larvae develop inside plant tissue, pupa develop in the soils and adults can fly away and all these stages are difficult to manage in a single bullet management option including chemical sprays due to resistance development among its populations (Guedes & Picanço, 2012; Lietti, Botto, & Alzogaray, 2005; Silva et al., 2011; Tonnang, Mohamed, Khamis, and Ekesi, 2015). Again, a nocturnal nature of moth and this makes it avoid management options most of which are done during the day (Harizanova, Stoeva, and Mohamedova, 2009). Again, existence of favorable environment and host range such as *S. incanum* harbor it during spray and they hide during the day as well as in tomato offseason (Salem and Abdel-Moniem, 2015). Also, being a new pest, many farmers do not have appropriate knowledge thus stranded on how to manage it (Materu et al., 2016). To reveal this, survey was conducted in agroecological regions growing vegetables in Tanzania to study host range of *T. absoluta* and estimate incidence of damage in each host for suggesting proper management strategies.

## MATERIALS AND METHODS

### Location of the study

Field survey on occurrence, host range, incidence of damage on host, density and yield loss by *Tuta absoluta* was conducted on 156 farmers' fields in thirteen regions namely; Arusha, Iringa, Morogoro, Tanga, Kilimanjaro, Manyara, Singida, Dodoma, Zanzibar, Dar es Salaam, Pwani, Mwanza and Mbeya from September 2016 to December 2016 whereas study on density and yield loss on tomato plantations was repeated from January to April 2017.

### Pheromone traps used in this study

Delta traps (*Tuta absoluta*-Optima, Russell IPM Company, London, UK) containing synthetic female *T. absoluta* sex pheromone, which consists of two components: (3*E*, 8*Z*, 11Z)-3, 8, 11-tetradecatrien-1-yl acetate (TDTA) and (3*E*, 8*Z*)-3, 8-tetradecadien-1-yl acetate (TDDA) (0.5mg per lure) were purchased from ZAIDI AGRO LTD, Dar es Salaam and stored at 4.0$^{O}$ C before use.

### Density and yield loss *T. absoluta* in tomato farms

To assess occurrence and density of *T. absoluta* in Tanzania, thirteen regions were surveyed as follows: In each region, one main tomato growing district was purposively selected based on information available at the regional agricultural office and in each district three villages (four farms from each) were selected. Each farm measuring 0.5ha was planted with tomato variety Tengeru 97. One week after transplanting, one pheromone trap (Russell IPM, UK) was hung 30cm from the ground. Number of *T. absoluta* trapped per delta trap was recorded whereas sticky cards were changed after seven days and lures were changed after six weeks. Other agronomic practices such as weeding, fertilization and irrigation were performed accordingly. In each farm, damage levels and yield loss by *T. absoluta* on tomato were established using methodology described by Kılıç, (2010). After fruit maturity, damaged tomato fruits were sorted from unperforated ones (marketable yield). The percentage of tomato loss was calculated by this formula: (Total Fruit –Marketable Fruit)/Total number of fruits) x 100. This study was conducted from August to November 2016 (dry season) and repeated from January to April 2017 (rainy season).

### Occurrence, host range and incidence of host damage by *T. absoluta*

To assess occurrence, host range and damage due to *T. absoluta* in different host plants, thirteen agroecological regions were selected in which in each district twelve (12) farms were used for this study. Twenty host plants known to be hosts of *T. absoluta* were randomly selected and critically examined for presence of mines on leaves as signs of infestation by the pest. Estimation of damage incidences by *T. absoluta* was calculated by counting number of plants with mines divided by total number of plants of similar species multiplied by 100% in an approximately 0.5-acre plot arranged in a zigzag format within each farm. Incidence of damage by *T. absoluta* larvae on host plants was rated as per Klic el al., 2010. To estimate ascertain occurrence and whether or not the leaf mines were due to *T. absoluta*, a set of pheromone trap was placed in the middle of the farm (farm size was approximately 0.5 acres) and insect trapped were counted on weekly basis and after every seven days sticky card was changed for new catch. This study started mid-August 2016 and ended after 12 weeks consecutively.

### Data analysis

Occurrence, density, incidence of damage on tomato, host range and yield loss were analyzed by SAS program. Mean difference were separated with Tukey's test of honestly significant difference (HSD) at 5% significance level of probability.

## RESULTS

### Distribution, density and yield loss by *T. absoluta* on tomato plants

Results showed that *T. absoluta* exist in 13 regions of Tanzania with varying densities and the number of adult *T. absoluta* trapped differed significantly (*p=<.0001*) between regions (Table 1). Of the surveyed regions southern zone appeared to have the highest moth density averaging 357.8± 25.5 and 299.3 ± 22.7 moths per trap in dry and rainy season respectively, whereas the lowest density of *T. absoluta* averaging 40.3 ± 2.1 and 13.3 ± 1.0 moths per trap was recorded in Mwanza in dry and rainy season respectively (Table 1). However, there was insignificant moth count between Iringa, Arusha and Morogoro whereas differed significantly (*p= <.0001*) in densities and levels incidence damage from rest regions (Table 1). The highest damage averaged 90 ± 0%, 86.6 ± 3.3%, 83.3 ± 5.7% and 80 ±0 in Iringa, Morogoro Arusha, Dar es salaam and Tanga respectively. The lowest damage by *T. absoluta* averaging 30 ± 5.7% was recorded in in Mwanza (Table 1).

### Occurrence and distribution of *T. absoluta* moth on host

Results showed that, out of 11 hosts, ten (10) hosts out grown in agroecological zones were revealed to host *T. absoluta* in Tanzania (Table 2). It was revealed *T. absoluta* moth was mostly attracted by tomato plant in which exhibited the highest moth counts amounting 307±22 moth/trap compared to potato and the rest hosts with lowest moth count averaging 00.00±0.0 in sweet pepper in all regions (Table 2).

**Table 1**: **Distribution, density and yield loss level by *T. absoluta* on tomato plantations**

| Region | Number of moth/ trap in dry season | Number of moth/trap in rainy season | Average fruit damage by *T. absoluta* larvae (%) |
|---|---|---|---|
| **Arusha** | 298.7±11.4a | 192.1 ± 12.1b | 83.3 ± 6.6a |
| **Dar es salaam** | 193.8 ± 9.0b | 135.7 ± 11.1b | 80 .0 ± 0.0a |
| **Dodoma** | 67.4 ±3.3c | 16.2 ±1.2c | 43.3 ± 3.3d |
| **Iringa** | 357.8 ± 25.5a | 299.3 ± 22.7a | 90 .0 ± 0.0a |
| **Kilimanjaro** | 98.0 ± 2.8c | 27.1 ± 2.2c | 53.3 ± 3.7 cd |
| **Mbeya** | 50.4 ± 2.7c | 22.0 ± 1.2c | 46.6 ± 6.6 d |
| **Manyara** | 209.3 ± 15.6b | 137.8 ± 11.3b | 70 ± 5.7bc |
| **Morogoro** | 274.9 ± 12. 5a | 173.1 ± 10. 1b | 86.7 ± 3. 3a |
| **Mwanza** | 40.3 ± 2.1c | 13.3 ± 1.0c | 30 ± 5.7e |
| **Pwani** | 20.8 ± 1.6c | 20.8 ± 1.6c | 43.3 ± 3.3d |
| **Singida** | 114.1 ± 3.6bc | 32.1 ± 3.6c | 43.3 ± 12.0d |
| **Tanga** | 248.0 ± 12.8b | 169.7 ± 14.9b | 80 .0 ± 5.70a |
| **Zanzibar** | 198 ± 18.2b | 121.9 ± 11.9b | 76.6± 3.3b |
| **P value** | <.0001 | <.0001 | <.0001 |

**Table 2: Average number of *T. absoluta* moth trapped on Delta trap on different host plants in thirteen regions of Tanzania**

| Region | SL | ST | SN | SI | SA | SM | CP | CL | DS | SD | CA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Arusha** | 234± 11a | 54±5.4ab | 45±5.1a | 67±11ab | 55±4.2ab | 28±04a | 00±0.0a | 4.0±0.3a | 13±0.0a | 11±0.2a | 12±0.3a |
| **Dares salaam** | 198±18ab | 14±1.7cd | 52±3.7a | 45±9.1bc | 12±2.6c | 12±0.0b | 17±1.0a | 1.0±0.0a | 11±0.7a | 12±0.1a | 09±0.2a |
| **Dodoma** | 54±4.6cd | 08±01cd | 10±0.8 | 12±1.0cd | 17±4.4c | 00±0.0c | 00±0.0b | 1.7±0.2a | 02±0.4a | 00±0.0a | 00±0.0b |
| **Iringa** | 307±22a | 87±09a | 34±7.1ab | 87±1.2a | 81±14a | 17±1.3ab | 04±0.0b | 02±0.2a | 17±1.6a | 7±0.4a | 12±0.5a |
| **Kilimanjaro** | 114±12ab | 52±00b | 28±4.3ab | 43±8.3bc | 87±12a | 20±2.1a | 00±0.0b | 00±0.0a | 12±2.0a | 14±0.6a | 00±0.0b |
| **Mbeya** | 52±3.5cd | 32±03c | 00±0.0d | 17±2.0cd | 00±0.9d | 03±1.1bc | 00±0.0b | 00±0.0a | 40±0.8a | 00±0.0a | 00±0.0b |
| **Manyara** | 179±10ab | 27±06c | 00±0.0d | 23±6.1c | 45±3.0ab | 19±2.0ab | 11±0.5ab | 00±0.0a | 15±1.3a | 08±0.0a | 00±0.0b |
| **Morogoro** | 211±23ab | 73±05ab | 40±6.9a | 51±7.2ab | 67±11ab | 22±1.7a | 16±2.1a | 00±0.0a | 11±0.0a | 00±0.0a | 00±0.0b |
| **Mwanza** | 13±1.2d | 00±00d | 00±00d | 10±00d | 00±0.0d | 2.0±0.8bc | 00±0.0bb | 00±0.0a | 04±0.0a | 00±0.0a | 00±0.0b |
| **Pwani** | 107±6.7b | 00±00d | 12±1.3c | 22±2.5c | 34±1.8bc | 13±1.1b | 00±0.0b | 00±0.0a | 16±1.2a | 00±0.0aa | 00±0.0b |
| **Singida** | 98±10bc | 24±4.2c | 27±3.3ab | 30±0.3c | 50±2.4ab | 12±2.1b | 00±0.0b | 00±0.0a | 05±0.0a | 11±0.0a | 00±0.0b |
| **Tanga** | 138±24b | 67±14ab | 51±5.4a | 33±1.7c | 34±2.6bc | 18±1.2b | 13±1.5ab | 00±0.0a | 06±0.0a | 9±1.9a | 00±0.0b |
| **Zanzibar** | 152±15ab | 00±00 | 49±7.5a | 22±1.8c | 11±1.5c | 00±0.0c | 00±0.0b | 00±0.0a | 07±0.0a | 12±2.1a | 00±0.0b |
| ***P-Value*** | *<.0001* | *<.0001* | *<.0001* | *<.0001* | *<.0001* | *<.0001* | *0.03* | *0.1* | *0.08* | *0.32* | *0.04* |

Average number of *T. absoluta* moth trapped on Delta trap on different host plants in thirteen regions of Tanzania.

The highest *T. absoluta* moth count was observed in Iringa, Arusha, Morogoro and Zanzibar regions with tomato, potato, night shade, African eggplant, eggplant and weed species especially *S. incanum* experiencing high count respectively. Of all these plants, tomato was found to be the most preferred host as it appeared to possess the highest number of *T. absoluta* moth leading to high damage rate compared to other hosts in all surveyed regions.

### Incidence of host damage by *T. absoluta*

Results showed that, potato was the second most preferred host after tomato in all surveyed regions. The highest damage rate reached 60% in Arusha and the lowest incidence was 00% in Morogoro, Tanga, Dodoma, Pwani and Mwanza (Table 3). Damage by *T. absoluta* larvae on night shade plant varied significantly (p<.0001) between regions in which Arusha exhibited the highest score averaging 33.3 ± 3.3 compared to other regions (Table 3). It was also revealed that Zanzibar was the only region where night shade seemed not to be infested by *T. absoluta* (Table 3). The damage by *Tuta absoluta* larvae on weed plant identified as *S. incanum* differed significantly (p<.0001) between surveyed regions with Arusha, Iringa Manyara and Kilimanjaro exhibiting the highest damage level compared to other regions (Table 3).

**Table 3: Percentage of *T. absoluta* damage on different host plants in thirteen regions of Tanzania**

| Region | SL | ST | SN | SI | SA | SM | CP | CL | DS | SD | CA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Iringa** | 90.0 | 36.7 | 26.5 | 30.0 | 23.4 | 10.0 | 3.3 | 7.0 | 3.3 | 3.3 | 0.0 |
| **Morogoro** | 86.6 | 0.0 | 21.0 | 23.3 | 16.6 | 16.7 | 10.0 | 3.3 | 3.3 | 3.3 | 0.0 |
| **Arusha** | 83.3 | 60.0 | 33.3 | 30.0 | 23.1 | 16.0 | 13.3 | 10.0 | 3.3 | 3.3 | 0.0 |
| **Dar es salaam** | 80.0 | 23.3 | 26.6 | 23.2 | 20.0 | 13.4 | 6.3 | 10.0 | 7.6 | 6.6 | 0.0 |
| **Tanga** | 82.0 | 0.0 | 23.3 | 20.0 | 20.0 | 20.0 | 6.0 | 10.0 | 6.5 | 3.3 | 0.0 |
| **Zanzibar** | 76.6 | 0.0 | 0.0 | 16.6 | 6.6 | 0.0 | 0.0 | 0.0 | 0 .0 | 0.0 | 0.0 |
| **Manyara** | 70.0 | 26.6 | 26.6 | 30.0 | 20.0 | 6.6 | 10.0 | 6.6 | 6.6 | 3.3 | 0.0 |
| **Kilimanjaro** | 53.3 | 36.3 | 30.0 | 30.0 | 23.3 | 13.3 | 10.0 | 10.0 | 6.6 | 3.3 | 0.0 |
| **Mbeya** | 46.6 | 33.3 | 23.3 | 13.3 | 20.0 | 6.6 | 10.0 | 3.3 | 0.0 | 0.0 | 0.0 |
| **Dodoma** | 43.3 | 0.0 | 10.0 | 6.6 | 10.0 | 3.3 | 0.0 | 3.3 | 0.0 | 0.0 | 0.0 |
| **Pwani** | 43.3 | 0.0 | 16.6 | 10.0 | 10.0 | 13.3 | 0.0 | 3.3 | 3.3 | 0.0 | 0.0 |
| **Singida** | 43.3 | 0.0 | 16.6 | 13.3 | 13.3 | 10.0 | 3.1 | 3.3 | 0.0 | 0.0 | 0.0 |
| **Mwanza** | 30.0 | 0.0 | 16.6 | 10.0 | 14.0 | 6.6 | 6.5 | 3.3 | 0.0 | 0.0 | 0.0 |

**Legend**: SL=*Solanum lycoperscum*, ST=potato (*Solanum tuberosum*), SN= nightshade (*Solanum nigrum*), SM=, e= eggplant (*Solanum melongena)*, SA=African eggplant (*solanum aethiopicum)*, CP=Chill pepper (*Capsicum*), SD= weed (*Solanum dubium*), SL= watermelon (*Citrullus*

Table 3. Percentage of *T. absoluta* damage on different host plants in thirteen regions surveyed

## DISCUSSION

The survey conducted in thirteen regions of Tanzania revealed that *Tuta absoluta* was present and has established in all regions surveyed. Availability of several host plant speeded up invasion of *T. absoluta* to new areas and rapidly multiplied to increase population (Desneux et al., 2011; Megido, Brostaux, Haubruge, & Verheggen, 2013).

The speed of dispersion and establishment of *T. absoluta* in invading areas was influenced presence of tomato as preferable host and presence other Solanaceae's crops including weed during offseason (Megido et al., 2013; Urbaneja et al., 2013). In 2014, *T. absoluta* was only reported at Ngarenanyuki, northern of Tanzania (Chidege et al., 2016), however survey by this study revealed that up to 2017 *T. absoluta* had invaded and established in more than 13 regions covering all major agro-ecological zones of Tanzania alarming that it will continue localizing many parts of Tanzania and might extend its invasion in rest of southern Sub Saharan Africa. This study found that *T. absoluta* distribution trend was from north (Arusha) to south (Iringa) showing the spread and distribution of *T. absoluta* is rapidly across south direction and adapt quickly to newly environment causing high damage in tomato (Guimapi et al., 2016). High spreading rate is also associated with availability of tomato host across seasons (Braham & Nefzaouil, 2016) which influence spreading not only in farm fields but also in market and town places where Solanaceae's crop are marketed. Although *T. absoluta* has a wide range of hosts and is extending its invasion on new hosts, tomato plant seemed to be the main host than other host in thirteen regions surveyed. This could be due to chemical cues and terpenes secreted by tomato which attract *T. absoluta* for oviposition and feeding (Braham and Nefzaouil (2016). Other Solanaceae's crop especially potato was second leading host of TLM particularly in Arusha region which could be influenced by attractive physiology and cues produced by potato leaves that is close related to tomato plant (Rakha et al., 2017). However, weeds were found to harbor *T. absoluta* in all thirteen regions making it plenty across seasons and sustained the pest during off seasons. This has great impact on insect reproduction potential and could influence leaf damage in early vegetative stage and magnify the problem during fruiting stage when crops are plenty available. However, the population of *T. absoluta* declined in wet season from January to April as high humidity and low temperature interfere with pest behaviour, reproduction and population. Surprisingly, none of *T. absoluta* larvae or moth was reported in *Capsicum annum* (green sweet pepper) thus there was no damage and loss of pepper due to *T. absoluta* larvae. This could be due to unpalatability and hard skin of sweet pepper leaf and fruit. This study informs farmers on the proper use of pheromone traps for early detection of the pest, perform good agricultural practices including weeding, crop rotation and scouting to reduce economic and environmental impact of the pest.

## CONCLUSION

This study revealed that *T. absoluta* is widely distributed and established in various solanaceous hosts causing massive damage and loss to small holders' farmers in Tanzania. Hence, we recommend for sustainable and integrative management options particularly biological control to suppress pest population and its impacts.

## CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

## ACKNOWLEGEMENT

Authors are thankful to Deutscher Akademischer Austauschdienst (DAAD) through special initiative program "a world without hunger" (grant number 57221138) and Net Health Limited for funding the first author in her this study. We also extend our gratitude to extension officers for their cooperation during study in all 13 regions and 156 villagers who offered their farms for this study.

## AUTHOR CONTRIBUTIONS

All authors participated effectively in this research. Author NZ conducted research and prepared first draft, author MC revised and reorganized the second draft whereas author HN advised on the methodology and revised second draft. Author EM participated in study design and data analysis. All author approved the final draft.



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