South American Tomato leafminer, *Tuta absoluta* in Bangladesh: Meeting the Challenge

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**Introduction:**
Tomato (*Solanum lycopersicum* Mill) is one of the important and popular vegetables in Bangladesh. It is a good source of Vitamin A and C, and it provides antioxidant elements such as lycopene which prevents cancer (Bhutani and Kallo, 1983). Regular consumption of tomatoes can prevent short sightedness, night blindness, and other eye diseases. Tomato is also helpful in preventing joint pain problems and respiratory problems. It is grown in 67,000 acres and produces 368,000 MT of tomatoes in Bangladesh (BBS, 2017). Tomato cultivation also creates job opportunities for hundreds of people, including women. In Bangladesh, insect pests like whitefly, tomato fruit borer, serpentine leafminer (*Liriomyza sp*), cutworm, aphid and thrips attack the tomato crop. All these insect pests are managed adopting IPM packages developed by the IPM Innovation Lab in collaboration with BARI. However, in 2016, the South American tomato leafminer, *Tuta absoluta* was detected in the northern part of Bangladesh. The South American tomato leafminer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae), is a serious pest of tomato and as the name implies, is a native of South America. It was first described in 1917 by Meyrick as *Pllorimaea absoluta* from specimens collected in Peru and given the scientific name *Tuta absoluta* by Povolny in 1994 (Muniappan, 2013). It is also known by other common names such as tomato borer, tomato moth, and South American tomato pinworm. It attacks other solanaceous crops like eggplant, potato, pepper and tobacco and some solanaceous weeds, but tomato is the preferred host. It is known to cause 80 to 100% crop loss in tomato unless proper control methods are implemented.

**Biology:**
The taxonomic position of tomato leaf miner is as follows: Class: Insect, Order: Lepidoptera, Family: Gelechiidae, Genus: *Tuta*, Species: *absoluta*. *Tuta absoluta* is a holometabolous insect with a high rate of reproduction. Its life-cycle comprises four development stages viz. egg, larva, pupa and adult, and is completed within 24 days at 270°C (NAPPO, 2012).
Tuta absoluta is a multivoltine and there are about 10-12 generations per year in the typical environment. Adult females lay eggs on host plants and a female could lay up to 260 eggs in its lifetime. The total life cycle is completed within 30-35 days. The adult moth lays its egg on the underside of leaves, buds, stems and calyx of unripe fruits (Muniappan, 2013).

**Eggs:**
Eggs are small, cylindrical, creamy white to yellow, and 0.35 mm long (Figure-1). Newly-laid eggs are creamy white and turn yellow, then yellow-orange during development (Exstay, 2009). When mature, eggs turn dark and the outline of the larval head capsule can be seen through the chorion; this is called the blackhead stage (Vargas, 1970). Eggs are on average 0.383 mm long by 0.211 mm wide (Vargas, 1970). The pre-oviposition period of this insect is short and ranges from 2.3 to 4.6 days depending on temperature. Generally, egg hatching takes place 4-6 days after eggs laying. Eggs are oval in shape.

**Larva:**
The larva is cream in color with a characteristic dark head. There are four larval instars. The larva becomes greenish to light pink in the second to fourth instars. Larval period is the most damaging period, which completes within 12-15 days. Fully-grown larvae usually drop to the ground on a silk thread and pupate in the soil.

**Pupa:**
Pupation may take place in the soil, on the leaf surface or within mines. It takes 4-5 days.

**Adults:**
Adults are 5-7 mm long and with a wingspan of 8-10 mm. The most important identifying characters is the filiform antennae, silverfish-grey scales and characteristic black spots present in the anterior wing.

**Behavior:**
Adults are nocturnal and hide between leaves during the day time (Fernandez and Montagne, 1990; Viggiani et al., 2009).

**Nature of damage:**
The moth lays eggs mostly on the lower leaf surface, and the larvae, upon hatching, mine into the leaves and feed on the mesophyll, affecting the photosynthetic capacity of the plant (Fernandez & Montagne 1990, Uchoa-Fernandes et al 1995, Pereyra & Sánchez 2006). These mines are blotchy and differ from the mines caused by Liriomyza spp., which are narrow and wavy (Figure-7). Typical damage symptoms of Tuta absoluta on leaves are blotch mines that are visible from both adaxial and abaxial leaf surfaces (Figure-2). These mines have dark colored excrement inside and some larva is found feeding on mesophyll tissue. Several such mines cause leaves to turn brown and die. In case of heavy damage, tomato plants shrivel and whole tomato fields appear scorched. Larvae also bore apical buds and stems, resulting in stunted growth, with dark frass visible outside. Usually the larva bore into fruit near the calyx and tunnel into the flesh, leaving galleries clogged with frass. More than one hole is often seen near the calyx on the fruit (Figure-3). When plants from infested fields are shaken, adult moths are found flying near the ground surface.
(Bajracharya, et al., 2016). Some larvae bore in petioles, stalks, young shoots and alter plant growth structure by boring into the stem, apical buds or flower buds. In addition, direct injury to fruits can result in severe yield losses (Colomo & Berta, 2002). Infestation can be at any developmental stage, from seedling to mature stage. It is known to cause 80 to 100% crop loss unless proper control methods are implemented.

Figure-2: Tuta-infested leaf
Figure-3: Tuta-infested fruit

Geographical Distribution:
The South American tomato leaf miner is native to South America. It was first described in 1917 by Meyrick as Phthorimaea absoluta from specimens collected in Peru and given the scientific name Tuta absoluta by Povolny in 1994 (Muniappan, 2013). It was first reported in 2006 on tomato crops in Castellón, Spain, and by 2007 its presence was reported in several places along the Mediterranean coast (David and Catania, 2009).

Figure-4: Geographical distribution in the last dozen years

The South American tomato leafminer invaded Egypt in 2009 (Temerak, 2011). The first report of the pest in Greece and Cyprus was in July 2009 and in November 2009, respectively (Roditakis and Seraphides, 2011). The earliest report of a UK interception for this pest was in a tomato packing facility in March 2009, and in the following July, an outbreak of Tuta absoluta was reported in a UK tomato crop for the first time (Gorman, et al., 2011). The pest was for the first time detected in Sudan in 2010 and it subsequently crossed the Sahara desert and into Kenya in 2014 (Desneux et al. 2011; Maroo, 2015). The pest was first detected in Ethiopia in 2012 (NAPPO, 2012). By early 2014, Tuta absoluta was reported in southern India (Kalleshwaraswamy et al. 2015; Sridhar et al. 2014; Shashank et al. 2015). In early 2016, the moth was found infesting tomato farms in the Kathmandu valley of Nepal (Bajracharya, et al., 2016). In addition, reports have confirmed the pest in north of Bangladesh (Hossain et al. 2016), thus showing how far east the tomato leafminer has spread so far (Figure-4). With its recent introduction into Europe, Central and South Asia and Africa, the tomato leaf miner has become widespread and an important pest throughout these regions in both open field and greenhouse tomato production.

Causes of rapid Dispersion:
The pest could have entered the country through the importation of other commercial goods, including native host plant species or used packing materials, or due to workers commuting between Middle Eastern countries and the Indian subcontinent.

Differences between Liriomyza sp and Tuta absoluta:
Several species of leaf miner are in Bangladesh. Among them, Liriomyza sativae, Liriomyza huidobrensis and Liriomyza trifolii are common in vegetables and ornamental plants. Liriomyza species are polyphagous pests (Spencer 1973, 1976). Bhuiya et al. (2011) conducted a survey in 45 vegetables and spices crops including tomato during 2008-2011 in Bangladesh and found that Liriomyza sativae was common pest (Figure-5). Major differences between Liriomyza sp and Tuta absoluta are described below:
<table>
<thead>
<tr>
<th>SL#</th>
<th><em>Liriomyza sativae</em></th>
<th><em>Tuta absoluta</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Taxonomically this is a fly under order Diptera and family Agromyzidae</td>
<td>Taxonomically this is a moth under order Lepidoptera and family Gelechiidae</td>
</tr>
<tr>
<td>2</td>
<td>Larvae (maggot): Yellowish to light green, head modified to two hooks; three instars</td>
<td>Larvae (Caterpillar): Dark green, head distinct with chewing mouth parts; a black band on prothorax; four instars</td>
</tr>
<tr>
<td>3</td>
<td>Pupation: Generally takes place in soil</td>
<td>Pupation: Takes place in soil, dead dry leaves or in infested parts</td>
</tr>
<tr>
<td>4</td>
<td>Adult: Yellow and brilliant black in color (Figure-5)</td>
<td>Adult: Silver or brownish in color (Figure-6)</td>
</tr>
<tr>
<td>5</td>
<td>Nature of damage: Causes zigzag serpentine mines on leaves</td>
<td>Nature of Damage: Infests both leaf and fruit; Making mines with blotchy symptom on leaf and also bores into fruits</td>
</tr>
<tr>
<td>6</td>
<td>Generally excreta is not found in affected parts</td>
<td>Excreta is found in affected parts</td>
</tr>
</tbody>
</table>

**Monitoring and Identification of Tuta in Bangladesh:**

The scientists of Bangladesh Agricultural Research Institute (BARI), with the support of USAID’s IPM IL (Integrated Pest Management Innovation Lab) at Virginia Tech, conducted a field study on monitoring of *Tuta absoluta* through sex pheromone traps in the border areas of Panchagarh, Jessore and Comilla in 2016. They have identified *Tuta absoluta* in the tomato fields of Chaklarhat Village of Tunirhat under Panchagarh District in May 2016 (Figure-9). They collected trapped insects from Panchagarh. They examined it and took photographs under the stereo-microscope at BARI (Figure-10) and communicated to IPM IL Management Entity. For confirmation, the dead and dry adult specimens were sent to USA and Sangme Lee, Arizona State University, USA confirmed the specimen as *Tuta absoluta* through morphological examination.
Reasons behind monitoring *Tuta* in Bangladesh:
When *Tuta absoluta* was first detected in India in 2014, it was suspected that it would only be a matter of time before it entered Bangladesh. In 2015, two seminars were organized by DAI and IPM IL, Virginia Tech, USA, on *Tuta absoluta* in Bangladesh to create awareness among scientists and policy makers. In 2016, IPM IL, Virginia Tech, USA offered a project for monitoring of *Tuta absoluta* in Bangladesh.

Causes of *Tuta* threats in Bangladesh:
Some characteristics of this invasive species demonstrates *Tuta* is a threat to Bangladesh and other countries. These are:
- *Tuta* can reproduce (10-12 generation per year) rapidly within 25°C temperature and 75% RH
- It can disperse rapidly through flying short distances
- It can establish rapidly in a new environment
- Some strains are resistant to chemical insecticides
- At high densities, damage could result in a loss of almost 80-100%
- Tropical climatic conditions favor its rapid multiplication

Meeting the challenges:
From the survey reports on *Tuta absoluta* in Bangladesh and other *Tuta*-affected countries, it is clear that tomato production of Bangladesh will be seriously affected if no remedial measure is taken. Therefore, the following necessary steps should be taken to eradicate this pest from Bangladesh:

Follow up Good Agriculture practices:
- Resistant variety; practice timely intercultural operation
- Control alternate hosts
- Follow crop rotation
- Use of healthy seedlings
- Use of pest exclusion net
- Hand picking of affected parts and destruction by burning or buried under soil

Use of biopesticides:
- Use of neem-based pesticides such as crude neem kernel extract, Bioneem plus etc.
- Use of Bt/Metarhizium anisopliae
- Installation of sex pheromone trap

Search for biological control agents:
- Effective biological control agent should be identified against *Tuta absoluta*

Integrated Pest Management:
Integrate the package (Foliar spray of Azadirachtin (Bio-Neem plus 1EC @ 1ml/L of water)+ Mass trapping through installation of Delta sex pheromone trap+Application of Metarhizium anisopliae biopesticide in soil @ 5g/L of water) with existing tomato IPM package

Strengthening Research on *Tuta absoluta*:
- At national level involving all relevant department and agencies
- Regional collaboration
- International collaboration

Seminar/workshop/Training:
Management workshop held in Nepal during February, 2017 may be followed. The recommendations are as below:

Recommendations for Management of *Tuta absoluta* from Nepal Conference
1. For Green Houses with pest exclusion nets:
   - Grow healthy tomato seedlings inside a nylon net.
   - Burn and destroy the crop residue from any previous crops or bury the residue one foot deep in a pit.
   - Do not grow other host crops (Solaneaceous crops such as potatoes, eggplant, peppers, tobacco) around the farm. If other solaneaceous crops are grown nearby, the same management practices described below should be followed for those crops. Remove solaneaceous weeds within 50 m of crop.
   - Apply a bio agent such as *Metarhizium anisopliae* @5g/lit in soil along with irrigation water at the time the land is prepared for planting to kill the larva and pupa residing in the soil.
   - Transplant only healthy seedlings free of *Tuta* eggs and larva.
   - Secure holes or openings in the greenhouse exterior to prevent moths entering.
   - Start mass trapping of *Tuta* moths 7 days before transplanting tomatoes in the greenhouse.

   - For mass trapping use 1 light trap (5 to 15 watt CFL bulb, or other rechargeable lights) and 2 Wota-T traps with TLM pheromone lures inside a greenhouse with an area of 12.6m. Change the TLM pheromone lures pursuant to the packaging label based on field viability. Generally, TLM lures have 50-60 days field viability.
   - Spray a bio agent (*Bacillus thuringiensis* @1-2g/lit) or neem oil (*Azadirachtin* @3ml/lit) on standing crops as soon as there are more than 5 moths trapped in any of the traps.
• In the green house, we are blocking the movement of insect pests as well as pollinators and natural predators, so pollination might be disturbed. Ensure pollination by various methods, such as gently brushing the flowers and shaking the staking ropes by hand, using a tuning fork or vibrator near flowers to vibrate the flowers.

• Beside insects, the netting around the green house also blocks the movement of air inside the green house, which causes an increase in temperature and humidity, especially during the hot summer months. This environment favors the growth of fungus and may lead to development of fungal disease inside the green house.

• To help remove this concern, make provision for ventilation at the top when building the green house, which will remove the hot air and make space for cool air to come inside the green house. The current recommendation is that the ventilation area at the top should be screened with netting material. The direction of the roof vent should be opposite the prevailing wind direction.

• Alternatively, a shade net can be used over the top of a green house during summer to reduce intensity of sunlight reaching inside.

• A double door system should be used to minimize entry of pests. If a double door system is used, when entering the green house, open the first door to get inside. After closing the first door, open the second door and get inside the green house and close the second door. After completing inside, get outside in the same way as entered. Place 1 sticky trap with TLM lure in the space between two doors to catch moths entering through the first door. Alternatively, a zipper can be used to create a single door system. A zipper system will be more cost friendly than the double door system. If a zipper door system is used, one will need to enter and exit the green house carefully and quickly. Pests in the green house are checked done by using the light and pheromone traps placed in the green house.

• Irrigation dew drums should be installed and operated from outside the green house to reduce the traffic flow into the green house.

• These recommendations for green houses with pest exclusion nets will reduce the need for use of chemical insecticides.

2. For Open Fields/Open Green Houses with no pest exclusion nets:
• Grow healthy tomato seedlings inside a nylon net.
• Burn and destroy the crop residue from previous crops or bury the residue 1 foot deep in a pit.

• Do not grow host crops (Solanaceous crops such as potatoes, eggplant, peppers, tobacco) around the field. If other solanaceous crops are grown nearby, the same management practices described below should be followed for those crops. Remove solanaceous weeds.

• Apply a bio-agent such as Metarhizium anisopliae @5g/lit in soil along with irrigation water at the time of land preparation to kill the pupa residing in the soil.

• Transplant only healthy seedlings free of Tuta eggs and larva.

• Use of plastic mulch reduces pupation in the soil.

• Mass trap Tuta moths seven days before transplanting tomato.

• For farmers with 1 or 2 open greenhouses (12x6m area), 1 light trap (5 to 15 watt CFL bulb, or other rechargeable lights) and 2 Wota-T traps with TLM pheromone lures are recommended for each green house. Change the TLM pheromone lures pursuant to the packaging label base on field viability. Generally, TLM lures have 50-60 days field viability.

• For farmers with large continuous open fields, one light trap and four Wota-T traps with TLM pheromone lures per 500m² are recommended. Change pheromone lures as recommended above.

• Mass trapping should be done on an area basis where all the nearby farmers growing tomatoes or other solanaceous vegetables will install the recommended light traps and pheromone traps in their fields.

• Spray Bacillus thuringiensis @1-2g/L when >5 Tuta moths are found trapped in any of the traps. Frequency of application will depend upon the nature and extent of the infestation.

• Pesticides with different modes of action, sprayed alternately, have been found effective. Alternating applications of botanical pesticides such as neem oil (Azadirachtin @3ml/lit) can be used alternatively with Bacillus thuringiensis @1-2g/L at 7-10 day intervals. Avoid using only one pesticide for a long period as this may lead to development of resistance in insects to that particular pesticide group.

• Regular field inspection is necessary to check for new infestations.

• Remove and destroy infested leaves, shoots and fruits immediately.

• If the above management strategy fails, it may be necessary to spray recommended chemical pesticides with the correct dosage as a “rescue operation.” Do not spray chemical pesticides unnecessarily. Two recommended pesticides that have been used for Tuta are:
Conclusion:
Since *Tuta absoluta* arrived in Bangladesh about three years ago it has spread to almost all tomato growing areas of the country. It has created a significant threat to tomato production especially in Panchagarh area. Therefore, effective control measures should be devised considering the host climatic conditions of Bangladesh.

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