Integrated management of Tomato leaf miner *(Tuta absoluta)* and other tomato pests in Kenya

A training manual for extension workers

Government of the Netherlands

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CAB International (CABI) is an inter-governmental, not-for-profit organization, owned and run by its 50-member countries. Our Mission is to improve people's lives worldwide by providing information and applying scientific expertise to solve problems in agriculture and the environment; with a Vision to be the number one 'go-to place' for insightful and practical science-based knowledge about agriculture and the environment. CABI delivers work in six core areas: Crop health; Value chains and trade; Invasive species management; Development, communication and extension; Digital development; and Science publishing and journalism. Gender and climate change adaptation and mitigation are key considerations across all of our thematic areas.

Koppert Biological Systems is the international market leader in the field of biological crop protection. The company contributes to better health of people and the planet. In partnership with nature, we make agriculture healthier, safer and more productive. We provide an integrated system of specialist knowledge and natural, safe solutions that improves crop health, resilience and production. Integrated Pest Management (IPM) is a key element for growers to sustainably manage pests and diseases. Koppert supplies the tools to achieve this. The company however does not only seek to offer ready solutions, but rather to also act as an enabler. Indeed, numerous solutions are developed through strategic partnerships, and disseminated through training and education. We believe that sharing knowledge is a key element for success.

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Cover: Tomato leaf miner damage symptoms on the fruit, and adult tomato leaf miner moth. (Photos: CABI)

Contents

Background

Development challenge

Tomato is one of the most popular and widely grown vegetables in Kenya, cultivated in almost all the 47 counties. However, despite its socio-economic significance, the production of this key crop is constrained by numerous abiotic and biotic factors, among them insect pests. Since its arrival in Kenya in 2014, the tomato leaf miner, *Tuta absoluta*, has become the most serious threat to sustainable tomato productivity, causing between 50-80% yield loss if no control method is applied.

Approximately 98% of Kenyan farmers suffer from *T. absoluta* attacks in their tomato fields each season. To manage this pest, smallholder vegetable farmers typically rely on insecticides and spray between 6-10 times per season. As a result, *T. absoluta* is developing resistance to pesticides, leading to production losses and increased input costs. A study by CABI on farmers' coping strategies towards the tomato leaf miner showed that 96.5% of farmers apply pesticides but only 27% report success. Furthermore, in addition to not using or improper use of Personal Protective Equipment (PPE) many farmers do not observe pre-harvest intervals resulting in pesticide residues entering the human food chain, posing health risks to applicators and consumers respectively.

Biological control methods, therefore, becomes an important component in the integrated management of this pest. They can offer a safer, more cost-effective and environmentally-friendly management option for smallholder tomato farmers.

The solution

CABI joined forces with world-leading biological control specialist **Koppert Biological Systems** to step-up a more sustainable fight against the tomato leaf miner ***Tuta absoluta***. The initiative focused on an Integrated Pest Management (IPM) approach, including use of a predatory mirid *Macrolophus pygmaeus* (MIRICAL), pheromone trap system (Pherodis plus Traps, and Trianum-P for the management of soil-borne pathogens, together with other good agricultural practices.

Purpose of the manual

This training manual is as a result of the collaborative work between CABI and Koppert Biological Systems. The objective of this manual is to guide trainings offered to tomato famers on sustainable tomato production with key focus on the management of the tomato leaf miner *(Tuta absoluta)*, based on lessons learned from the project. The manual also provides information about other key tomato pests that farmers are likely to encounter on their farms and how they can be managed within the IPM framework. The information provided is applicable to tomato farming in both greenhouses and open fields.

How the manual is organized

The manual is organised in 6 modules covering the management of pests and disease on tomato, with greater emphasis on tomato leaf miner:

Module 1: Introduction

Module 2: Tomato good agricultural practices

Module 3: Overview of major pests and diseases of tomato and their management

Module 4: Identification of tomato leaf miner *(Tuta absoluta)*

Module 5: Management of tomato leaf miner *(Tuta absoluta)*

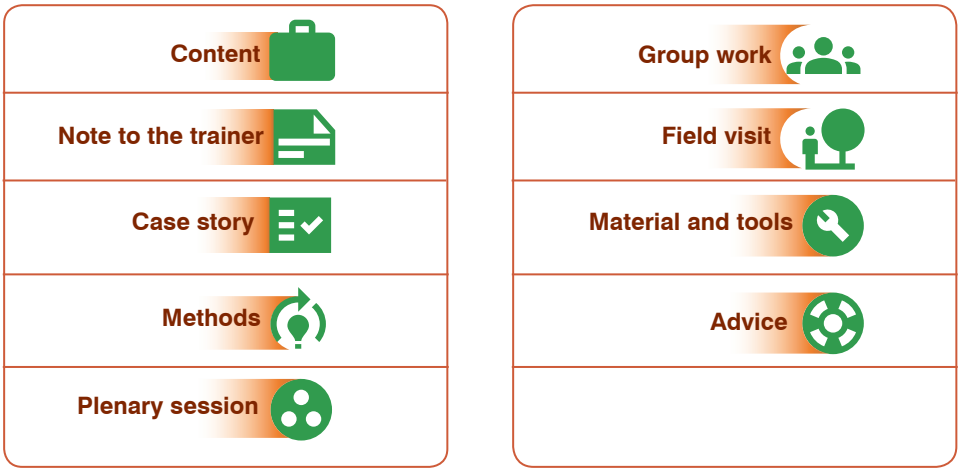
Module 6: Integrated Pest Management (IPM) practices for tomato leaf minere *(Tuta absoluta)*

Under each module, the following are covered:

i. Module number and name (this is split into topics for modules with a lot of content) .
ii. Learning objective(s).
iii. Case stories, lesson(s) learnt, or example from the field in Kenya.
iv. Content – important information about the topic.
v. Methods – methods used for training e.g. Q&A, plenaries, group work, field visit, etc.
vi. Materials and tools - e.g. writing materials, demonstration materials, reference materials etc.
vii. Notes to the facilitator – things to keep in mind while handling the topic.
viii. Advice – points of emphasis, additional information, or take-away messages.

How to read/use this manual

The manual is a guide for extension workers, plant doctors, farmers' trainers and community facilitators who work with farmers. It offers content, case stories, examples from the field in Kenya and guidelines/ advice to facilitators to prepare and conduct their sessions. Trainers may propose sessions depending on the level of awareness of the farmers or the specific needs of the farmers at a particular point in time.Icons are used throughout the document to provide guidance to the facilitator:



Module 1: Introduction

Objectives

1. Understand the importance of tomato production, where the crop is grown and contribution to the economy of the country
2. Know the different production requirements of tomato in the open field, and in green houses
3. Know available tomato varieties, their growth habits and, pest and disease tolerance

Tomato production in Kenya

- Kenya is one of sub-Saharan Africa's top tomato producers and grows more than 400,000 tonnesw of the fruit every year. Tomato is cultivated in all 47 counties in Kenya.
- Tomato is the second most valuable vegetable in terms of production and value after potato in Kenya.
- Tomato meets domestic and nutritional food requirements.
- Tomato generates income and creates employment for both the rural and urban populations in Kenya.
- However, farmers are getting up to 80-100% crop losses due to this insect pest and disease complex.

Content

Tomato classification

- Scientific Name: *Solanum lycopersicum*
- Order / Family: Solanaceae
- Common name: Tomato
- Local Names: Nyanya (Swahili)

What is tomato, a fruit or a vegetable?

- Tomato is both a fruit and vegetable
- When eaten RAW it is a FRUIT and when COOKED it is a VEGETABLE
- Scientifically, a fruit is the reproductive body of a seed plant. Simply "anything on a plant by which means the plant gets its seeds out into the world, is a fruit".
- Vegetables- are a wide range of plants whose parts are edible like roots, stems, and leaves.

Uses of Tomato

- Tomatoes are mainly eaten raw (for fresh consumption, in salads and starters).
- Are also processed industrially to produce, tomato paste, peeled tomatoes, tomato ketchup, tomato juice and canned tomatoes among others.

Ecological Requirements for tomato production

- **Altitude:** Tomato can be cultivated up to 2,000 metres above sea level
- **Rainfall:** Tomato performs well in areas that receive over 600 mm of rainfall annually. The rainfall should be well distributed throughout the growing season.
- **Temperature:** Tomato performs well in warm climatic conditions. The optimal day and night temperature range is 20 – 25°C and 15 – 17°C, respectively
- **Soil:** Tomato requires well drained sandy loam, or clay loam soils. The optimal soil PH range is 6.0 – 7.5.

Nutrition Requirements for tomato production

- **Soil testing** – Helps the farmer in choosing the proper nutrition regime for his or her tomatoes in order to optimise crop production; protect the environment from contamination by runoff and leaching of excess fertiliser; save money by applying only amount of fertiliser needed.
- **Primary nutrients** – They include nitrogen, phosphorus and potassium (pH is important in fertilizer choice; emphasize on potassium on fruit setting and quality).
- **Secondary nutrients** – They include calcium, magnesium and sulphur (highlight the importance of calcium and prevention of blossom end rot).
- **Micronutrients** – They include zinc, boron, molybdenum, copper etc (Emphasize the importance of boron- cell wall formation and stability, maintenance of structural and functional integrity of biological membranes, movement of sugar or energy into growing parts of plants, and pollination and seed set).
- **Soil microbial amendments** – They include beneficial micro-organisms such as *Bacillus subtilis, Trichoderma* species and *Mycorrhiza* (Panoramix-GR). These are important for nutrient solubilisation.

Note to the trainer Timing is very critical in the application of nutrients.

Tomato production practices

Tomato production in Kenya is conducted in either open field or greenhouses. Productivity of tomato under either system varies, as well as management regimen. Farmers choose either system based on the available resources.

Open field tomato farming

- This is where tomato is grown in open field and relies on natural climatic conditions for growth.
- It can be either rainfed or irrigated.
- Most smallholder farmers in Kenya grow tomato in open field.

Greenhouse farming

- In greenhouse farming, horticultural crops (flowers, fruits and vegetables) are grown under controlled climatic conditions.
- Greenhouse farming is one of the modern technologies that ensures year-round production.

Selection of tomato variety to grow

The following should be considered before selecting a variety to cultivate as the choice of best variety to grow is critical for good yields:

- Growth Habit - determinate (bush) vs indeterminate (climbing).
- Disease resistance/tolerance: indicated by initials after variety name e.g.) “F” for *Fusarium wilt*, “N” for Nematodes.
- Fruit quality- (shape, size & colour). Market requirement will determine fruit type. Those for processing have an intense red colour & more solid. Those for fresh market consumers pay attention to the shape, colour & durability in storage.
- Hybrid or Open Pollinated Variety (OPV).
- Hybrid seeds give higher yields but are more expensive.
- Adaptability and reliability to climatic conditions.
- Plant quality (firmness).
- Availability and suitability to the growing conditions.
- Production practices- open field or greenhouse.

Note to the trainer

- It is important to note that no single variety will combine all the characteristics above
- Some tomato varieties are preferred for open field farming while others are for green house farming. For example, the bush types (determinate) varieties would take up lots of valuable floor space in a greenhouse whereas the indeterminate varieties make best use of the vertical space and are, therefore, far more productive in terms of total yield and the best tomatoes to grow in the greenhouse.

Common tomato varieties in Kenya and their characteristics

- Farmers in Kenya grow a wide range of tomato varieties including cherry tomatoes. It is wise to avoid varieties that offer no resistance to serious diseases prevalent in your area. Table 1 shows the most common varieties in Kenya and their characteristics.

Table 1: Common tomato varieties in Kenya and their characteristics

Variety	Growth habit	Fruit shape	Tolerance/resistance to pest/disease	Remarks(maturity; yield)
Fresh market				
Money maker	Indeterminate	Round	*Tomato leaf curl virus,* bacterial wilt as well as nematodes	67 days; 32-50 T/ha
Rio Grande	Determinate	Square-round	Verticillium and fusarium wilt	128 days; 84 T/ha
Anna F1	Indeterminate	Oval	Fusarium, Verticillium Wilt, Alternaria Stem Canker and Nematodes	75 days: 74 T/acre
Eden F1	Determinate	Oval	Alternaria stem Canker, Verticillium wilt, Fusarium Wilt, Nematodes, Grey leaf Spot and Bacterial Speck	75 days: 40–50 T/acre
Rambo F1	Determinate	Oval	Verticillium wilt, Fusarium Wilt, Nematodes, bacterial leaf Spot	75 days from transplanting; 30 T/acre
Kilele F1	Determinate	Oval	*Tomato Yellow Leaf Curl Virus*, *Tomato Mosaic Virus*, Verticillium, Fusarium Wilt & Nematodes	75 days after transplanting; 30 T/acre
Assila F1*	Determinate	Oval	*Tomato Yellow Leaf Curl Virus* (TYLCV), Fusarium wilt, Verticillium wilt and Nematodes	75 days; 23 T/acre
Fortune Maker	Indeterminate	Oval shaped	Fusarium and bacterial wilt	80 days; 32 T/acre
Kentom	Indeterminate	Round	Bacterial wilt , Tobacco Mosaic virus (TMV), Root-knot nematodes	70-75 days; 38 T/acre
Processing				
Cal- J	Determinate	Pear	Verticillium, Fusarium Wilt	120 days; 73 T/ha
M-82	Determinate	Pear	Verticillium, Fusarium Wilt	120 days; 57 T/ha
Roma VF	Determinate	Pear	Verticillium, Fusarium Wilt	120 days; 83 T/ha

References:

KALRO. (2016). *Tomato Production Manual 2016.* Retrieved from https://www.kalro.org/sites/default/files/Tomato_production_manual.pdf
SHEP PLUS. (2019). *TOMATO PRODUCTION.* Retrieved from https://www.jica.go.jp/project/english/kenya/015/materials/c8h0vm0000f7o8cj-att/materials_26.pdf

Note to the trainer

Farmers may also have other varieties known to them. Farmers can discuss them in plenary and their characteristics given the above criteria.

Methods

- A power point presentation and discussions on the basics of tomato production as above.
- Plenary discussion.
- Farmers can expand the list of varieties based on their experiences.

Material and tools

- Power point slides, flip charts, marker pens.

Advice

- Emphasise the need to grow tomato varieties that are demanded by the consumers.

Module 2: Tomato good agricultural practices

Objectives

- Obtain knowledge about tomato good agricultural practices for achieving a higher yield and quality tomatoes.

Good agricultural practices improve yield

Good agricultural Practices (GAP) ensure; economic viability, environmental sustainabilty, social acceptability and food safety and quality. The concept of GAPs has evolved to address the concerns of different stakeholders about food production and security, food safety and quality, and the environmental sustainability of agriculture.

A farmer in Kenya displays his tomato harvest (Photo: Maina Waruru)

Producers need to apply good agricultural practices from seed selection to harvesting to ensure quality, and thus higher incomes.

Content

Good agricultural practices (GAPs) are a set of principles, regulations and technical recommendations applicable to production, addressing human health care and environment protection.

By using GAPs farmers and their families obtain healthy and good quality food to assure their nutrition and nourishment, generating a value added in their products to access markets in a better way; consumers enjoy better and safe quality food, with sustainable production; and the population in general, benefits from a better environment.

When applied throughout the cropping season, GAPs are an important component for achieving high yield and better-quality tomato. GAPs also help to manage pests and diseases, and are important in integrated pest management (IPM) strategy (see module 6 on IPM).

GAPs in tomato production, what is the best place to start?

Land preparation

Ensure appropriate land selection and preparation to enhance crop growth. The following are important considerations:

- Know the history of the field, recognize more fertile lands and with availability of water.
- With the support of a technician analyze the type of soil and its depth for good growth of the roots.
- Undertake soil testing to understand the level of nutrients to guide fertility management plan.
- When preparing land for planting, hardpans or compacted soil should be thoroughly loosened by deep ploughing to enable the root system to spread to a depth of 40 – 60cm.
- The field should be near a reliable water source as tomatoes require frequent watering.
- Low soil pH can be corrected by addition of Lime. High soil pH or sodic soils remediation is done by application of Gypsum.

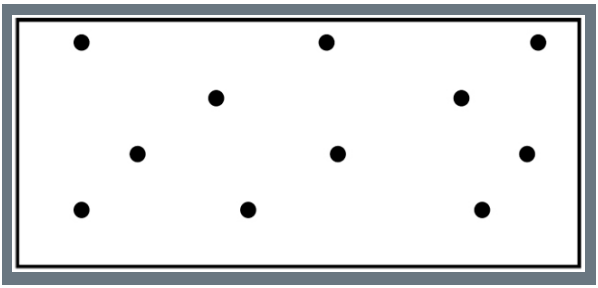
- Manage soil-borne pathogens and nematodes by soil solarization after a deep plough, or drench the soil with Trianum-P or other registered products.
- Regular ridges should be done about 30 - 35 cm high and 25 – 30 cm wide.

Note to the trainer

In situations where farmers can practice minimum tillage in tomato production systems, this is encouraged to keep the disturbance of the soil and loss of organic matter to a minimum.

Simple soil sampling guide

Step 1: Using a hoe or panga obtain thin slices of soil from at least 13 randomly distributed spots in a given field. See illustration below as a guide:



Step 2: Mix all the soil taken from the field into one composite sample. Spread soil on newspaper in a warm room to air dry overnight. Do not heat.
Step 3: Take 1 cup of representative sample and place in the soil mailing kit bag. Send the soil sample and submission form to your testing lab.

Note:
1. Avoid taking samples from areas such as lime piles, fertilizer spills, ant hills, gate areas, live stock congregation areas, poorly drained areas, dead furrows, fertilizer bands, old fence rows, or any other unusual areas.
2. Do not use galvanized, soft steel or brass equipment if analysis for trace metal analyses is desired. Clean all tools between sampling

Seed selection

- Use certified disease-free seed of suitable varieties.
- Use varieties tolerant or resistant to pests and diseases. (see module 1 for some tomato varieties).

Raising seedlings

Farmers are advised to raise their own seedlings or buy clean seedlings from certified nursery operators. Sourcing for seed from unknown sources can be a source of pests and diseases, including soil-borne diseases. The following should be followed when raising own seedlings:

The following should be followed when raising own seedlings:

- Seedlings should be raised in a nursery large enough to meet the farmer's requirement for planting materials.
- Dimensions: The 'bed' should be 1 meter wide, 10-20 cm between seedling rows. If you need another 'bed' – make them at least 50 cm apart.
- Nursery trays can also be used for a small garden.
- After sowing, water the nursery regularly. Avoid over watering.

- Drench the nursery with Trianum-P shortly after germination for preventive control of soil-borne pathogens such as *Fusarium*. (More details provided in Module 6)
- Harden the seedlings 1 – 2 weeks before transplanting: by reducing the frequency of watering and gradually exposing the seedlings direct sunlight.
- Control insects such as whiteflies and aphids using biopesticides. Examples of biopesticides that can be used and available in Kenya are:
    - o Nimbecidine- active ingredient is *Azadirachtin* (neem based)
    - o Mycotal (*Lecanicillium muscarium*)
    - o Biocatch - active ingredient is *Lecanicillium muscarium*
- Insects can be blocked from reaching the seedlings by use of an insect proof net

(see picture of a simple netting)

Note to the trainer

- Emphasize the need to manage soil-borne pathogens in the nursery. Trianum-P is a low risk option and is easily available in Kenya.
- Since tomato is usually consumed as a fruit, it is important for farmers to use low risk products.
- Emphasize the use of biopesticides and safe handling of plant protection products.

Seedlings raised in a nursery tray (Photo: SHEP-PLUS)

Netting on a nursery bed (Photo: SHEP-PLUS)

Transplanting stage

- Seedlings are transplanted 30 – 45 days after seed sowing.
- Recommended: transplanting should be done either early in the morning or late in the evening.
- Recommended spacing: ranges from 75 – 100 cm (between rows) and 40 – 60 cm (between seedlings) depending on tomato variety.
- Correct spacing produces short, stocky plant with good roots system. Plant population per acre ranges between 6,666 to 13,333 plants depending on plant spacing.
- Avoid transplanting seedlings near to an old tomato crop.
- Ensure that a new field is sited uphill, particularly where surface irrigation is used to avoid spread of soil-borne diseases.
- Plant border rows of coriander, fenugreek, maize, marigold, millet, pigeon pea or sorghum. They act as windbreaks; fenugreek and coriander are repellent to whiteflies, and provide refuge for natural enemies.
- Apply organic manure, mixing it well with the soil before transplanting.

Field management

Watering: Tomato is sensitive to insufficient water especially immediately after transplanting, during flowering and fruit development. So, plants should be provided with adequate water. However, tomato plants are equally sensitive to water logging. If flooded, fields should be drained within 1 – 3 days. Furrow and drip irrigation are the most effective methods for providing irrigation water.

* Furrow irrigation minimizes spread of fungal diseases, such as "Early Blight" but may spread soil borne diseases such as bacterial and *Fusarium* wilts.
* Drip irrigation on the other hand is efficient on water utilization.
* Overhead irrigation encourages spread of diseases such as "Early Blight".
* Watering can irrigation can also be used, it is only suitable for small plots.

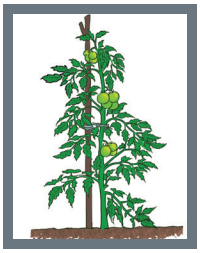
Weed management: generally, keep the field weed-free as much as possible to avoid competition for nutrients, sunlight and moisture. Weeds also provide habitat for pests and diseases. Avoid bruising the roots during weeding by using appropriate weeding tools. Weeding tomato field when the soil is wet can increase the spread of some bacterial (Bacterial Wilt) and fungal (*Fusarium* Wilt) diseases.

Fertiliser application: Proper fertilization provides the required nutrients to the plant and this gives the plant a competitive ability to tolerate pest damage, and achieve higher yields for farmers. If possible, farmers can obtain technical support for soil testing to inform their nutrition regime.

— Apply a compound fertilizer that has adequate amounts of Nitrogen, Phosphorus and Potassium at transplanting, and 30 –45 days after seed germination at the rate of 80 kg/ acre =10g/hole =2 bottle tops/ hole).
— Where possible obtain a fertilizer providing secondary and micronutrients.
— Top-dress with fertilizer such as CAN (Calcium Ammonium Nitrate) in 2 splits at 40 kg/ acre and 80 kg/acre). This is equivalent to 5g (1bottle top) and 10g (2 bottle tops) per plant in each application respectively.
— Apply adequate amounts of Potassium and Boron during the top-dressing exercise.
— Top dressing should be done at 4 and 8 weeks after transplanting.
— Application method should be-circular band around the stem (placement method) using e.g. a bottle top.

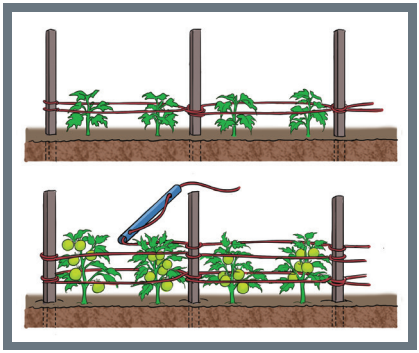
Training and staking: Staking tomatoes improves fruit quality by keeping fruit off the ground and increasing air flow through the plant. A structured training system can also make tomatoes easier to harvest.

* Staking systems are usually installed 2-3 weeks after transplanting or when plants reach a height of 12-15 inches.
* Farmers can select any of the two most common training systems; stake and weave and Trellis [illustration -3]



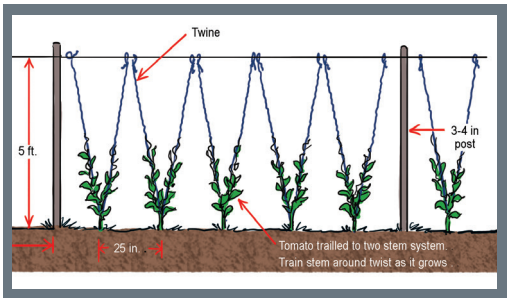
Single stake

Single stake - A single, 8-foot-long stake is driven about 2 feet into the ground approximately 3 to 4 inches from each plant. Tie the plant to the stake with strips of old nylon hose or sisal about every 12 inches up the stem. Tie the material in a loose figure 8, with the stake in one loop and the stem in the other. The roots of the tomato plants may be injured if the stakes are put in later in the season.



Stake and weave

Stake and weave - Wooden or metal stakes are driven between every other tomato plant. Lines of twine are strung between stakes on either side of the plants to provide support.



trellis system for tomato

Trellising - A system used to train indeterminate tomatoes. It consists of heavy gauge wire strung horizontally across the top of widely spaced, sturdy (3-6 inch) support posts. Lengths of twine are dropped from this top wire and secured to the base of each tomato plant (or to a bottom wire, if used). Support posts should stand 5-6 feet above the soil and be spaced 12-20 feet apart down the row.

Note to the trainer

The growth habit of your specific variety will help determine stake length. Indeterminate varieties require longer stakes (5-6 feet) than determinate varieties (3-4 feet).

Pruning: Good pruning achieves the optimum balance between vegetative growth and fruit production. Pruning helps increase fruit size, fruit quality and yield, so it is important to strike the right balance between reducing vigorous foliage and stripping the plant. When pruning:

— Remove side shoots, extra flowers, fruits and diseased leaves.
— Sterilize pruning blades by use of chlorine bleach (Jik) and water at a ratio of 1:1.
— Use of unsterilized blades can lead to spread of diseases e.g. *Tomato Mosaic Virus* and Bacterial Wilt.

Methods

- Presentation on key aspects of tomato agronomy.
- Group discussions on current farmer practices and how they compare with what has been covered in the presentations.
- Carry out demonstrations on key aspects e.g.
    - Nursery establishment
    - How to drench with Trianum-P
    - How to transplant and do spacing in the field
    - How to prune.

- Farmers can visit established farms nearby and judge if good agricultural practices are being followed and advice their fellow farmers on what can be improved.

Material and tools

- Presentation
- Writing materials e.g. flipchart, markers etc.
- Seed, Trianum-P, and other inputs if demonstrations will be done

Advice

Trainer should emphasize;

- Importance of GAPs in achieving good yield, environmental protection and food safety.
- Use of low risk plant protection inputs such as Trianum-P for soil borne pathogens, and biopesticides for management of insect pests e.g. white flies.
- Detailed information on management of key pests and diseases is covered in Module 3.

Module 3: Management of major pests and diseases of tomato

Objectives

- Farmers know signs and symptoms of common pests and diseases of tomato.
- Farmers get tips on how to prevent key tomato pests and diseases.
- Farmers learn available methods for management of key tomato pests and diseases.

Pest and disease identification capacity limited for smallholder farmers

Although tomato is among the promising commodities in horticultural production in Kenya and over the years production has intensified, farmers are not seeing increased yields.

A farmer in Juja using a hand lens to identify tomato pest/disease with the help of a technical person (Photo: CABI)

Analysis of plant clinics data from 14 counties in Kenya by CABI has shown that this is due to a myriad of constraints related to climate change and soil health, but most importantly due to plant pests and diseases.

While farmers in Kenya apply various methods for the control of the pests and diseases, capacity for proper identification remains a challenge to effective control of the problems. Some insect pests/diseases can not be identified with naked eyes and require use of hand lenses. In some cases, farmers may confuse nutritional deficiencies to pest/disease symptoms.

As such, farmers tend to indiscriminately apply chemical sprays with the associated negative health and environmental impacts.

Content

This module covers the most important pests of tomato. This module covers the most common pests, diseases and pathogens for tomato, identification, and management practices (Tables 2, 3, and 4).

Note to the trainer

- This module covers other pests other than tomato leaf miner which is covered in detail in Modules 4, 5 and 6.
- To enhance identification by farmers, use the photo sheets for the various pests. Further information can be accessed via phone or tablet using the Plantwise Factsheets Library App (available on google play store).

Advice

- In plenary, introduce the topic through a presentation to farmers, cover the three categories of pests – soil-borne, insect pests, diseases.
- After field activity/group work, go through the management practices as indicated in Tables 2, 3 and 4, including discussion on what farmers know.

Group work

Farmers discuss.

i. What key pests and diseases are commonly seen on tomato fields/crops.
ii. At what time of the season do they observe the pests.
iii. How farmers are managing the key pests. Divide the practices into cultural, physical, chemical and biological.

Field visit

i. Farmers visit a nearby tomato farm to identify pests and diseases, diseased plants, and symptomatic plants.
ii. Use photo guide to help farmers to identify and differentiate the various pests/ diseases.
iii. Discuss management options for each.

Content

- Flipchart, markets
- Photo guides
- Magnifying glass/lens
- Vials and khaki bags

Advice

- It is important for farmers to clearly identify pests and diseases affecting their crop, which guides in making decision on which management practice to use. Depending on the available time, the trainer may choose to cover each category of pests separately to give more time for discussion with farmers. The categories as indicated in this manual are; soil pathogens, insects pests, and diseases.
- Emphasize the importance of using certified or clean planting materials, good agricultural practices and field sanitation as a preventive measure for pest and disease management.
- Emphasize use of Trianum-P (a preventive fungal Bio-fungicide) or any other registered product with known efficacy against soil borne pathogens. Detailed information on how to apply Trianum-P is covered in (Module 6).

Table 2: Problems from the soil (Soil borne diseases of tomato)

Disease	Symptoms	Management Measures
Fusarium Wilt *(Fusarium oxysporum sp. lycopersici)*	• The lower leaves of the plant usually wilt, turn yellow and die, mostly on one side of plant. • One or more branches may exhibit such symptoms. • Affected stems and petioles, just above ground level, show a reddish-brown discolouration of the water conducting tissues, when cut diagonally.	• Monitor and scout for symptoms regularly. • Use resistant tomato varieties (refer to Table 1 in the Introduction section). • Use certified seeds/ clean planting material. • Do not locate seedbeds on land where *Fusarium* wilt is known to have occurred. • In acidic soil, raise the pH by applying lime. • Avoid excessive nitrogen fertilisation and control root-knot nematodes. • Use of Trianum-P (a preventive fungal Bio-fungicide- (see module 6).
Bacterial Wilt *(Ralstonia solanacearum)*	• It is reported as the most serious problem for tomato production in the tropics. • The disease causes rapid wilting and death of the entire plant without any yellowing or spotting of leaves • Plant wilts while still green. • Total collapse of the plant usually occurring when temperatures reach 32 °C and above. • For diagnosis, conduct a field bacterial streaming -test: * Cut a stem or rhizome and suspend it in a glass of water. After a few minutes, you should be able to see a thin, milky line of bacteria streaming out of the cut stem, veins and tissues. Fig 3.1.	• Monitor and scout for symptoms regularly. • Use certified seeds/ clean planting material. • Practice crop rotation with crops such as cereals. • Remove wilted plants, with the soil around roots, from the field and destroy them. • Solarize planting beds. • Spot treatment with *Sodium Hypochlorite* at 10 % dilution (Jik) or with lime/ ash. • Sterilize pruning tools.
Damping-off- *(Pythium spp., Rhizoctonia spp. and Sclerotinia)*	• Damping-off occurs when seedlings die before they have pushed through the soil, resulting in patches that appear to have germinated poorly. • Seedlings may also emerge but fall over and die some time afterwards. • The base of stem of affected seedlings become wet and brown.	• Monitor and scout for symptoms regularly. • Avoid locating the seedbed on previously infested field, overcrowding of seedlings, excessive fertilizer application or excessive watering to young seedlings while still at nursery bed. • Use certified seeds/ clean planting material. • Use Trianum-P (a preventive Bio-fungicide). • Apply products containing Metalaxyl + Mancozeb.
Nematodes *(Meloidogyne sp.)*	• Root-knot nematodes are very destructive to tomatoes. • They cause small lumps known as root knots or galls on the roots. • Heavily infected roots are severely distorted and swollen and with time they rot. • The affected plants get stunted, wilt, yellow or die in hot weather. • The plants, in most cases, just wilt with the foliage still green - some times without yellowing. • Nematode problem is primarily due to improper crop rotation.	• Monitor and scout for symptoms regularly. • Rotate tomato with poor or non-hosts crops e.g. cereals, leguminous crops etc. • Do not locate seedbeds where susceptible vegetables (e.g. okra, sweet pepper, egg plant, Irish potato, carrot or cucurbits) have been previously grown. • Use tolerant or resistant tomato varieties. • Use nematode- free seedlings. • Maintaining high levels of organic matter in the soil (manure and compost) improves crop heath, and encourages growth of microbes that reduce nematode activity. • Neem has naturally-occurring compounds that kill nematodes. Mix neem cake in the soil to increase the organic content and kills nematodes. • Soil solarisation. • Fallowing land gradually reduces soil population densities of nematodes.

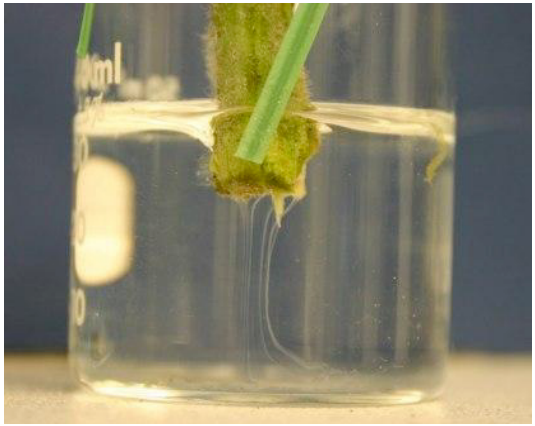


Figure 3.1: Bacterial Streaming Test for Bacterial wilt diagnosis (Notice the thin, milky bacterial lines from the stem) (Photos: M.J. Munster, ncsu.edu)

Table 3: Major anthropod pests on tomato

Pest	Symptoms	Management Measures
African Bollworm *(Helicoverpa armigera)*	• Caterpillars of the African bollworm feed on leaves, flowers and the tomato fruit. • The damage on the leaves reduces leaf area, impacting plant growth and productivity. • Flower feeding prevents fruit formation. • Caterpillars bore holes into the fruit and eat the inner parts, causing damage to tomato fruit. • Excrements (faeces / waste) of the feeding caterpillars are evi dent on damaged plant parts.	• It becomes difficult to control larvae once they have entered the fruit as they are protected by the flesh of the tomato fruit. • Monitor and scout regularly for presence of the pest, look out for eggs and small caterpillars. • Prevent infestation in the next crop by; (1) Planting the tomato crop away especially from maize and cotton (2) Remove and destroy infested fruits and other plants. (3) plough soil after harvest to expose pupae to sunlight and natural enemies. (4) Rotate tomatoes with onions or cereals like rice where possible. • Conserve natural enemies such as *Trichogramma*, and predators (syrphid flies, lady bird beetles) to reduce pest populations. This can be done by reducing or judiciously using synthetic pesticides, trap cropping, intercropping etc. • Use low-risk pest management options such as biopesticides e.g. Nimbecidine or *Bt*- based products. • Ensure proper weed management to reduce pest hiding places. • On small plots, handpick and destroy eggs and small caterpillars. • Use registered compatible chemicals e.g. *Cyhalothrin, Lambda-cyhalothrin* etc.

Red Spider Mites *(Tetranychus evansi)*	• The leaves are injured as a result of the mites sucking out valuable substances from the underside of leaves causing speckling and tarnishing and eventual leaf fall. • Infested plants look unhealthy and will have a dusty appearance to the undersides of their leaves Under severe attacks they will cause stunted growth and reduce yields. • The mites and its webbing, just visible to the eye, can be seen on the underside of the leaf. • Spider mites may also cause spots on the fruit.	• Regular scouting of the crop to determine the presence of the pest and the level of infestation in an early stage. • Natural enemies are effective in the control of Spider Mites. e.g. *Phytoseiulus persimilis* by Real IPM or Spidex by Koppert or Phytotech by Dudutech. • Inter-planting tomatoes with garlic or onion, field hygiene (as trap crops) will help reduce the pest. • Plant resistant cultivars. • Adequate irrigation is important, because water-stressed plants are most likely to be damaged. • Dusty conditions often lead to mite outbreaks; Apply water to pathways and other dusty areas at regular intervals. • Avoid broad-spectrum chemical pesticides.
Whitefly *(Bemisia tabaci)*	• Crops are weakened by the feeding of large numbers of white flies, whilst the sooty mould impairs leaf function. • Leaf distortion and stunting if the attack is very early. • However, by far their major importance as crop pests is their transmission of diseases of plants e.g. tomato mottle, and toma to yellow leaf curl virus.	• Use of parasitic wasps *Encarsia formosa, Eretmocerus spp*. Or predatory bugs forex ample *Macrolophus* • Encourage the build-up of natural enemies like lacewings and ladybird beetles that feed on whiteflies and other pests through plant diversification and avoiding broad-spectrum pesticides. • Use of microbials eg *Lecanicilium muscarium* (Mycotal), *Beauveria bassiana*. • Use of yellow Horiver sticky traps. • Use of botanicals such as Neemroc, Nimbecidine, Neemark EC, and Achook 0.15 EC which are neem-based.
Thrips	• Attacked leaves have a silvery sheen and show small black spots (thrips excrements). • Under heavy infestation attacked buds, and flowers usually fall off. • Attacked fruits show speckling and small necrotic patches on the surface affecting fruit quality. • Fruits may become deformed. • Thrips feed on tomatoes at all stages, but their feeding on seed-lings is particularly damaging. • The primary damage caused by thrips to tomatoes is the vector ing of *Tomato spotted wilt virus*.	• Encourage build-up of predators such as ladybird beetles, lacewings and spiders. • Check plants daily in the nursery, and crop borders in the field. Pay careful attention to flowers and flower buds. • Destroy thrips pupae in the soil to reduce subsequent thrips populations. • Plough and harrow before transplanting to expose pupae in the soil from previously infested crops to natural enemies and desiccation. • Soil solarisation and flooding previously infested fields prior to planting / transplanting destroy a large proportion of thrips pupae present in the soil. • Spray botanical pesticides e.g. Neem. • Use of blue or yellow Horiver sticky traps. • Use of compatible chemicals. • If possible, avoid planting tomatoes next to onions, garlic, or cereals, because high thrips numbers often build up on these crops. • Avoid fields near greenhouses where ornamentals (cut flowers) are grown because these plants serve as hosts for the virus and thrips. • Discard any infested plants by securely bagging and putting in the trash. • Trap using blue sticky traps to kill or reduce their numbers.

Table 4: Major diseases and disorders of tomato

Pest	Symptoms	Management Measures
Early Blight *(Alternaria solani)*	• Leaf spotting first appears early in the season on the oldest leaves and progresses upward on the plant. • Spots on the stem resemble those on leaves but tend to be more elongated and the circular or ring-like pattern is more pro nounced. • Dark, leathery, sunken spots may develop on the fruit at the points of attachment to the stems. • These spots may also show concentric markings like those on foliage.	• Field sanitation will reduce the amount of inoculum available for infection the following year. • Deep-plough to bury tomato debris, or dead plants should be removed from the garden and destroyed. • Clean seed and healthy transplants will help control the disease. • Use resistant varieties. e.g. Summerset F1, Zest F1. • Practice crop rotation with non-Solanaceae plants to break the pest cycle for at least one and half years and remove volunteer plants. • Avoid planting adjacent to earlier planted or old crops of brinjals (eggplants), pepper, potatoes orolder tomato crops as they could be a source of disease. • Use of plant essential oils e.g. NoPath for preventive and curative management.
Late Blight *(Phytophthora infestans)*	• Irregular, greenish-black, water-soaked patches on the leaves • The spots soon turn brown and many of the infected leaves wither, yet frequently remain attached to the stem. • Under moist conditions white fungal growth may be seen on the underside of leaf spots. • In damp weather the disease spreads so rapidly, that almost all the foliage is affected, and the plants look as though scorched. • Unlike other fungal diseases, this plant problem does not over winter in the soil or on garden trash. Instead the spores are intro duced by infected tubers, transplants or seeds. Winds will also carry the disease from nearby gardens.	• Field sanitation to reduce the source of primary inoculum from adjacent tomato fields or plants. • Avoid planting tomatoes after potatoes or other Solanaceae plants. • Use clean planting material. • Use tomato transplants from a disease-free nursery. • Scout fields regularly to look for late blight. • Remove volunteers from the garden prior to planting and space plants far enough apart to allow for plenty of air circulation. • Use of compatible chemicals.
Tomato Common Mosaic	• Affected plants exhibit a mottling with raised dark green areas and distortion of the youngest leaves. • Under conditions of high temperature and high light intensity, the mottling is frequently severe. • Under conditions of low temperature and low light intensity, the mottling is not noticeable, stunting and leaf distortion are severe. • Internal browning of the fruit sometimes occurs and this symptom is most common when fruits become infected at the mature green or pink stage.	• Use resistant varieties and certified disease-free seeds. • Remove crop debris and roots from the field. • Field hygiene should be well practiced. • Wash hands with soap and water before handling plants. • Disinfect equipment. • Use clean soil each year in seedbeds, or sterilize old soil. • Do not plant in a field with infected debris.

Module 4: Identification of Tomato leaf miner

Objectives

- Farmers understand different stages of development for the tomato leaf miner.
- Farmers effectively differentiate tomato leaf miner from other similar pests.
- Farmers understand modes of dispersal of the tomato leaf miner and the agents involved.

Tomato leaf miner causes significant yield losses to farmers in Kenya

Tomato leaf miner *(Tuta absoluta)* is an invasive pest with its origin in South America. The pest arrived in Africa from southern Europe into North and West Africa then onward to the south. Since its arrival on the African continent in 2008, the tomato leaf miner, remains the most important biotic constraint to tomato production in North and sub-Saharan Africa.

In Kenya, the tomato leaf miner was first reported in 2014. A survey of tomato farmers in Kenya in 2018 showed that about 98% of tomato growers experienced the pest on their farms, and about 40% of the farmers had lost a big proportion of their crop to this pest. Seasonal production loss due to the tomato leaf miner was estimated to be at least 114,000 tonnes, which translates to US$ 59.3 million (CABI evidence note).

Yield losses affect the farmer's income directly due to reduction in marketable yield and indirectly through higher production costs, as a result of increased investment in pest management. The consumers too are affected by the increased price of tomatoes occasioned by the higher production cost incurred by the farmer.

A farmer's tomato garden in Kajiado county, Kenya devastated by the tomato leaf miner (Photo: CABI)

Content

The tomato leaf miner, is a major pest of field- and greenhouse-grown tomatoes. The pest is oligophagous (feeds on a limited number of crops, of related genera or the members of a single taxonomic family). The pest mainly feeds on crops/plants in the *Solanaceae* family, but the main host is tomato. Such plants in the Solanaceae family include; potato, egg plant, capsicums etc.

Identity

Scientific name: *Tuta absoluta*
Common name: Tomato leaf miner

Biology and life cycle

The tomato leaf miner has four stages in its life cycle (Figure 4.1).

- **Eggs stage**
  - * Eggs are yellow in colour turnin g darker about a day before hatching
  - * The eggs are oval cylindrical, 0.4 mm in length and 0.2 mm in diameter
  - * Eggs are mostly (73%) laid on underside of Leaves-, buds, stems and calyx of unripe fruits and hatching occurs within 4-7 days at 27°C.

- **Larva stage**
  * There are 4 larval stages (instars).
  * Early stages are whitish or cream with a black head
  * Later turn pink or green
  * Fully grown larvae drop to the ground in a silken thread and pupate in soil
- **Pupa stage**
  * Pupae are brown, about 4.3 mm in length and 1.1 mm in width.
  * Pupation takes place in soil or on plant parts such as dried leaves and stem.
  * Pupation has also been reported on packaging/storage equipment/material.
- **Adult Stage**
  * Adult moths are small, grey-brown, thin. They have brown or silver colour with black spots on the wings
  * They are usually active at dusk and dawn and hide between leaves during the day
  * Body length 4.5- 7mm, with a wingspan of 8-10 mm.
  * The total live cycle is completed within 30-35 days depending on the environmental conditions, producing about 10–12 generations per year.

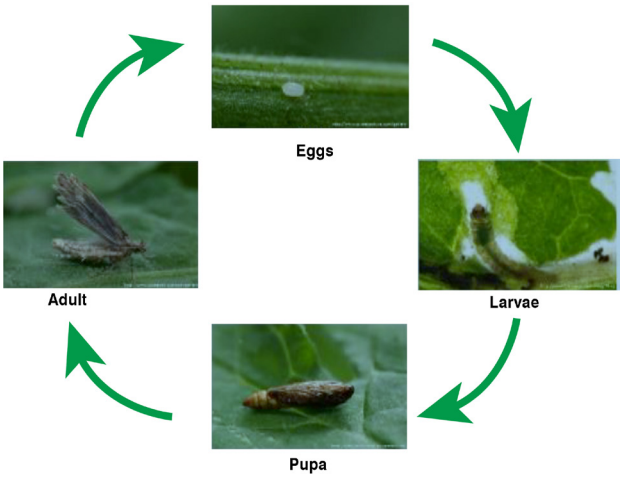


Figure 4.1: Life cycle of *Tutal absoluta (Source: R. Muniappan, coraf.org)*

Note to the trainer

The tomato leaf miner may be confused with the Potato tuber moth *(Phthorimaea operculella)*.

- They are both moths (Lepidopteran) belonging to the same family of insects.
- They attack crops belonging to the same family -*Solanaceae*.
- Among a range of species within the *Solanaceae*, tomatoes appear to be the primary host of the tomato leaf miner, while potato tuber moth primarily attacks potatoes.

Tomato leaf miner, Tuta absoluta (Photo: CABI)

Potato tuber moth, Phthorimaea operculella (Photo: Agripest.net)

Symptoms

- **Vegetative symptoms**
  - Thin silvery trails (tunnels) on leaves which may join together to form white blotches.
  - Leaf mines are irregular and may later become 'burned' (necrotic-dead-dry).
  - Green larvae with black heads, and their black frass, inside the tunnels.
  - Tiny holes on stems.
  - Silky webs produced by larvae appear to fold leaf.
  - Leaves may fall off if badly attacked.
- **Fruit symptoms**
  - Holes in fruit, possibly surrounded by black frass.
  - Larvae and galleries inside fruit.
  - Sunscald of fruit due to leaves prematurely falling.

Note to the trainer

Fruits can be attacked by the tomato leaf miner as soon as they are formed, and the galleries bored inside them can be invaded by secondary pathogens leading to fruit rot.

Dispersal and spread

- Short distance spread occurs as a result of natural means (flight) and/or being carried by air currents (winds) from one plant/farm to the next.
- Different stages of the tomato leaf miner can also survive on tomato, eggplant fruits and packaging material, including crates, boxes etc.
- Infested transplants also form another pathway for entry and spread of the pest.
- Agricultural trade of tomato fruits has been cited as the main pathway in which the tomato leaf miner has been spread over long distances expanding its ranges.

Methods

- Presentation
- Field visit – farmers visit a nearby farm and identify possible symptoms and signs of tomato leaf miner
- In plenary, farmers discuss the difference between tomato leaf miner and other tomato pests, based on symptoms and signs

Content

- Writing materials e.g. flipchart and markers
- Tomato leaf miner photo guide and fact sheet for farmers

Advice

- Identification of the tomato leaf miner is important for effective control. Farmers need to ensure routine monitoring and scouting of their gardens to ensure early detection of the pest.

Photo sheet 1: Tomato leaf miner (*Tuta absoluta*) identification

Larva and adults of Tuta absoluta (Photo: CABI)

- Larvae: Small, yellow-green with black heads, turning pinkish-green with age. Found in tunnels on leaves, stem and fruit.
- Adults: Small, grey-brown, thin, about 4.5- 7mm in length with a wingspan of 8-10 mm. Hide between leaves during the day.

Vegetative symptoms (Photo: CABI)

- Thin silvery irregular trails or mines (tunnels) on leaves which may join together to form white blotches. Under heavy infestation, leaves acquire a burnt appearance.
- Green larvae with black heads, and their black frass, inside the tunnels/mines.
- Tiny holes on stems and branches, silky webs produced by larvae to fold leaf, leaves shrivel and may fall off if badly attacked.

Fruit symptoms (Photo: CABI)

- Presence of exit holes in fruit, possibly surrounded by black frass and/rots due secondary infection.
- Larvae and galleries inside fruit.
- Puncture marks on fruits.
- Sunscald of fruit due to leaves prematurely falling.

Module 5: Management of Tomato leaf miner

Objectives

- Understand the strategies to use to prevent the tomato leaf miner from spreading to new farms.
- Understand how to monitor tomato leaf miner populations on the farm.
- Understand alternative control options for the tomato leaf miner.

Management of tomato leaf miner in Kenya is dominated by pesticide sprays despite safety concerns of pesticide use

CABI undertook a study in June 2019 to assess farmers' practices for management of the tomato leaf miner in Kenya. Results showed that 96.5% of farmers applied chemical pesticides. Of these, an average of 51% applied between one and five sprays/season and 27% applied between six and ten sprays/season to contain this pest.

A tomato farmer in Oloitoktok mentioned that some farmers are known to apply up to 12 sprays during the 3-month cropping cycle, a practice that usually follows a spraying program rather than a pest management decision made through monitoring. He says; *"The pest spreads very fast and if you don't spray, you may not harvest anything. So, we start spraying two weeks after transplanting whether there is Tuta or not".*

This practice is likely to lead to pesticide resistance, and this might explain one finding from the same CABI study that showed that only 27% of farmers thought pesticide treatments to be successful. Further, some farmers don't observe pre-harvest intervals, thus toxic substances are likely to enter into the human food chain posing long-term health risks to consumers and the environment. Alternative control measures for the tomato leaf miner need to be made available and accessible to smallholder farmers to address safety concerns.

Scouting and monitoring tomato fields is key for early detection of the pest and effective management of the tomato leaf miner (Photo: CABI)

Content

This module covers the management options for the tomato leaf miner, with focus on the use of non-chemical and biological control approaches. These approaches offer safer, cost effective and environmentally friendly option to the smallholder farmer.

The approaches should be embedded in the farming cycle starting early in the season with preventive measures, and field management once the pest is detected on the farm.

Prevention

- Plant clean seedlings free from all stages of the moth.
- Crop rotation with non-solanaceous crops such as maize, beans and cabbages, helps in breaking the lifecycle of the tomato leaf miner.
- Remove and destroy wild host plants such as Sodom apple around the farm.
- Remove from the farm and burn all infected crop residues.
- Clean all equipment used in transportation of tomatoes such as boxes, crates and trucks using soap and water.
- Inspect packaging equipment to ensure there are no eggs, larvae or pupae that might develop and spread.

Scouting and Monitoring

- Early scouting and/or monitoring is important in establishing early enough the presence of the pest, threshold levels and for decision making.
- Use pheromone traps for early detection.
- Look out for 'burnt' leaves with irregular mines that have black deposits (frass).
- Look out for black frass on the stem and exit holes on the fruit surface leading to tunnels in the fruit.
- Scout for moths in the field/ greenhouse walls.
- Start control once you notice 1-3 moths or larvae per week.
- Use pheromone-based strategies to help in monitoring and early detection of the tomato leaf miner. E.g. use of Pherodis with Delta trap from Koppert.

Cultural and physical control

- Destroy infested plants and plant parts to limit the possibility of the pest at a particular life-stage from developing to the next and thus controlling the pest population.
- Bury (50-100 cm) all pest infested fruits and foliage.
- Remove alternative reservoir hosts such as nightshades before and during the cropping cycle.
- Crop rotation with non-host crops ensures a long-term reduction in pest pressure.
- In greenhouses, keep infested greenhouses closed after harvest to prevent the migration of adult tomato leaf miners to open-field crops.

Use of semio-chemicals

- Pheromones traps can be used for mass trapping or mating disruption which helps in reduction of pest population.
- Mass trapping removes males from the field, while mating disruption confuses the males so that they cannot find females to mate with, hence reducing the overall population over time. For example, the use of Pherodis plus Tutasan water trap from Koppert.

Note to the trainer

Koppert has produced many types of pheromone traps for different insects. See module 6 for details

Use of microbial pesticides

- These are pesticide formulations that consist of a beneficial microorganism (e.g. a bacterium, fungus, virus or protozoan) as the active ingredient.
- Different microbial pesticides have been tested and found effective against *Tuta absoluta* and are commercially available. They include; *Bacillus thuringiensis* var. kurstaki (Btk), *Beauveria bassiana, Heterorhabditis bacteriophora,* and *Metarhizium anisopliae.*

Use of botanicals

- These are plant extracts used in the management of pests and may be contact or systemic. Several plants extracts have been used to control the tomato leaf miner. For instance, extract from neem seeds *(Azadirachta indica),* have been used as contact insecticide against the tomato leaf miner and other crop pests.
- Many products containing *Azadirachtin* are available commercially in Kenya and include; *Neemroc, Nimbecidine, Neemark EC, Achook 0.15 EC, and Azadirachtin (0.15%).*

Biological control

- Natural enemies play a key role in checking the populations of pests. The most common predators against the tomato leaf miner are the mirid bugs, *Nesidiocoris tenuis and Macrolophus pygmaeus (Mirical),* minute pirate bug, Orius and parasitic wasps.
- Ladybird beetles, parasitic wasps and predatory bugs have potential to check populations of the tomato leaf miner.
- Often the effectiveness of existing natural enemies in regulating pest numbers is affected by adverse farming practices such as the use of broad-spectrum pesticides.
- Farmers should be advised to conserve natural enemies either through establishment of insect zoos, crop/hedge diversification, destruction of ant colonies, and judicious use of chemical pesticides. This encourages natural pest regulation.

Note to the trainer

Koppert has quite a number of natural enemy products. Other suppliers are Dudutech and Real IPM.

Methods

- Presentation of various control measures
- Plenary discussion about farmer control measures for the tomato leaf miner and effectiveness of various measures
- Plenary discussion about alternative control approaches based on agronomy and natural pest regulation
- Visual - Photo sheet 1- 4
- Recognising natural enemies, parasitoids and predators

Note to the trainer

The module aims to emphasize the importance of alternative and non-chemical measures for management of the tomato leaf miner. While chemical pesticides are available, they should be used as a last resort and proper handling should be adhered to. Some of the pesticides have been specified in the pest management decision guide (PMDG). Trainers can refer to the PMDG to answer questions related to pesticide use.

Material and tools

- Writing materials e.g. flipchart and markers
- Tomato leaf miner photo guide and fact sheet for farmers

Advice

It is important to note that no single control strategy is enough for the management of T. absoluta or any other pest. Integrating various control options is effective, cheaper and sustainable against pest populations

Photo sheet 2: Identification of some natural enemies for the tomato leaf miner

Predatory bug, Macrolophus pygmaeus (Photo: KOPPERT)

Minute Pirate Bug - Orius sp. (Photo: Tom Murray, Bugguide.net)

Tomato mirid bug, Nesidiocoris tenuis (Photo: Debbie Roos, NSCU.edu)

Natural enemies of *Tuta absoluta*

i. **Predatory bug**, *Macrolophus pygmaeus*: Adult and nymphs of predatory bugs actively search for their prey and consume them
ii. **Minute pirate bug**, *Orius* sp.: Adults: 2-3 mm long, oval-shaped, black with white markings, wings longer than the body. Feed on smaller insects, larva and eggs pests
iii. **Tomato mirid bug**, *Nesidiocoris tenuis*: Nymphs: 1-4 mm in length, yellow-green to emerald green; Adults: 5- 6 mm in length, black spots on clear hindwings. Feed on the eggs and/ or larvae of leaf miners, whiteflies, spider mites, moths, aphids

Module 6: Integrated Pest management (IPM) practices for the tomato leaf miner

Objectives

- Farmers know how to place/apply IPM principles and strategies in their tomato farms.
- Farmers get to know how to select, treat seeds and prepare land for raising seedlings in nursery beds of transplanting.

Case from the field

The CABI/Koppert project aimed to demonstrate biological approaches for sustainable management of tomato leaf miner in Kenya, to reduce pesticides use and associated risks. Koppert offered farmers training on biological crop protection through farmer field days, demonstrations and offered technical support through our field support team. Ten open field demonstrations were done in Kajiado county, Kenya. Field data collection showed significant low pest pressure on demonstration plots compared to farmer practice (Figure 6). Three greenhouse demonstrations were set up in Juja, Rironi and Kikuyu to showcase biological control of pests. In one site, the *Tuta absoluta* damage score was comparable in both the IPM greenhouse as well as the Farmer Practice greenhouse. For the other two locations, the lower *Tuta absoluta* damage was recorded in the IPM greenhouses compared with the standard Farmer Practice (FP) (Figure 6).

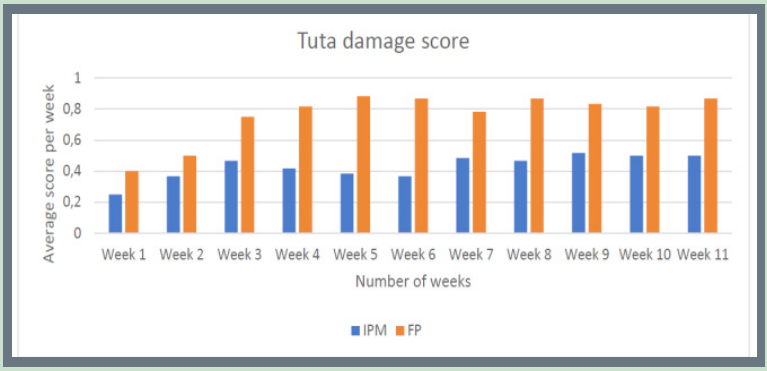


Figure 6: Tuta damage score on 6 farms in Kajiado county during September – December 2019 cropping season (Source: Koppert field report)

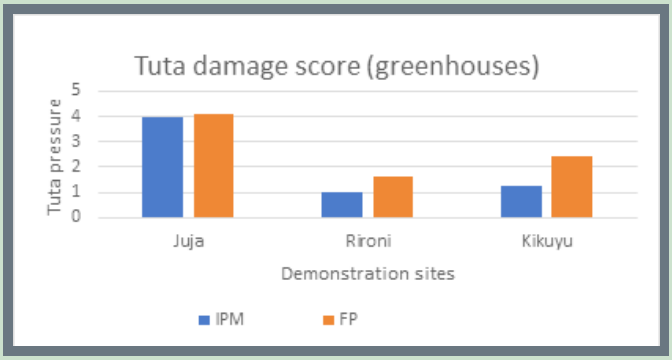


Figure 6.2: Tuta damage score on 6 farms in Kajiado county during September – December 2019 cropping season (Source: Koppert field report)

Content

What is IPM?

Integrated Pest Management (IPM) is a system of pest management that incorporates preventive cultural, mechanical, physical, biological and chemical controls in a compatible manner to keep pest population below economically injurious levels.

The key objectives of IPM are economic viability, social acceptability and minimal risk to human health and the environment.

IPM not only focuses on the existing pest but also on reducing pest invasion and pest emergence and keeping the pest population low. A successful IPM program focuses on this implementation approach.

IPM emphasizes the growth of a healthy crop with the least possible disruption to agroecosystems and encourages natural pest control mechanisms (FAO and WHO, 2014). It involves a combination of all available control measures and strategies: cultural, physical, biological and judicious use of registered pesticides.

Benefits of IPM

- Encourages use of Interventions that reduce or minimize risks to human and animal health and/or the environment.
- Encourages use and conservation of natural pest control mechanisms.
- Encourages surveillance, monitoring and early detection of both pests and natural enemies.

Koppert IPM regime for tomato leaf miner management

This approach is based on CABI/KOPPERT joint initiative to demonstrate biological options for management of the tomato leaf miner. Farmers can obtain active ingredients of the mentioned products or adapt best practices from this regime.

The IPM package comprises integration of:

1. Good agricultural practices (see Module 2)
2. Management of soil borne diseases with Trianum-P (Topic 6.1)
3. Pest monitoring and mass trapping using Pherodis (Delta traps and Tutasan) (Topic 6.2)
4. Use of Mirical for biological control of tomato leaf miner (Topic 66.3)
5. Use of Horiver sticky traps (Topic 6.4)

These practices are discussed in detail in the respective topics/modules indicated in parentheses.

Note to the trainer

It is advisable for farmers to use these practices in combination for best results. However, farmers may also choose what practices to use based on their resources. The trainer can advise farmers before they invest.

Advice

Since the tomato leaf miner is a mobile pest, management of this pest should be done on an area-wide or community scale. Area-wide integrated pest management approach is more cost-effective and sustainable as it proactively targets the entire pest population. In this way, pest populations can be contained at low levels for longer periods and pest management methods can be integrated that are less reliant on synthetic pesticides and that better address ecological and environmental concerns.

Farmers in the same locality can be advised to use the area-wide approach that may include;

- Synchronised rotations.
- Regular monitoring of the pest.
- Timing of planting.

- Conservation of natural enemies.
- Removal of volunteer crops and other host plants from the environment to prevent re-invasion into new fields.
- Removal of the old crop with its remaining pests and disease organisms remote from the growing area helps to reduce or delay infection in the new crop.
- Removing infested plants or plant parts from the start of the new crop limits sources infection.
- Cleaning the greenhouse structure with all that is in it, is also important.
- Synchronised farm activities including application of pest control products.

Topic 6.1: Management of soil-borne pathogens using Trianum-P

Topic Objectives

- Farmers understand how to apply Trianum-P for management of soil-borne diseases.
- Farmers understand the conditions necessary for effectiveness of Trianum-P.
- Farmers understand handling and precautions when using Trianum-P.

Content

Soil-borne pathogens are very difficult to observe with the naked eye. They are very small or microscopic in size and cannot be adequately examined without the aid of magnification (greater than 10X).Soil-borne pathogens include fungi, bacteria and nematodes.

Pathogens are parasitic; that is, they depend on a host to survive and reproduce. Soil-borne pathogens prefer to live within the soil, causing root disease. These pathogens will not only harm a plant, but they can even affect the soil itself.

This topic describes the use of Trianum-P in the management of soil-borne pathogens, how it works and how farmers can apply it in their fields.

What is Trianum?

- Is a fungal-based product supplied by Koppert in Kenya
- It contains spores (seed) of a beneficial fungus known as *Trichoderma harzianum* (strain T-22.).
- *Trichoderma harzianum* Rifai Strain T-22 is a naturally occurring fungus that is used to protect crops and seeds from various fungi that cause plant diseases.
- It reduces soil-borne diseases such as *Pythium* spp., *Rhizoctonia* spp., *Fusarium* spp. and *Sclerotinia* spp on a variety of crops including tomato.
- If applied correctly, it develops mycelia, which grow along the roots (rhizosphere) and protects them against diseases.

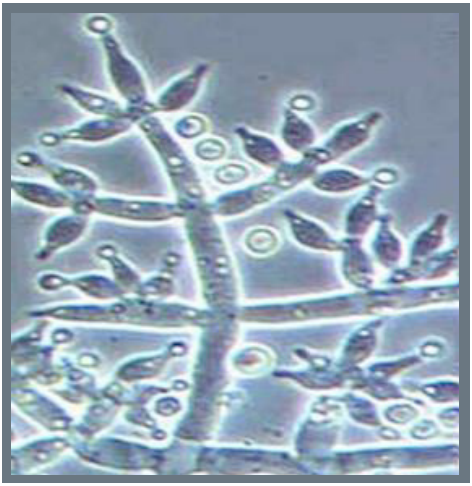
How to use Trianum-P

Trianum works by strengthening plant growth while competing with the pathogens.

- **Competition for space -** Trianum grows faster on the surface of the root than other soil-borne fungi. Other fungi get no chance to establish themselves on the roots allowing the plant to estalish faster.
- Competition for nutrients - Trianum takes away the source of nutrients that the pathogens need to feed on. They therefore have no chance to develop.
- **Acts as parasite on the disease pathogen** - Trianum grows around the mycelia of the pathogen. The cell walls break down and the pathogen dies.
- **Strengthening of the plant** - Trianum improves the root system through the formation of more root hairs, for better water and nutrients absorption leading to a stronger and more uniform crop and hence better yields.
- **Induced resistance** - Trianum strengthens the defense mechanism of the above ground plant parts (ISR- Induced Systemic Resistance).
- **Facilitating the absorption of fixed and non-fixed nutrients** - Trianum has the capacity to make certain "fixed" nutrients available for the plant to absorb.

Methods of application of Trianum-P

Trianum-P can be applied via drench application, drip-irrigation, or use of a sprayer while sowing.



Left: Trianum-P package; Right: Visual of Trianum-P growth on roots surface (Photos: Koppert)

How to prepare Trianum-P for application

- Add 1 volume of Trianum-P to 5 volumes of water in a container and mix thoroughly.
- Add suspension to the required amount of water to obtain the final drench solution.
- Agitate continuously to maintain an even distribution of spores (spores do not dissolve in water and have the property to precipitate).
- To increase spore attachment to the roots, avoid run-off and excess drainage during the first two days after application of the product.
- Trianum-P is not a systemic product and is therefore not taken up by the plant.

Methods

- Introduce the topic through a presentation to farmers.
- Demo-Navigating through the Koppert App on 'side effects' of pesticides on Trianum-P.

Note to the trainer

- Trianum-P can be applied multiple times to maximize on efficacy.
- Make sure you use every amount prepared. It cannot be used be used after staying overnight.
- Trianum-P is used in the cultivation of vegetables, fruits, herbs, bulbs, ornamentals, perennials, and turf.
- Check the product label for which crops Trianum–P is registered for use in your country.

Material and tools

- Flipchart, markers
- Photo guides
- Product for demonstration or contacts where product can be obtained

Advice

Emphasize the importance of managing soil borne pathogens, as they can be as harmful as above ground pests and diseases, They affect crop growth from below ground, and affect nutrient intake by the plant. Tianum is obtainable from Koppert, but other products for management of soil-borne pathogens may be available for farmers to use.

Topic 6.2: Using Pherodis plus Traps (Deltatraps and Tutasan Water traps)

Topic Objectives

- Understand what Pherodis plus traps are and their purpose.
- Know the types of Pherodis plus traps available in the market.
- Learn how the Pherodis plus traps (Deltatraps and Tutasan) work to manage the tomato leaf miner.
- Learn how to apply Pherodis plus traps in the farm.

Content

What is Pherodis?

The Pherodis are capsules that release a species-specific sex pheromone to lure adult malesof the pest into the trap.

Pherodis is used in combination with Deltatrap for monitoring pests, or Tutasan water trap for mass-trapping of insect pests.

Application of Pherodis with delta trap

- When applying, do not touch the dispenser, since manual contact can spread pheromones or interfere with efficacy.
- Open the packet, remove the capsule and place it on the adhesive plate of the Delta trap (figure A) and hang the trap in a suitable position approximately 10 cm above the crop (Figure B).
- Hang the traps as evenly distributed as possible. This also make it easy to inspect.
- Remove the sticky trap once covered by flies and replace with a another one as necessary.

Figure A: Pherodis capsule placed on the delta trap

Figure B: Pherodis trap placed in the field

Figure C: Pherodis trap after trapping flying insect pests

(Photos: Koppert)

Application of Pherodis with Tutasan

- Place the pheromone (inside the green basket, fixing it to the upper central part of the trap.
- Fill the trap with water until it starts to overflow.

- Add a small amount of vegetable oil or soap as a wetting agent.
- Place 20-25 traps per ha for effective management evenly distributed in the field
- Assign each trap a serial number and write it as well as the type of pheromone it contains on the outside.
- Wash your hands between assembling pheromone traps in case of different species of butterflies and moths.
- During the first few days following the installation of a new pheromone capsule, tomato leaf miner moths may be caught more often than usual.
- Pheromone dispensers remain effective for 6 weeks. Replace the capsule in the trap after 6 weeks, but only with a dispenser containing the same kind of pheromone.
- Always check for the shelf life (expiry date) on package for storage.

Water trap after trapping the adult flying insects (Photos: Koppert)

A water trap placed in the field (Photos: Koppert)

Note to the trainer Cold storage in a fridge is necessary while the product is in storage or transit with Koppert or distributors.

Handling and Best conditions for Pherodis to work

- Never open the "plastic tube" of pheromone dispenser- the pheromone will completely evaporate almost immediately making it useless.
- The plastic tube is permeable, and the pheromone will gradually diffuse through the wall.
- Pheromone dispensers and the sachets containing them should be kept at temperatures below 4°C while on transit from Koppert appointed distributor).
- The production date is printed on the packaging.
- The dispensers have a shelf life of 2 years after the production date when stored in a freezer, and 1 year when stored in a refrigerator (4-6°C).

Advice Farmers should be encouraged to only buy enough product to use immediately (a couple of hours or days at room temperature with the farmer before application should be ok).

Advantages of using pheromones

- Pheromones are completely harmless to humans and other beneficial insects
- They can be used to detect pest infections early.
- They are not toxic to food or the environment. No pre-harvest interval is needed.
- They do not cause resistance in pests.
- They optimize the use of the same trapping devices, reducing the cost.

Methods

- Demonstrate how scouting can be done and what to look out for.
- Demonstrate how to handle, install, service and dispose of Pherodis

Topic 6.3: Use of Mirical (Macrolophus pygmaeus) for biological control of tomato leaf miner

Topic Objectives

- Understand biological control using Mirical.
- How to manage and conserve Mirical and other biological agents e.g. natural enemies.

Content

Mirical *(Macrolophus pygmaeus)* is used for biological pest control of certain whiteflies and the tomato leaf miner.

Its efficacy in green house tomato production has been tested and confirmed. Its use in open field is still under trial, but preliminary results from the CABI/Koppert project showed promising results.

Use Mirical for:

- Greenhouse whitefly
- Tobacco whitefly
- Two spotted spider mites
- Thrips
- Eggs of butterflies and tomato leaf miner moth
- Aphids
- Leaf miner larvae

When to use Mirical-N?

- As nymphs of *Macrolophus* are less mobile than adult *Macrolophus*, Mirical-N can be used for biological pest control in hotspots.
- Introduce *Macrolophus* at the beginning of the growing season, as the predatory bug population needs time to establish and develop. After a few months, highly dependent on climatic conditions and availability of food, density of *Macrolophus* should be high enough to control the pests.

How does Mirical work?

- Adult predatory bugs and nymphs actively search for their prey and consume them. In case of whitefly eggs, larvae or pupae only the skin is left behind in its original state.

Side effects

- Pesticides can have (in)direct effects on biological solutions. Our side effects app tells you how harmful different pesticides are.

Note to the trainer

Only use products that are permitted in your country/state and crop. Check local registration requirements.

Methods

- Presentation.
- Demonstration on application of the Mirical.
- Field scouting to check the establishment of Mirical and pest damage.

Material and tools

- Writing materials eg flip charts, markers.
- Mirical for demonstration (if available).

Advice

Mirical contains living organisms (predatory bugs) that are introduced in the field to manage tomato leaf miner. Farmers should employ practices that conserve the organism and help its establishment. For example, farmers should minimise spraying synthetic pesticides. ≈

In case the crop is damaged and spraying can't be avoided, use the pesticide judiciously and select compatible pesticides (such as) Indoxacarb (AVAUNT 150 EC, Merit etc.), *Flubendiamide* (Belt), *Chlorantraniliprole* (Coragen), Imidacloprid 175g/L + Novaluron 30g/L (GRIZLY), Azadirachtin (Nimbecidine), Emamectin benzoate (Improve) among other registered products (Refer to PMDG).

Conservation practices also help the reproduction of other natural enemies for pests, helping to keep pests in check, and survival of crop pollinators.

Topic 6.4: Use of Horiver sticky traps

Topic objectives

- Understand how to use sticky traps for pest monitoring and mass trapping.
- How to make management decisions based on pest economic threshold levels.

Content

Mass trapping techniques like use of Yellow and Blue Horiver cards contributes to control of the flying stages of pests like whitefly and thrips and monitoring of adult tomato leaf miner.

Note to the trainer

- These sticky traps don't control the tomato leaf miner but may be included as part of the IPM strategy.
- For the tomato leaf miner, use of Pherodis plus Deltatrap for monitoring and Pherodis plus Tutasan Watertrap for mass trapping is recommended. This applies for both greenhouse and open field settings where this has been repeatedly proven to work.

When to use Horiver?

Horiver is used to monitor and trap the adult tomato leaf miner. It is also used for other pests such as aphids, whiteflies, thrips and sciarids.

How does Horiver work?

Sticky traps are essential in the detection and partial elimination of many species of flying pests in greenhouses. Sticky traps make it possible to detect pests at an early stage and then use biological measures to combat them. This prevents unnecessary applications of chemicals.

Counting the captured insects on the sticky traps on a regular basis makes clear when pests are present in the greenhouse, how fast their population is developing, and when their population is likely to reach its peak. In this way growers are much better prepared for potential threats.

How to use Horiver

- Tear a sticky trap from the pack.
- Hang on a stick, wire of rope just above the crop to help with monitoring of the pest.
- Check regularly and count the trapped insects.
- In tall crops, position above the plant, and adjust the height (upwards) while it grows.

Instructions for usage of Horiver

- With regards to tall crops such as cucumber, tomato and pepper, position the traps just above the top of the plant and adjust while the plants grow.
- When it comes to crops with a low canopy, support the traps by canes or wire holders and install them maximum 30 cm above the crop.
- The traps must be placed in areas where the risk of pest infestation is high, e.g. at doors, gable ends and lateral ventilation openings.
- Traps must be removed when significant numbers of flying parasites are caught. This happens when traps hang among the plants (instead of above).

Dosage

- With regards to monitoring purposes, the advised rate is five traps per 1,000 m^2. If the traps must contribute to the biological control of pests in so-called hot spots (i.e. mass trapping), use at least one trap per
- 20 m^2 or at most one trap per 2 m^2. Both small and larger traps can be used for this purpose.

Note to the trainer

Only use products that are permitted in your country/state and crop. Check local registration requirements.

Methods

- Presentation.
- Demonstration on how to install the traps in the field and how the count of trapped insects can be interpreted to help make decisions by the farmers.

Material and tools

- Horiver traps and strings/wires for demonstration.
- Writing materials.

Advice

- Sticky traps may be included as part of the IPM strategy for management of flying insects.
- For the tomato leaf miner, use of Pherodis plus Deltatrap for monitoring; and Pherodis plus Tutasan Watertrap for mass trapping is recommended.
- This applies for both greenhouse and open field settings where this has been repeatedly proven to work.

FACT SHEET FOR FARMERS

Tomato leaf miner *(Tuta absoluta)* Kenya

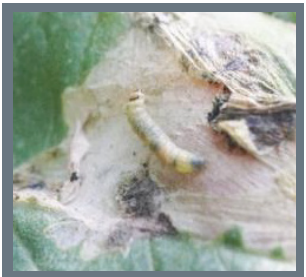
Recognise the problem

The tomato leaf miner, *Tuta absoluta,* is a native of South America (Peru), now present in several countries in Africa, Asia and Europe. It has gained pest status and is the most important and devastating pest of tomato wherever it has invaded. *Tuta absoluta*'s primary host is tomato, though it can feed and develop on other members of the tomato family (Solanaceae) with potato, eggplant capsicums etc. being some of the crops of economic importance that are attacked by this pest.

Damage is caused by the feeding activity of the larval stage of this insect resulting in irregular mines on the leaf and fruit surfaces. Subsequently, damaged leaves shrivel, and may fall off decreasing the photosynthetic capacity of the plant and potentially decreasing the plant's ability to defend itself from other biotic stresses. Under heavy infestation, leaves acquire a burnt appearance. The galleries and mines in the leaves alter the general development of the plant and can cause necrosis. They also provide suitable entry routes for secondary infection by pathogens, further increasing the damage and cost of control, and lowering the market value of the fruits.

Damage on the growing tips of the plant results in their death halting the development of the plant, negatively affecting the yield of the crop. Yield losses of up to 50–100% have been reported as a result of the direct and indirect damage of *Tuta absoluta.* Other indirect damages result from overuse or misuse of synthetic pesticides leading to the increase in chemical residues on the fruit and impacting negatively on the market (local and international), human and environmental health, beneficial organisms e.g. pollinators, natural enemies etc. and increase in the production costs of tomato resulting from the purchase and application of the pesticides. Consumers are also affected by the increased price of commodities due to the higher production cost incurred by the farmer.

Tuta absoluta larva. Note the black band on the head: Inset: Tuta absoluta adult (Photo: CABI)



Burnt appearance of leaves due to extensive mining by the leafminer larvae (Photo: CABI)

Exit holes of tomato leafminer on tomato fruits (Photo: CABI)

Background

Biology, field identification and dispersal.

Adult tomato leaf miner is small, silvery-brown moths, about 4.5- 7mm in length with a wingspan of 8-10 mm. They are nocturnal, being most active at dusk and dawn, and rest on leaves and other plant parts during the day. Female moths lay about 260 eggs, mostly singly or in small batches, on the underside of leaves, stems and young fruit. The eggs are yellow, turning darker about a day before hatching. Hatching occurs in 4-7 days at 27°C. The total live cycle is completed within 30-35 days depending on the environmental conditions, producing about 10–12 generations per year.

Infestation in the field will be easily noticed by the mines in leaves, stems, puncture marks, abnormal shape, exit holes and/or rot due to secondary infection, and frass (fine powdery material that plant-eating insects pass as waste after they digest plant parts) and webbing on stems and fruit.

Short distance spread occurs as a result of natural means (flight) and/or being carried by air currents (winds) from one plant/farm to the next. Infested transplants also form another pathway for entry and spread of *Tuta absoluta*. Agricultural trade of tomato fruits is the main pathway in which *Tuta absoluta* has been spread over long distances expanding its ranges.

Management.

1. Early scouting and/or monitoring are important in establishing early enough the presence of the pest, threshold levels and for decision making. Use pheromone traps for early detection, mass trapping and/or mating disruption.
2. Plant clean seedlings free from all stages of the moth.
3. Practice orchard hygiene by removing from the farm and burn all infected crop residues and destroying wild host plants such as Sodom apple and nightshades around the farm; Bury (50-100 cm) all pest infested fruits and foliage.
4. Crop rotation with non-solanaceous crops such as maize, beans and cabbages, helps in breaking the life-cycle of the tomato leaf miner.
5. Clean all equipment used in transportation of tomatoes such as boxes, crates and trucks using soap and water; Inspect packaging equipment to ensure there are no eggs, larvae or pupae that might develop and spread.
6. Conserve natural enemies like ladybirds, mirid bugs, minute pirate bug etc.– establishment of insect zoos, crop/hedge diversification, destruction of ant colonies, and judicious use of chemical pesticides. *Macrolophus pygmaeus* is a predatory mirid, commercalised as MIRICAL by Koppert, that feeds on immature stages of tomato leaf miner.
7. Use low-risk control options like biopesticides e.g. botanicals like Neem-based products (*Azadirachtin*), Microbials pesticides e.g. products containing *Bacillus thuringiensis* var. *kurstaki* (Btk), *Beauveria bassiana*, *Heterorhabditis bacteriophora*, and *Metarhizium anisopliae* (e.g. Met69 supplied by Real IPM).
8. Judiciously use chemical products containing *Emamectin benzoate*, *Abamectin, Flubendiamide*, *Chlorantraniliprole*, *Spinetoram* against Tuta absoluta. Some of the chemical products registered in Kenya are: Escort, Alonze, Belt, Coragen, Radiant respectively

Note:

For chemical use,

1. Use personal protective clothing, every time you use pesticides.
2. Follow the instructions contained in the packet or bottle of insect pests, regarding rate, Pre-harvest interval PHI, re-entry period, storage etc.
3. Include adjuvants (stickers or spreaders or wetter) to improve the performance of chemical.
4. Rotate chemical compounds (active ingredients) to limit development of pesticide resistance.
5. Only apply chemical pesticides if the wind direction favours on-target deposition. Do not apply when the wind velocity exceeds 15 mph.

Area-wide management

For effective results, implement an integrated approach on an area-wide scale against this pest by combining cultural, biological, physical and (only as a last resort) synthetic pesticides.

PEST MANAGEMENT DECISION GUIDE

Tuta absoluta (tomato leaf miner) on Tomato

Disease *(Tuta absoluta)*

Tuta absoluta and mining damage on tomato leaves (Credits: Rwomushanaet al (2019)

Burnt appearance of leaves due to extensive mining by the leaf miner larvae on tomato leaves (Photo: CABI)

Tuta absoluta damage on tomato fruit. Open wounds from the mining results to fruit rotting as a result of secondary infection (Photo: CABI)

Prevention

i. Use clean planting materials (seedlings). Check for infested transplants and destroy them properly. Disinfect the rest before planting to kill young larvae that may have been missed.

ii. Clean all materials used for the transportation of tomatoes such as boxes, separators and even trucks using soap and water.

iii. Ensure proper post-harvest handling of fruits: Sort harvested fruits by removing infested and punctured fruits. Dispose any infested fruits properly by burning or burying deep. Clean harvested pro- duce with water before marketing.

iv. Observe field hygiene: e.g. cultural and mechacal control of weeds / alternate host plants like nightshades etc. from the field. Remove all affected plant and plant residues and properly dispose them by burning or burying them deep. This will help in reducing the chances of tomato leafminer- from overwintering and spreading within the farms.

v. Practice crop rotation with non- solanaceous crops e.g. maize, cabbage, beans etc. to break the cycle of the pest and limit the damage within the farm.

vi. Apply manures or fertilizer to enhance and maintain high soil fertility. This will make your crops grow well and make them withstand pest infestation. Also, plough deep and leave the farm for some time before planting the new crop to burry and/or expose any pupa present in the soil to solar or predators. Use of plastic mulch has also been effective in reducing pupation in the soil.

vii. Insect isolation or exclusion- use nets to keep off tomato leafminer and other pests especially in the nursery. For greenhouse farmers, install double door system.

viii. Mass trap using pheromone traps/lures or light traps before transplanting.

Monitoring

i. Regularly (weekly), randomly select five points in the field (in a W- or Z- pattern), and observe plants in those selected spots. Always start from a different point ensuring the entire farm is covered. Observe the following:

   a. Irregular mines on leaves, young stems and branches some resulting in burnt appearance.
   b. White or cream exit holes and rots/decay on fruits as a result of secondary infection from the wounds created by the mining on fruits.
   c. Frass (fine powdery material that plant-eating insects pass as waste after they digest plant parts) and webbing on stems and fruit.
   d. Blue-green caterpillars with characteristic black heads in the holes.

ii. Use pheromone traps/lures to monitor population density. If populations are high, as indicated by high number on traps, manage the pest starting with cultural and mechanical practices.

Direct control

i. Mass trap using light traps or pheromone traps. This should be done before transplanting and during the cropping cycle. This can be done on a community level (areawide pest management) due to the mobile nature of tomato leaf miner.

ii. Spray with neem-based or biopesticides when 1- 5 larvae are observed from weekly monitoring. Some of the products include Nimbecidine, *Bacillus thuringensis (Bt)*

iii. Use biocontrol agents (natural enemies) e.g. the predatory mirids, *Macrolophus pygmaeus,* commercialised in Kenya as MIRACAL by KOPPERT.

iv. Spray chemical pesticides as last resort "rescue operation".

   a. Use personal protective clothing, every time you use pesticides or pesticides in the field.
   b. Follow the instructions contained in the packet or bottle of insect pests, regarding rate, PHI, re-entry period, storage etc.
   c. Include adjuvants (stickers or spreaders or wetter) to improve the performance of chemical.
   d. Rotate chemical compounds (active ingredients) to limit development of pesticide resistance.
   e. Only apply chemical pesticides if the wind direction favours on-target deposition. Do not apply when the wind velocity exceeds 15 mph.

Recommended chemical pesticides against *Tuta absoluta*

Active ingredient	Trade name	Rate	WHO class	PHI
Spinetoram	Radiant	8- 30 mL/20L	III	3 days
Chlorantraniliprole	Coragen	5ml/20L	U	3 days
Flubendiamide	Belt	4ml/20ml	III	3 days
Emamectin benzoate	Escort	10ml/20l + INTEGRA 3 ml/20l	III	3 days
Abamectin	Alonze	3ml/20l +INTEGRA 3ml/20l	III	3 days
Spinetoram	Radiant	4-5 ml/20l	V	3 days

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