Seminar on
Insect pest complex of tomato and their management through IPM

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Introduction

Tomato, *Solanum lycopersicum* Mill, is one of the most popular solanaceous vegetable crops grown all over the world, ranking second in importance next to potato in many countries. The highest productivity of tomato is incurred by Spain having 66.81 t/ha. It is grown in 814 (000) million ha area with 20515(000) million tones production and 25.20 t/ha productivity in the country. In India, Madhya Pradesh contributed maximum production (2970.64 T) and share 14.63% of total state production but highest productivity was occupied by Maharashtra (28.20 tons/ha). (Anonymos 2018) In U.P., tomato grown in an area of about 21.2 million hectare and production is about 832.50 million tons **(Anonymos2017 -18)**

The key insect-pests of tomato in this region include fruit borer, *Helicoverpa armigera* Hub. Thrips, *Thrips tabaci,* aphid, *Myzus persicae* Thomas, white fly, *Bemisia tabaci* Gen. mites, *Tetranychus evansi* Mealybugs, *Maconellicoccus sp.,Phenacoccus solenopsis* tobacco caterpillar, *Spodoptera litura* leaf minor, *Liriomyza trifolii* Blanchard. The tomato fruit borer, *Helicoverpa armigera* (Hub.) is a key pest as it infests fruits and makes them unfit for human consumption causing considerable 55% crop loss. It has been estimated that crops worth Rs.1000 crore are lost annually by this pest.**(Kumar *et al.* 2017).**

"IPM means 'intelligent pest management'.

(G. Zweig and A. Aspelin. 1983)

IPM refers to an "**Integrated control is a pest management system that in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest populations at levels below those causing economic injury** (FAO – 1967)

"Integrated Pest Management (IPM) is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistance varieties. Pesticides are used only after monitoring indicates they are needed according to established guidelines, and treatments are made with the goal of removing only target organism. Pest control materials are selected and applied in a manner that minimizes risks to human health, beneficial and nontarget organisms, and the environment."

Important insect pests of tomato and loss, caused by them

S. No.	Common name	Scientific name	% yield loss	Reference
1.	Fruit borer	*Helicoverpa armigera* (Hub.)	24-73%	Rai 2009
2.	Tobacco caterpillar	*Spodoptera litura (Fabricius)*	24-25%	Patnaik 1998
3.	White fly	*Bemisia tabaci* (Genn.)	20-40%	Sutton 1991
4.	Leaf miner	*Liriomyza trifolii* (Burgess)	100%	Arturo *et al*.2012
5.	Thrips	*Scirtothrips dorsalis* (Hood)	75-100%	Kumar & Irulappan 1991
6.	Aphid	*Aphis gossypii* (Glover)	20-40%	Sutton 1991

7	Tomato pinworm	*Tuta absoluta* Meyrick	80-100%	Illakwahhi, 2017

FRUIT BORER

Common Name : Tomato fruit borer, corn earworm, cotton bollworm

Scientific Name : *Helicoverpa armigera*

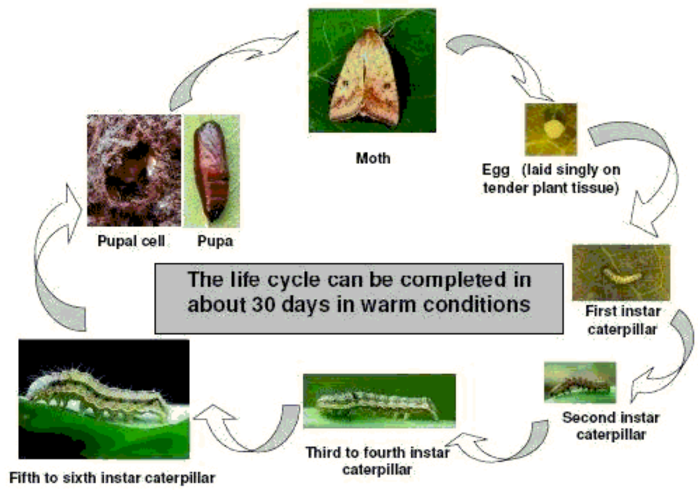
Noctuidae : Lepidoptera

Biology

It is a **polyphagous pest**, infesting gram, lablab, safflower, chillies, groundnut, tobacco,cotton etc

- **Egg:** Spherical, yellowish eggs are laid singly on tender parts and buds of plants.

  The egg period lasts for 2-4 days.
- **Larva:** Caterpillars are of varying colour, initially brown and later turn greenish with darker broken lines along the side of the body. Body covered with radiating hairs. The larval period lasts for 18-25 days. The full grown caterpillar pupates in the soil.
- **Pupa:** Pupation takes place inside the soil in an earthen cell. Pupal stage lasts 7-15 days.
- **Adult:** Moth is stout, medium sized with brownish colour



Nature of Damage & symptoms caused by insect

- Young larva feeds on the leaves for some time and then attacks fruits. Internal tissues are eaten severely and completely hollowed out. While feeding the caterpillar thrust its head inside leaving the rest of the body outside.
- Bored fruits with round holes.
- Fed leaves, shoots and buds.
- The activity of *Helicoverpa* starts on green gram, summer vegetables and maize and continues their generation by Aug-Sept months synchronizing with main crop.

Favourable conditions

- Warm weather conditions followed by light rains and dry spells are favourable for multiplication.

IPM for fruit borer

Monitoring

Pheromone trap is effective *Helicoverpa* monitoring tools among various monitoring techniques . Moth becomes active at March-April which coincides with fruiting period of tomato. Thus, monitoring of *Helicoverpa* armigera in that period gives fruitful results . Adult is nocturnal in nature so that it can be monitored through light traps **(Rijal ,2019)**

Host plant Resistant

Resistant genotypes are best for insect pest management but in tomato these genotype are not widely used. Several genotype of chickpea, cotton and pigeonpea have shown high level of resistance. Earlier, in United States, L. *esculentum var. cerasiforme* (LA1310 and LA 1320) accessions and commercial cultivers (Tiny Tom) are resistant to *Helicoverpa armigera* **(Rijal ,2019)**

Cultural Method

- Transplant 45 days old marigold seedling in a pattern of one row of marigold for every 16 row of tomato. (**Barkat Hussain** 2008)
- Deep ploughing during summer reduces number of pupa whereas fall ploughing reduces the number of overwintering population of *Helicoverpa*
- Planting 40 days old marigold (American Tall) as trap crop with 25 days old tomato seedlings @ 1:16 row ratio. **. (Amutha, 2013)**
- Early sowing, balance dose of fertilizer application, better intercultural operation and irrigation practice reduce no of *Helicoverpa* in tomato field. Strip cropping or Inter cropping with marigold, wheat, sunflower, sesame, soybean, cowpea and mungbean reduce *Helicoverpa* infestation in tomato (**Swodesh Rijal 2019)**

Mechanical method

- Erect bird perches @ 50/ha to encourage predatory birds.
- Collect and destroy damaged fruits..
- Installation of pheromone traps @ 12 traps /ha at 20DAT. Replace the lures with fresh lures at every 20- 25 days interval. (**Amutha 2013)**

Biological method :-

- Give sprays of Ha NPV @ 250 LE /ha coinciding with early instars of Helicoverpa. (**Revathi, 2019)**
- Neemosal was applied when *H. armigera* population reached its ETL (3 larvae/eggs per 25 plants). **(Noor-ul-Ane *et al, 2015)***
- Firstly, the spray of Spinosad was done when *H. armigera* reached its ETL. Second spray of Neemosal was applied at ETL of *H. armigera*. After 7 days of Neemosal application, release of *H. hebetor* was made. This sequence of three practices was carried out till the maturity of the crop**(Noor-ul-Ane *et al, 2015)***
- Spinosad was applied when H. armigera population reached its ETL (3 larvae/eggs per 25 plants) . (**Amutha, 2013)**
- Use of SlNPV or HaNPV @ 250 LE per acre e or chlorantraniliprole @ 0.3 ml/ lt or spinosad @ 0.3 ml/ lt (**Revathi, 2019)**
- One release of *Trichogramma chilonis* @ 50,000/ ha at three days after moth emergence. (**Amutha, 2013)**
- Foliar application of HaNPV @ 250 LE/ha, once at seven days after the *T. chilonis* release. (**Amutha, 2013)**
- Foliar application of Btk @ 1.0 kg/ha during fruit formation stage. (**Amutha 2013)**

List of bio agent and their dose

Sr. N.	Bio agent	Active Ingredient	Dose
1	Neem (Aza-Direct®) spray	1.2% Azadirachtin and other ingredients 98.8%	10 ml/1 liter of water
2	Petroleum Spray Oil (Volck oil spray®)	Petroleum Oil 97%, other ingredients 3%	20 ml/1 literof water
3	BotaniGard (BotaniGard® 22WP)	*Beauveria bassiana* Strain GHA 22%, inert ingredients 78%	2.4 grams/1 liter of water
4	DiPel (DiPel® DF)	*Bacillus thuringiensis,* subsp. *kurstaki*, strain ABTS-351, fermentation	15 grams/1 liter of liter

		solids, spores, and insectidial toxins 54%; Other ingredients 46%	

(Reddy, 2014)

Parasitoid

Sr	Scientific name	Does	Time of application
1	*Trichogramma Brasiliensis*	50000 egg/ha	Six time at weekly interval from flowering stage
2	*Trichogramma Pretiosum*	50000 egg/ha	Six time at weekly interval from flowering stage

Predators:

Sr	Commen name	Scientific name
1	Lacewing	*Chrysoperla carnea* Stephens
2	Lady bird beetle	*Coccinella septempunctata*
3	Spider	*Latrodectus Hesperus*
4	Fire ant	*Solenopsis geminate*
5	Dragon fly	*Anisoptera berthold*
6	Robber fly	*Laphria flavicollis*
7	Praying mantis	*Stagmomantis carolina* Kaldari
8	Wasp	*Vespula vulgaris*
9	Earwig	*Forficula auricularia*
10	Ground beetle	*Carabidae Latreille*

The efficacy of *Trichogramma chilonis, T. pretiosum* and *Trichogramma brasiliense*

- The efficacy of *T. chilonis*, *T. pretiosum* and *Trichogramma brasiliense* at 50,000, 75,000 and 100,000/ha in controlling *H. armigera* infesting tomato.

- The difference was observed in the larval population and the lowest mean larval population (0.5 larvae/5 plants) was recorded when *T. chilonis* was released at one lakh/ha. Parasitism (41.07%) was highest in *T. chilonis* was released at one lakh/ha, and it was at par with releasing 75,000/ha of *T. chilonis (*40.00%).
- The lowest fruit damage (8.01%) was recorded when *T. chilonis* was released at one lakh/ha, which was followed by the release of *T. chilonis* at 75,000/ha (9.20%), one lakh/ha of *T. brasil*- iense (11.66%), and *T. pretiosum* at 100,000 and 75,000/ha (10.88 and 11.82%, respectively).
- The highest (261.07 q/ha) yield was obtained with the release of *T. chilonis* at one lakh/ha, followed by *T. chilonis* at 75,000/ ha (248.27 q/ha) **(Kumar et al 2004)**
- The results revealed that, under conditions of this test, the maximum parasitisation was shown by *Trichogrammatoidae bactrae* (87.83%), which was found most effective and resulted in, significant parasitisation of pink bollworm eggs over the rest of the treatments. Whereas *Trichogramma chilonis* (Ishii) was recorded with 83.83 percent parasitisation **(Mohammad Faheem Malik 2001)**
- Reported that, the maximum percent parasitisation (95.81%) by *T. bactrae* against pink bollworm eggs under complete light conditions and **(Nadeem and Hadim 2008)**

Feeding potential of Ladybird Beetle, *Coccinella septempunctata* Linnaeus

- Coccinellids, persistently known as **ladybird beetles** belong to the order **Coleoptera** and the family **Coccinellidae,** are the forthcoming predators of as array of insect pests, principally **aphids, scale insects, mealy bugs, thrips and other soft bodied insects,** besides phytophagous mites. The predator beetle is an efficient feeder and prey on wide range of soft bodied insects. Both adults and grubs are voracious feeder of aphid species. **(Rasheed et al 2018)**

Feeding potential of adult Male

Treatments	No. of Aphids offered	Mean of Aphids consumed	Consumption (Percentage %)

I	120	115	95
I I	140	136	97
III	160	157	98
IV	180	176	97

(Rasheed et al 2018)

Feeding Potential of adult Female

Treatments	No. of Aphids offered	Mean of Aphids consumed	Consumption (Percentage %)
I	120	118	98
I I	140	137	97
III	160	158	98
IV	180	179	99

(Rasheed et al 2018)

Chemical control

- Quinolphos 25 EC (@ 250 g a.i./ha **(Ravi ,2008)**
- Indoxacarb 14.5 SC (@ 75 g a.i./ha) **(Ravi ,2008)**

- Foliar application of chlorpyriphos 20 EC @ 2.5 ml/lit/ at 75 days after transplanting(**Amutha 2013)**
- Foliar application of carbaryl 50 WP 2g/lit. at 105 DAT(**Amutha 2013)**.
- Chlorantraniliprole 18.5 EC @ 150ml/ha + Novaluron 10 EC @ 1 L/ha(**Choudhary *et al* 2021)**
- Emamectin benzoate 5% SG @200 ml/ha(**Choudhary *et al* 2021)**
- Chlorantraniliprole 18.5 EC @150 ml/ha(**Choudhary *et al* 2021)**

Economic thresh hold level

- 1 larva /m row length or one larva/plant or 2% fruits damaged.

  8 eggs per plants

2 Serpentine leaf miner

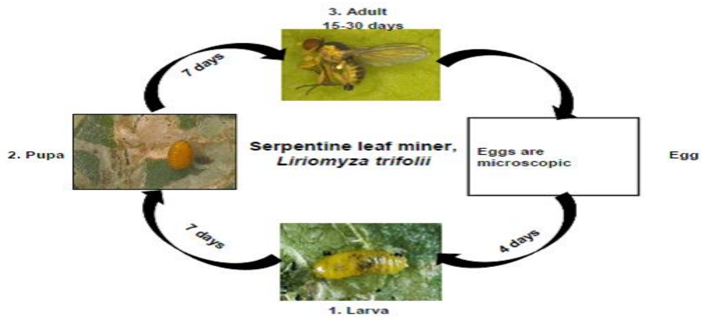
Liriomyza trifolii

Family : Agromyzidae

Order : Diptera

Biology

- **Egg:** Eggs are minute in size and orange yellow in colour. The egg hatches in 4 days.
- **Larva:** Apodous maggot feeds on chlorophyll mining in between epidermal layers. Full grown maggot measures 3 mm. Larval duration is about 7 days.
- **Pupa:** Pupation is in soil. Some pupae are found in leaves. Pupation takes place inside a thin loose mesh of silken cocoon. Pupal period is about 7 days.
- **Adult:** It is a pale yellowish fly, measuring 1.5 mm in length. The female fly punctures upper surface of leaf to lay eggs singly. Total life cycle takes 3 weeks.



Nature of Damage & symptoms caused by insect

- Maggots mine between the epidermal layers of the leaves in a characteristic serpentine manner
- Drying dropping of leaves in severe cases

Favourable conditions

- Warm weather conditions are favourable for multiplication

Sampling

Only the number of live mines on five randomly selected leaves per plant should be counted and recorded. Five plants per spot should be observed. Five spots randomly selected per acre of main field should be sampled.

IPM module

Host plant Resistance

- Host monogenic resistance of leaf miner, L. trifolii in melons has been studied. Antibiosis type of resistance is conferred by the line Nantais Oblong, a Charentais type melon, against L. trifolii**. Dogimont et al., 1999 2.**
- Genetic resistance in some chrysanthemum cultivars like Chrysanthemum pacificurn IVT 78 173 and C. morifolium 'Penny Lane' has been reported**. De Jong and Van De Vrie, 1987 3.**
- Antibiotic and antibiotic resistance have been identified in Apium species, Apium leptophyllum and A. prostratum has been reported **Trumble et al., 1997**

Cultural

- Exclusion of leafminers from greenhouse growing areas by physical barrier (mesh protection) **Schuster, 1994**
- Elimination of host weeds in the crop environment **Price and Harbaugh, 1981 3.**
- The use of gravel as a substrate in the greenhouse to reduce leafminer survival **Oetting, 1985 4**.
- Leafminer population was higher in tomatoes grown with plastic mulches or when they were tied to stakes and this was due to the lower activity of parasitoids. **Price and Poe, 1976 5**.
- Introducing trap crops such as shallots and cucumbers reduced the leafminer populations as well as increased the parasitoid population and parasitism. **Saleh et al., 2018**

Physical

- Remove infested leaves at time or with in a week of transplanting.
- Yellow sticky traps were used to monitor adult population levels, and leaf samples were used to monitor larval population levels **Weintraub, 2001**
- Yellow sticky traps trapped higher leaf miner fly and significantly reduced the leaf miner populations in Uganda **Rose et al., 2019**.
- Among four types of trap viz., yellow water, yellow sticky board, bottle with 20% protein hydrolysate, and funnel with 10% casein hydrolysate, against Liriomyza huidobrensis (Blanchard) in the coastal region of Peru, the yellow sticky boards were the most effective in trap capture with a mean of 1193.92 L. huidobrensis per week. (**Chavez and Raman, 1987)**

Biological

- Apply neem cake @ 250 kg/ha at 20 days after transplanting.
- In Hawaii, Ganaspidium utilis Baerdsley, Neochrysocharis punctiventris and Chrysocharis oscinidis were released for L trifolli and L. sativae control in watermelons, legumes, tomatoes, pumpkin, beans, and Irish potatoes with great success (**Liu et al., 2009)**
- *Dacnusa sibirica* along with *Diglyphus isaea* is as inundative biological control. L. trifolii was effectively being controlled by releasing these two parasitoids in tomatoes and cucumbers greenhouse; the combination of these parasitoids is available commercially (**Abd-Rabou, 2006)**
- Spray 2-3 time 5 % NSKE(1) at 7-10 days interval depending on infestation.
- Spray neem seed powder extract 4 % or neem shop 1% at 15 – 20 day after transplanting.

Botanicals

- Some fruit extracts such as Melia azedarach (Meliaceae) have also been investigated for their effects on the control of leafminers (**Banchio et al., 2003)**
- The use of basil oil, spruce oil, juniper oil and clove oil in yellow sticky traps predominantly increased the number of insects trapped (**Górski, 2005**)
- NeemAzal-T/S has greatest potential to control L. sativae in netted greenhouses. Hossain and Poehling, 2006 8 CURACRON®, Belt ® and botanical extracts of Almond Extract, @3.00%, Walnut Extract @3.00 were also tested for their efficiency against the pea leaf miner. (**Rizvi et al., 2015)**
- Fish amino acid 0.5% and NSKE 5% at 10 days interval was found to be the efficient method for controlling leaf miner population. (**Mohan and Anitha, 2017)**
- The effects of M. azedarach fruits on survival of L. sativae Blanchard and its parasitoid D. isaea (Walker) were tested under laboratory conditions. It has been found that the M. azedarach was more compatible to use with biological control by the parasitoid D. isaea and at the same time, it lowers the leaf miner population to considerable level (**Hammad and McAuslane, 2010**)

Parasitoids:

1.Chrysocharis pentheus **2.** ***Diglyphus isaea*** ***3. Gronotoma micromorpha***



Predators:

1. **Lacewing (***Chrysoperla carnea* **)**

Feeding potential of green lacewing

A single larva of *C. carnea* consumed Aphid and 97.33 eggs of *Corcyra cephalonica* followed by Aphid (80.00±2.65 nymphs/adults) and *A. craccivora* (64.33±0.67 nymphs/adults) per day. However, the all three larval instars of *C. carnea* consumed 369.00±6.11 eggs of *C. cephalonica* followed by Aphid (277.67±4.37 nymphs/adults) and *A. craccivora* (206.67±1.86 nymphs/adults) during whole larval period **(Kumar et al 2019)**

2. **Lady beetle (***Coccinella septempunctata)*

The aphid consumption was significantly ($P<0.05$) higher in case of 4th instar grubs of ladybirds as compared to 1st, 2nd and 3rd instars, might be due to advancement in age of insects. Moreover, the aphid consumption under laboratory conditions of the ladybirds was significantly ($P<0.05$) higher as compared to those under field conditions. This was happened due to the fact that under laboratory conditions, the beetles had less area to move and hence their activity was only to feed on aphids, while under field conditions, the beetles cover more distance and spent greater time in searching the aphid. These results are further supported by **Ali et al. (1994), Alamgeer et al. (1999), Gautam et al. (2002) and Omkar et al. (2003).**

Chemical

- About eight insecticides were tested for their efficacy against L. trifolii on variety Avinash of tomato. From the result, it is concluded that Profenophos 40% +

Cypermethrin 4% was found to be the most effective in control over other insecticides **Rai et al., 2013**

- Chlorantraniliprole 4.3% + Abamectin 1.7% SC was significantly effective while spraying twice fortnightly and also incidence of L. trifoli were reduced and fruit yield was increased. **Selvaraj et al., 2017**
- Vertimec 18 EC in the dose of 1000 ml cp / ha showed 80% efficiency against L. huidobrensis in potato cultivation. **Barros et al., 2017**
- Chlorantraniliprole 18.5 SC 0.03% at 10 days interval reduces the leaf minor damage, number of mines and larvae per plant. **Mohan and Anitha, 2017**
- Tetraniliprole 200 SC as foliar application was found to be more effective in controlling tomato leaf miner, L.(**trifolii Kousika and Kuttalam, 2020**
- The insecticide cyantraniliprole 10.26 OD, abamectin 1.9 EC and deltamethrin 2.8 EC registered lower leaf miner infestation. **Ramesh et al., 2020**
- Tetraniliprole 200 SC as foliar application was found to be more effective in controlling tomato leaf miner, **L.trifolii Kousika and Kuttalam, 2020**

ETL

2-5 miner / plant

3. Tobacco caterpillar

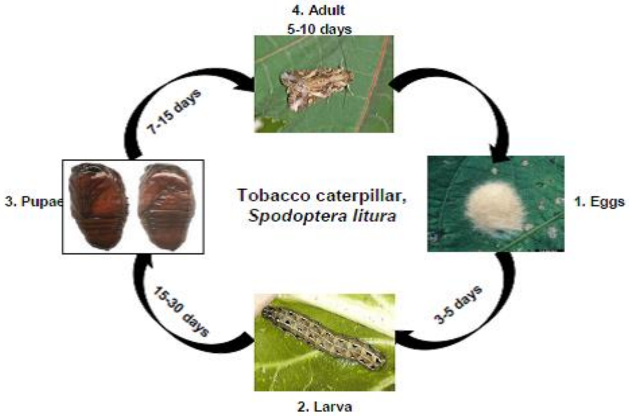
Spodoptera litura Fabricius

(Lepidoptera: Noctuidae)

Biology

It is found throughout the tropical and subtropical parts of the world, wide spread in India. Besides tobacco, it feeds on cotton, castor, groundnut, tomato, cabbage and various other cruciferous crops.

- **Eggs:** Female lays about 300 eggs in clusters. The eggs are covered over by brown hairs and they hatch in about 3-5 days.
- **Larva:** Caterpillar measures 35-40 mm in length, when full grown. It passes through 6 instars. Larval stage lasts 15-30 days
- **Pupa:** Pupation takes place inside the soil. Pupal stage lasts 7-15 days.
- **Adult:** Moths are active at night. Adults live for 7-10 days. Total life cycle takes 32-60 days. There are eight generations in a year.



Nature of Damage & symptoms caused by insect

- In early stages, the caterpillars are gregarious and scrape the chlorophyll content of leaf lamina giving it a papery white appearance. Later they become voracious feeders making irregular holes on the leaves.
- Irregular holes on leaves initially and later skeletonization leaving only veins and petioles
- Heavy defoliation.
- Bored fruits with irregular holes

Favourable conditions

Warm weather conditions and rainy conditions are favourable for multiplication.

ETL - One larva per plant

IPM MODULE

Monitoring

It is a relative method of insect population estimation where no direct observations on the plants for the presence of insect-pests are needed. However, the pest population is estimated with the help of attractant traps. Page | 57 For monitoring whiteflies, aphids, thrips and leaf miner adults, yellow sticky cards (4″x12″ or 8″x12″) and blue-coloured sticky traps for thrips are used in the protected environment. Hang the yellow sticky cards/traps in the crop with the help of strings about 4″ to 6″ above the plant canopy. The traps are placed in a grid pattern and 1-2 yellow sticky cards per 100 square meter of floor area are used (**Mandeep et al., 2018).**

Besides, sex pheromone, baited traps can also be used for detecting moths of tobacco caterpillar and tomato fruit borer. These traps allow visualizing population trends and can be used to time the application of pesticides or release of bio-agents. (**Sharma et al)**

Cultural

- Grow castor along field borders, irrigation channel as trap crop.

Biological

- Spray *Spodoptera* NPV 250 LE/ha + 1% jaggery along
- with sticker (0.5 %) in evening hours.
- Entomopathogens **-** *Bacillus thuringiensis*, SlNPV, HaNPV
- Parasitoid - *Trichogramma chillonis*
- Predator - *Chrysoperla carnea*

Mechanical / physical

- Collect and destroy egg masses and larvae on trap crop of castor at periodic intervals.
- Collection and destruction of egg masses and gregarious larvae on tomato.
- Poison baiting: Mix 5 kg rice or wheat bran with 0.5 kg jaggery by adding a little water in morning hours.
- In the evening add carbaryl 0.5kg and 3 litres of water to the above mix and sprinkle in one hectare of field

Chemical control

- Novaluron 5.25% +indoxacarb 4.5 SC @ 825-875 ml /ha
- Spinosad 45 SC 160 -220 ml/L water (**Sharma et al)**
- Indoxacarb 14.5 SC 500 ml/L water(**Sharma et al)**
- Chlorantraniliprole @ 0.3ml/L water (**Sharma et al)**
- Flubendiamide @ 0.1ml/L water(**Sharma et al)**

4. Whitefly

Bemisia tabaci Gennadius

Hemiptera: Aleyrodidae

Biology

Bemisia tabaci can complete a generation in about 20–30 days under favourable weather conditions **(Saini, 1998).**

Different stages of whitefly

- **Egg:** Pear shaped, light yellowish Stalked
- **Nymph:** On hatching - Oval, scale-like, greenish white
- **Adult:** White, tiny, scale-like adult

Nature of Damage & symptoms caused by insect

Bemisia tabaci can cause significant economic losses to crops by causing damage to the host plants during feeding through secretion of honeydew and transmission of plant viruses Both nymphs and adults of *B. tabaci* cause damage by inserting their mouthparts into the plants during feeding and by transmitting a large number of viruses that can severely damage susceptible plants species . **(Sani et al 2020)**

It has been found that *B. tabaci* nymphs can inject enzymes that cause changes in plant physiology, leading to irregular ripening of fruit and retarded internal coloration The honeydew excreted by *B. tabaci* provides a medium for the growth of sooty mold on the leaves and fruits, thus reducing photosynthetic activities, which could negatively affect the quality of farm produce . In addition, the feeding of *B. tabaci* on leaves can cause yellowing and crumpling, which subsequently results in stunted plant growth and deformed fruits**(Sani et al 2020)**

- Chlorotic spots
- Yellowing
- Downward curling and drying of leaves.
- Vector of tomato leaf curl disease.

Virus Transmission by Whiteflies

- Geminiviruses are transmitted by *B. tabaci* in a persistent circulative manner **(Brown 1994; Duffus 1994).**
- Their thread-like mouth parts must contact a suitable vascular bundle for successful feeding of the insect and virus acquisition **(Cohen *et al.* 1998).**
- Once an adult has acquired the virus by feeding on an infected plant, it may retain the virus for a long period and transmit it to healthy plants **(Brown 1994).**
- After acquisition, whiteflies can transmit virus up to 5–20 days **(Khurana and Singh 2003).**
- Transmission occurs only after a latent period of 4–10 h. The females are more efficient in transmitting the virus than the males **(Boulehya *et al*. 1997).**

Favourable conditions

- Warm weather conditions are favourable for multiplication.

IPM

Sampling :- Count and record the number of whitefly adults present on five randomly selected leaves per plant Five plants per spot should be observed.

Cultural Methode

- Cultural control is vitally important in managing whiteflies. Incorrect crop management, in particular, can create or exacerbate whitefly problems. Continuous culture of plants allows whiteflies to move from older to younger plants; the disruption of the whitefly population with host-free periods is important **(Dhawan *et al*. 2007)**
- Use seedling trays for raising plants kept under nylon nets or polyhouses.
- Physical and mechanical methods are techniques emphasizing the creation of unfavorable environments for pests, which include the removal of pest breeding sites and the use of healthy seedlings and resistant varieties. **(Sani et al 2020)**

- Cultural methods such as crop rotation could increase host periods or reduce intercrop migrations through careful consideration of the types and special arrangement of planted crops, thus, ultimately leading to the control of the *B. tabaci* population .**(Sani et al 2020**)
- The application of an electric field screen to greenhouse windows can prevent the entry of whitefly, but requires the presence of a guard at the greenhouse entrance area. **(Sani et al 2020)**

Biological

Beauveria bassiana (Balsamo-Crivelli) Vuillemin is one of the most commonly encountered EPF, and has been commercially developed as a microbial insecticide to control *B. tabaci*. (**Zafar et al 2016)**

- Applied three different isolates (Bb-01, Bb-08, and Bb-10) of *B. bassiana* against eggs and the second nymphal instar of *B. tabaci* on four host plants (*Gossypium hirsutum*, *Lycopersicum esculentum*, *Solanum melongena*, and *Capsicum annum*). The results showed a significant reduction of *B. tabaci* eggs and nymphs. Meanwhile, **(Prithiva et al**. **2017)**
- Release first instar larvae of green lacewing @ 10000/ ha
- **Predator** - *Orius laevigatus* , *Chrysoperla spp Among predators*, *Chrysoperla carnea*, *C. scelestes*, *Geocoris bicolor* and *Mallada boninesis* feed on eggs and nymphs of *B. tabaci*. *Brumoides saturalis*, *Menochilus sexmaculatus* and *Euseius hibisci* predate only on nymphs. *Scymnus syriacus*, *Euseius hibisci* are important predators of nymphs and adults of *B. tabaci* **(Dhawan *et al.* 2007).**

Chemical

- Addition of mineral oil at 1.0% to insecticidal spray solution improves the efficacy of these pesticides through its ovicidal effects and reduction of adult activity. In fact, adults cannot fly properly after mineral oil application and become unable to transmit the virus **(Boulehya *et al*. 1997)**
- Various combinations of organophosphate and pyrethroid insecticides, e.g., Sumicombi-30 (fenitrothion + fenvalerate), have also been used and found to be effective (**Ba-Angood and Mogahed 1997)**
- Imidacloprid 20 g a.i./ ha (**Jha and Kumar 2017)**
- Cypermethrin 25 g a.i./ ha(**Jha and Kumar 2017)**
- Indoxacarb 50 g a.i./ ha(**Jha and Kumar 2017)**

Economic thresh hold level 4 adults/ leaf

5 .Thrips:

Thrips tabaci
Frankliniella schultzei
Thysanoptera: Thripidae

Damage stage – Nymph and adult

Nature of Damage & symptoms caused by insect

Nymphs and adults cause damage with their feeding, which distorts plant growth, deform flowers, and causes **white to silvery patches** on emerging leaves that often have tiny black fecal specks in them

The primary damage caused by thrips to tomatoes is the vectoring of tomato spotted wilt virus (TOSPO VIRUS)

IPM

Monitoring

Monitoring information on the development of thrips population levels relative to the economic thresholds is assessed to decide on the employment of control tactics. Monitoring is based on regular visual scouting of thrips adults on flowers and fruits or on the use of sticky traps.Compared with yellow sticky traps, blue traps have shown to catch more thrips; yellow sticky traps can also be used for monitoring aphids, whiteflies and leafminers. The use of monitoring tools has been expanded by the addition of semiochemicals as lures that significantly increase thrips catches. Based on thrips samplings, models for predictions of thrips population growth and spread of thrips have been developed as potential decision tools for IPM programmes.(**Mouden et al 2017)**

Cultural, mechanical and physical

Ancient time, farmers have been relying on cultural or physical practices for the management of pests. Sanitary practices such as removing weeds, old plant material and debris form the first line of thrips defence. .(**Mouden et al 2017)**
Screening greenhouse openings prevented thrips immigration into protected crops but requires optimisation of ventilation.(**Mouden et al 2017)**.
thrips incidence in protected tomato was reduced by 20% using greenhouse window screens..(**Mouden et al 2017)**
Irrigation, creating a less favourable environment for thrips, reduced numbers of thrips adults..(**Mouden et al 2017)**
In contrast, high relative humidity favoured thrips larval development and stimulated pupation in the plant canopy..(**Mouden et al 2017)**
High rates of phosphorus favoured thrips development but did not lead to increased thrips damage.(**Mouden et al 2017)**.

Intercropping French beans with sunflower, potato or baby corn compromised bean yield but reduced damage to the bean pods, increasing marketable yield. .(**Mouden et al 2017)**

Host plant resistance

In the course of evolution, plants have evolved a variety of defence mechanisms, constitutive and inducible, to reduce insect attack, and this has led to host plant resistance. The study of host plant resistance involves a large web of complex interactions, mediated by morphological and chemical traits that influence the amount of damage caused by pests. Understanding the nature of plant defensive traits plays a critical role in designing crop varieties with enhanced protection against pests. **(Mouden et al 2017)**

Biological

Predatory mites

The principal arthropod predators associated with thrips biological control are phytoseiid mites (*Amblyseius* spp.) and pirate bugs (*Orius* spp.). Several species of *Amblyseius* have been recorded as predators of thrips, and various species have been assessed for their efficacy. The first predatory mites used for thrips control were *Amblyseius bar keri* and *Neoseiulus* (formerly *Amblyseius) cucumeris*, which primarily feed upon first-instar larvae. Owing to the inadequate control achieved, a number of other mites have been studied in order to find a superior thrips predator. Species such as *A. limonicus*, *A. swirskii*, *A. degenerans* and *A. montdorensis* proved to be effective predators of thrips**(Mouden et al 2017)**

Predatory bugs

Orius, commonly known as **pirate bugs**, are known to be generalist predators, preying on adults and larvae of a wide range of insect species such as **aphids, whiteflies, spider mites and thrips**. Several species of *Orius* have been tested to evaluate their use against thrips**(Mouden et al 2017)**

Parasitoids

To date, *Ceranisus menes* and *C. americensis* are the only two parasitoid wasps investigated for their potential to control thrips

Chemical

Spinosad 45SC @ 56 g ai. ha (**Misra 2012)**

Cyantraniliprole @ 105 g ai. /ha and Cyantraniliprole @ 90 g ai/. h was found equally effective for controlling tomato thrips(**Misra 2012)**

6. Tomato pinworm

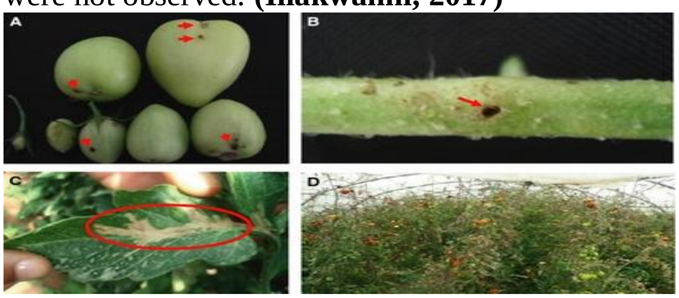
Scientific name : *Tuta absoluta* Meyrick

Lepidoptera: Gelechiidae

This insect originated in South America, and has spread to several European, Middle Eastern, and North African countries since its discovery in Spain in 2006 (Desneux et al., 2010). Recently, it was reported from India as well **(Kumari et al., 2015).**

Nature of Damage & symptoms caused by insect

T. absoluta, being a leafminer damages tomato leaves, terminal buds, flowers, and fruits (Moraes and Normanha Filho, 1982; Haji et al., 1988; Lopes-Filho, 1990; Castelo-Branco, 1992), causing a reduction of crop yield that can be as high as 90% (Apablaza, 1988). Damage is so high because the larvae feed on the mesophyll, thereby affecting photosynthetic capacity of the crop **(Urbaneja *et al.*, 2012).**
Adult moths have no problem but its Larvae can destroy tomato plants during all growth stages. The pest life cycle start with eggs, larvae, pupa and adult moth. Larvae pass through four growth stages or instars. The larvae feeds upon tomato plants, producing large galleries in leaves, burrowing in stalks, and consuming apical buds and green and ripe fruits and can thus cause up to 100% loss in tomato production if control measures were not observed. **(Illakwahhi, 2017)**



Biology

Females lay eggs on the plant canopy; larvae normally hatch in the morning and wander about for 5–40 min before they start mining.

Young larvae (1st–2nd instar) bore into the plant and, once mature (3rd–4th instar), they leave their mines and move to new locations for feeding.
If food is available and climatic conditions are favourable, larvae feed almost continuously and generally do not enter diapause.

Pupation occurs mainly on the leaves and in the soil, in function of environmental and growing conditions, whereas a small proportion may take place in other sheltered sites such as stems and fruits (**Fernandez & Montagne, 1990; Uchoˆa Fernandes *et al.*, 1995; Viggiani *et al.*, 2009**)

IPM module

Monitoring

Sex pheromone of insect is serving as alternative to monitor male moth population through trapping **(Braham, 2014).**

Sex pheromone is chemical secretion released in the form of fluid that triggers the opposite sexual interest (**Medido *et al*., 2013; Illakwahhi and Srivastava, 2017).**

This sex pheromone is released by virgin female tomato leafminer and strongly attractant to male moths **(Quiroz, 1978).**

Mostly male moths are attracted to the secreted pheromone **(Braham, 2014**).

Therefore, mass trapping of male moths is encouraged by using pheromone and imperative to early warning of pest abundance and monitor insect population **(Megido *et al*., 2013; Ghoneim, 2014; Retta and Berhe, 2015).**

The trapped insects can be damaged mechanically or by applying chemical. These techniques have been successfully applied in controlling leafminers on both greenhouses and open field **(Chermiti and Abbes, 2012; El-aassar *et al*., 2015).**

Pheromone trap data give early warning of the infestation and also will alert the user to low level of populations before they become serious. Different types pheromone trapping techniques are known , these include:

Water trap; it consist of a plastic container holding water and a pheromone lure. The lure is secured above the water with a wire attached at both ends of the container.

Sticky rolls; these are rolls with T. absoluta pheromone incorporated into the sticky glue, with the pheromone gradually released from the adhesive layer.

Delta traps; these are of two types i.e Cardboard delta triangle with sticky surface and Cardboard delta triangle with a removable liner. Either one is suitable, although delta traps with nondrying sticky liners are preferred. Traps are available from several suppliers in multiple colors and all should be considered equivalent. **(Illakwahhi 2017)**

Cultural

- Good agricultural practices for the control of *Tuta absoluta* include crop rotation with non-solanaceous crops (preferably Cruciferous crops), ploughing, adequate irrigation and fertilization, removal of infested plants and complete removal of post-harvest plant debris and fruit
- Remove weeds that may be host to the pest within the area of vicinity. To prevent population build up one should not leave infested plant material (from pruning or weeding) on the ground, as the larvae will quickly leave them and colonize new plants. After harvesting, crop residues should be destroyed as soon as possible. **(Illakwahhi 2017)**
- The crop residue after the harvest of tomato, potatoes, eggplants or peppers should be destroyed as soon as possible. They can be destroyed by either burning, buried or covered with transparent plastic film to ferment them.
- Soil solarisation may be useful in warm climates to kill pupae that remain in the soil. Leave a minimum of six weeks between successive susceptible crops. **(Illakwahhi 2017)**

Biological control

- The entomopathogenic fungus *Baeuveria bassiana* was considered as the best and effective candidate against larvae of *T. absoluta*. These fungal strain, with high dose treatment (4.75×107 conidia/ml), resulted in 100% larval death within 3 days, while low doses led in a fatality rate of 87% within 4 days (**Ikram and Abdallah, 2011**).
- Fortunately, well-concealed pest stages of the notorious *T. absoluta* have effective natural enemies.
- Entomopathogenic nematodes (EPNs), *Steinernema carpocapsae* Weiser, *Steinernema feltiae* Filipjev, and *Heterorhabditis bacteriophora* Poinar attack *T. absoluta* larvae, pupae, and adults that remain hidden within galleries in leaves (Batalla-Carrera et al., 2010).
- The host plant has an important effect on EPN efficiency. For example, the corn earworm, *Helicoverpa zea* Boddie feeding on tobacco, has been shown to reduce virulence and reproduction of the EPN *S. riobrave*, when compared to tomato and eggplant diets (**Hazir *et al*., 2016).**

- Entomopathogenic fungus species, *Metarhizium anisopliae* var. *anisopliae* Metchnikoff Sorokin that can be applied with irrigation water **(Contreras et al., 2014).**
- As investigators reported, *Trichogrammatoidea bactrae* and *Trichogramma pretiosum* are egg parasitoids of *T. absoluta* (**Lewis et al., 2003).**
- However, the endoparasitoid, P. dignus, and the ectoparasitoid, D. phtorimaeae formed more than 50% of natural parasitism in the larval stage of T. absoluta **(Sánchez et al., 2009; Luna et al., 2010)**

Predators

These may include Predatory bugs such as *Macrolophuspygmaeus*(commercially available as *Macrolophuscaliginosus*) and *Nesidiocoristenuis* have been identified as the most promising natural enemies of *T. absoluta* in Europe as they are large consumers of eggs of the pest. In the Mediterranean production areas, these two species naturally colonize tomato crops not sprayed with broad-spectrum insecticides and they are released for biological control in greenhouse tomato crops. Other identified predators of *T.absoluta* are the mirid *Dicyphus maroccanus*, the nabid *Nabispseudo ferusibericus* and the two phytoseid species *Amblyseiuss wirskiiand Amblyseius cucumeris* **(Illakwahhi 2017)**

Parasitoids

Parasitoids of *T.absoluta* eggs, *Trichogramma acheae* has been identified as a potential biological control agent of the pest and is currently being released in commercial tomato greenhouse**(Illakwahhi 2017)**

Biochemical bio-pesticides (Plant extracts)

- Botanicals are very important natural resources used to control different agricultural pests for long period of time. Crude extracts from seeds, leaves, bark, bulbs, and fruits of the different plant species have been extensively tested on agricultural pests for bioactivity worldwide **(Isman and Seffrin, 2014).**
- Ethanolic leaf extract obtained from Piper amalago var. medium, for instance, caused 70% larval and pupal mortality in twoAynalem 15 day exposure through exhibiting acute toxicity at the concentration of 2,000 mg L-1 **(de Brito *et al*., 2015).**
- The ethanolic extract from the Neem (Azadirachta indica) and petroleum ether extract from Jatropha (Jatropha curcus) seeds are tested on T. absoluta egg and larval stage as bio-insecticides **(Kona *et al*., 2014)**
- Thus, the ethanolic extract of Neem results in 24.5% egg and 86.7 to 100% larval mortality of *T. absoluta* at different concentration. The observed larval mortality is better than Neem Azal T/S 0.3% registered with active ingredient of azadiractin which kills 84 to 87% of first to fourth instars larvae after 14 days of exposure (**Yankova *et al.*, 2014).**
- In the same way, the petroleum ether extract obtained from Jatropha also achieved 18 to 25% egg and 87 to 100% larval death on *T. absoluta* after being exposed for 4 days in different concentration **(Moreno *et al*., 2011; Kona *et al*., 2014).**
- The extracts obtained from jojoba (*Simmondsia chinsis*) seed at 100% concentration resulted in 75% mortality on 2nd larval instars of *T. absoluta* **(Abdel-Baky and Al-Soqeer, 2017).**

RNA INTERFERENCE (RNAI)

- The RNA interference (RNAi) is a mechanism that small RNAs can rapidly cause post-transcriptional specific gene silencing **(Hannon, 2002).**
- Such biotechnological approach is currently becoming the potential application for agricultural insect pest control **(Gordon and Waterhouse, 2007; Katoch *et al*., 2013)**
- Tomato pinworm, *T. absoluta* mitigation was initiated by targeting on gene silencing approaches using small RNA interference **(Price and Gatehouse, 2008; Camargo *et al*., 2016)**

Conclusion

- The goal of IPM is to reduce the adverse impacts of pest control on human health, the environment and non-target organisms, while managing pests effectively

- Integrated pest management (IPM) uses environmentally sound, yet effective, ways to keep pests from annoying you or damaging plants.

- Integrated Pest Management (IPM) is a modern, sustainable approach that encourages the use of natural pest control mechanisms with the aim to grow healthy crops with the least possible disruption to agroecosystems and risks to human health and the environment.

- IPM programs usually combine several pest control methods for long-term prevention and management of pest problems without harming you, your family, or the environment.

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