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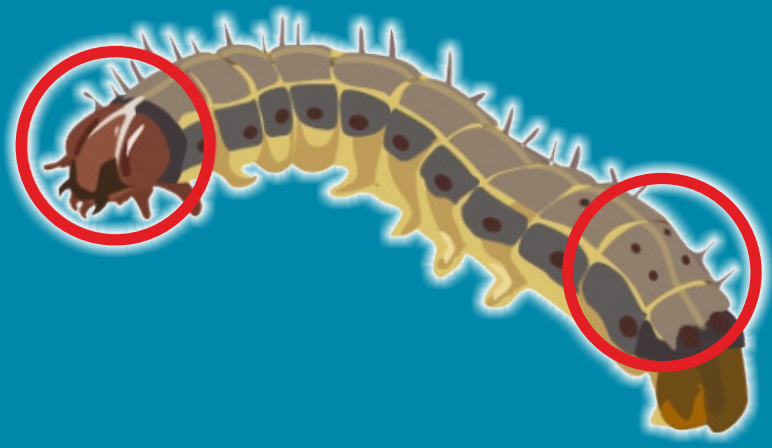

TECHNICAL BULLETIN

Integrated Management of Fall Armyworm in Maize

2019

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ICAR
NATIONAL INSTITUTE OF BIOTIC STRESS MANAGEMENT
Rendering solution to biotic stresses

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NIBSM

Integrated Management of Fall Armyworm in Maize

Contents

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COVER PHOTO TOP RIGHT : Identification marks of FAW
COVER PHOTO LEFT : Whorl damage
CURRENT PAGE PHOTO : Pheromone trap

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Acknowledgements

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Key Points

- Awareness campaign to farmers and capacity building programmes to extension officers and input dealers
- Scouting and monitoring at early stage of crop
- Summer ploughing
- Early synchronised sowing
- Raise border and intercrops
- Weed free condition
- Destruction of egg masses and larval stages
- Application of neem oil at early stage of crop
- Use eco-friendly methods and traps
- Release egg parasitoid, *Trichogramma pretiosum*
- Spray bio-pesticides
- ETL based application of insecticides

Fast Facts on Fall armyworm

- **A hungry, hungry caterpillar:** It's not a worm. It's a caterpillar that grows into a moth. This means it can travel far once it reaches the adult stage.

- **100 km per night:** The adult moth can travel over 100 kilometres per night, and with the help of a good wind it has been known to travel more than 1,000 kilometres in 30 hours.

- **1,000s of eggs** per female. In the adult stage, the Fall armyworm reproduces quickly.

- **80 plant species** make up the menu for this hungry, hungry caterpillar. This includes key staples, like maize, millet, sorghum, rice, and wheat, as well as sugar cane and vegetables.

- **$13 billion US:** The predicted losses in maize, sorghum, rice, and sugar cane that African farmers will experience this year. Small but devastating for sure.

- **An invader from the Americas:** It was first reported in Africa in 2016, where it is causing significant damage to maize crops and has great potential for further spread and economic damage. It has since spread to 28 countries in Africa. In 2018, it began to spread widely in India. In January 2019, heavy infestation of fall armyworm was recorded from corn plantations of Sri Lanka.

Source: farmradio.org

Summer ploughing

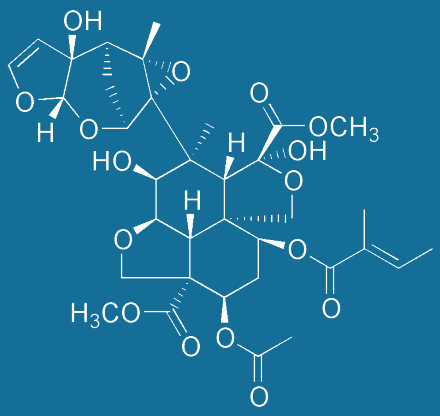
Source: agric.wa.gov.au

Maize-legume intercropping

Source: Kevan Christensen, One Acre Fund

Light trap

Source: Rahul Jain



Azadirachtin

Introduction

In India, maize (*Zea mays* L.) is third important crop after rice and wheat that provides food, feed and fodder and serves as source of basic raw material for the number of industrial products, *viz*., starch, oil, protein, alcoholic beverages, food, sweeteners, cosmetics, bio-fuel, *etc*. Thus, Maize has attained an important position as industrial crop because 83% of its produces are used in starch and feed industries. Maize is being cultivated in an area of 8.69 million ha in India with the production and productivity of 21.81 million tonnes and 2509 kg/ha, respectively. Andhra Pradesh, Karnataka, Bihar, Maharashtra, Rajasthan, Madhya Pradesh and Uttar Pradesh are the major maize producing states of India with the highest area under cultivation in Shimoga, Belgaum and Hassan districts of Karnataka.

The fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera:Noctuidae), an invasive pest has become a threat to farmers and Indian Agriculture and first detected on the Indian subcontinent in May 2018 in maize fields at the College of Agriculture, Shivamogga, Karnataka. The ICAR-National Bureau of Agricultural Insect Resources, Bengaluru has reported the damage intensity of FAW as 9 to 62% with the yield loss of 34% in Karnataka. FAW is an insect native to tropical and subtropical regions of the Americas where they primarily attacked maize crops during the autumn months. FAW was detected in Central and Western Africa, Nigeria, Sao Tome, Benin and Togo in early 2016. Then it spread to India *via* Karnataka state. The early emergence in crop life cycle, voracious feeding habit, large-scale aggressive behavior, high fecundity, fast migration, wide host-range and irreparable nature of crop damage make FAW as a key pest on maize. It is difficult to trace its arrival in to India. However, it is believed that the FAW arrived in India from Africa through human-aided transport, natural migration (capable to fly hundreds of kilometers in one night on prevailing winds) and escaped regulatory systems or quarantine. Since the FAW is an invasive pest in the country, the Ministry of Agriculture and Farmers Welfare, GOI, inter alia has constituted a High Powered Committee (HPC) for efficacious management of FAW. Agriculture Commissioner (DAC&FW) suggested to constitute sub-committees at state level for continuous monitoring and implementing various IPM strategies at the ground level. Periodical awareness campaign to farmers and suitable training to extension workers and pesticide dealers are required to manage FAW successfully in India.

Maize in India

- Area: 8.69 million ha
- Production: 21.81 million tonnes
- Productivity: 2509 kg/ha

FAW status in India

- Damage intensity: 9-62%
- Yield loss: 34%

Major maize growing states

- Andhra Pradesh
- Karnataka
- Bihar
- Maharashtra
- Rajasthan
- Madhya Pradesh
- Uttar Pradesh

Climate condition

More cloud cover, coupled with low temperature and high rainfall favour the rapid increase of population of FAW to an outbreak.

Host range

In addition to maize (major host), FAW can eat more than 80 plant species including rice, sorghum, cotton, sugarcane *etc*.

Damage potential

Fall armyworm has caused extensive damage to crops, especially maize, which is very critical for the animal feed industry and also crops such as sugarcane and millets. Consequently, India is forced to import maize for feed and starch industries, which together consume nearly 80 percent of the domestic production.

Due to the FAW infestation and unfavourable weather, maize production fell by about 15-20 percent during 2018. As a result, prices have shot up turning the economics of the fast-growing feed industry unviable. This pest can cause substantial harm to the harvest and eventually, profitability of the farmers. Ultimately, rise in raw material prices will push the prices of meat, egg and milk up and will negatively impact the consumers.

Economic threshold

On maize, if 5% of seedlings are cut or 20% of whorls of small plants (during the first 30 days) are infested, it is recommended that an insecticide be applied. In sorghum, the pest threshold level is as one (or two) larvae per leaf whorl and two per head.

Present Status of FAW in India

Area under maize, infested in various states during kharif 2019

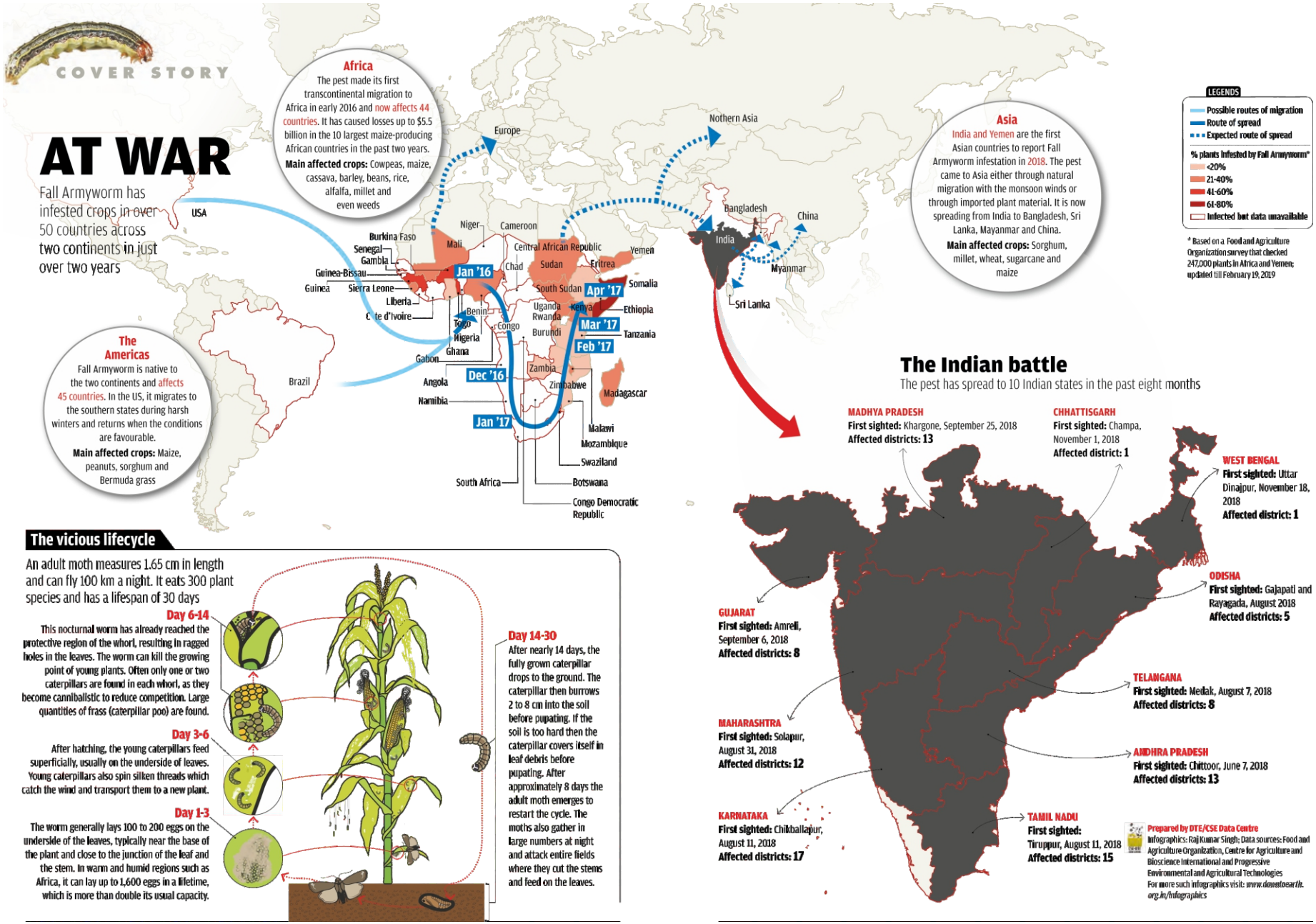
Karnataka: 1.4 lakhs ha out of 6.20 lakhs ha
Andhra Pradesh: 137 ha out of 32,000 ha
Tamil Nadu: 200 ha out of 2700 ha
Maharashtra: 2000 ha in Nasik district
Rajasthan: 59,000 ha out of 7 lakhs ha
Madhya Pradesh: 85,000 ha out of 11.3 lakhs ha
Uttar Pradesh: Reported in Kannauj district
Bihar: Infestation expected in the coming days

- Main host: Maize
- Alternate host: 80 plant species
- About 15-20% reduction in maize production
- ETL: 5% seedlings cut or 20% whorls damage

Fall armyworm damaged cob

Source: pioneer.com

Route map of spread and distribution of Fall armyworm



Source: downtoearth.org.in

Life stages of FAW

The life cycle FAW is completed in about 30 days during the summer, but 60 days in the spring and autumn, and 80 to 90 days during the winter. The ability to diapause is not present in this species.

Egg

The egg is dome shaped; the base is flattened and the egg curves upward to a broadly rounded point at the apex. The number of eggs per mass varies considerably but is often 100 to 200, and total egg production per female averages about 1500 with a maximum of over 2000. The eggs are sometimes deposited in layers, but most eggs are spread over a single layer attached to foliage. The female also deposits a layer of grayish scales between the eggs and over the egg mass, imparting a furry or moldy appearance. Duration of the egg stage is only two to three days during the summer months.

Larva

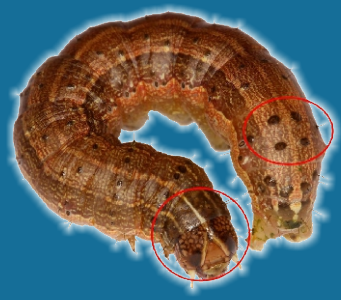
There are six instars in fall armyworm. Young larvae are greenish with a black head, the head turning orangish in the second instar. In the third instar, the dorsal surface of the body becomes brownish, and lateral white lines begin to form. In the fourth to the sixth instars the head is reddish brown, mottled with white, and the brownish body bears white sub-dorsal and lateral lines. Elevated spots occur dorsally on the body; they are usually dark in colour, and bear spines. The presence of four black spots arranged in square shape on dorsal aspect of the penultimate abdominal segment is another important mark to differentiate it from other cutworms. The face of the mature larva is also marked with a white inverted "Y". Duration of the larval stage tends to be about 14 days during the summer and 30 days during cool weather.

Pupa

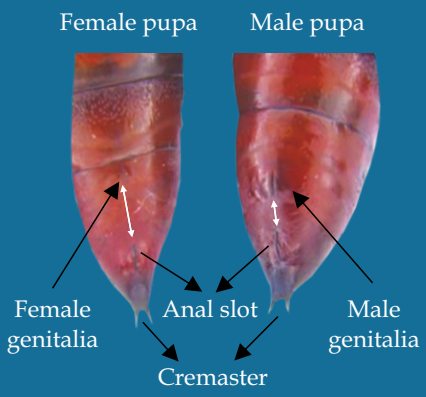
Pupation normally takes place in the soil, at a depth 2 to 8 cm. The larva constructs a loose cocoon, oval in shape by tying together particles of soil with silk. If the soil is too hard, larvae may web together leaf debris and other material to form a cocoon on the soil surface. The pupa is reddish brown in color. Duration of the pupal stage is about eight to

Fall armyworm egg masses

Source: © D Visser ARC-VOP Roodeplaat



Source: © D Visser ARC-VOP Roodeplaat



nine days during the summer, but reaches 20 to 30 days during the winter.

Adult

In the male moth, the forewing generally is shaded gray and brown, with triangular white spots at the tip and near the center of the wing. The forewings of females are less distinctly marked, ranging from a uniform grayish brown to a fine mottling of gray and brown. The hind wing is iridescent silver-white with a narrow dark border in both sexes. Adults are nocturnal, and are most active during warm, humid evenings. After a preoviposition period of three to four days, the female normally deposits most of her eggs during the first four to five days of life, but some oviposition occurs for up to three weeks. Duration of adult life is estimated to average about 10 days, with a range of about seven to 21 days.

Male adult

Female adult

Mounted by: U Vys, ARC-PPR;
Photos by: © D Visser ARC-VOP Roodeplaat

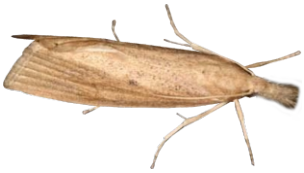
Comparison at larval and female adult stage

Fall armyworm (*Spodoptera frugiperda*)
Source: © D Visser ARC-VOP Roodeplaat

American bollworm (*Helicoverpa armigera*)
Source: © D Visser ARC-VOP Roodeplaat

Tobacco cutworm (*Spodoptera litura*)
Source: © D Visser ARC-VOP Roodeplaat

Stem borer (*Chilo partellus*)
Source: © A Erasmus ARC-GCI



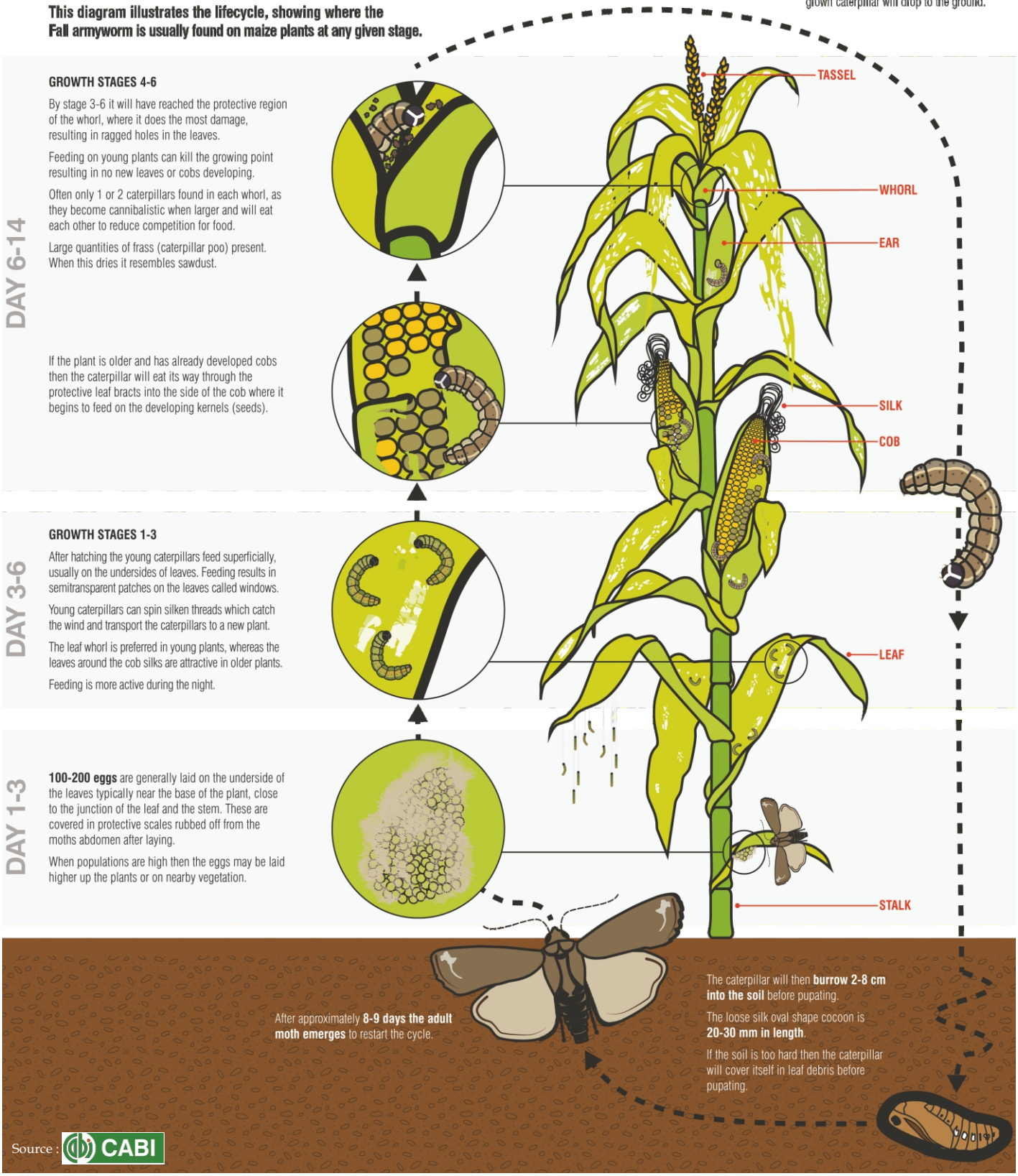
Damage like grazed by cattle

Source: plantwise.org

Fall armyworm: Life cycle and damage to Maize

The Fall armyworm lifecycle includes egg, 6 growth stages of caterpillar development (instars), pupa and moth.

This diagram illustrates the lifecycle, showing where the Fall armyworm is usually found on maize plants at any given stage.



Nature and symptom of damage

Young larvae initially consume leaf tissue from one side, leaving the opposite epidermal layer intact. By the second or third instar, larvae begin to make holes in leaves, and eat from the edge of the leaves inward. Feeding in the whorl of corn often produces a characteristic row of perforations in the leaves (shot holes). Larval densities are usually reduced to one to two per plant when larvae feed in close proximity to one another, due to cannibalistic behaviour. Older larvae cause extensive defoliation, often leaving only the ribs and stalks of maize plants, or a ragged, torn appearance. The early whorl stage is least sensitive to injury, the mid-whorl stage intermediate, and the late whorl stage is most sensitive to injury. The mean densities of 0.2 to 0.8 larvae per plant during the late whorl stage could reduce yield by 5 to 20 percent.

Larvae also will burrow into the growing point (bud, whorl, *etc.*), destroying the growth potential of plants, or clipping the leaves. In maize, they sometimes burrow into the ear, feeding on kernels. The FAW feeds by burrowing through the husk on the side of the ear.

Ragged appearance of maize leaves

Source: CABI

Larvae feeding on maize cob

Source: news.psu.edu

Cob tip damage

Source: ag.umass.edu

Feeding hole in maize cob

Source: Lyle J. Buss

Fall armyworm first instars

Young larvae feeding on maize leaf

Spread of young larvae by using silk threads

Source: © D Visser ARC-VOP Roodeplaat

Shot hole damage

Source: CIMMYT

Whorl damage with saw dust like frass

Source: thehindubusinessline.com

FAW management

A. Preventive Methods

i. Monitoring

Installation of pheromone traps @ 5/acre in the current and potential area of spread in crop season and off-season.

ii. Scouting

Start scouting as soon as maize seedlings emerge

- At Seedling to early whorl stage (3-4 Weeks after emergence)- Action can be taken if 5% plants are damaged
- At Mid whorl to late whorl stage (5-7 weeks after emergence) –Action can be taken if 10 % whorls are freshly damaged in mid whorl stage and 20% whorl damage in late whorl stage
- At tasseling and post tasseling (Silking stage)- Do not spray chemical insecticides. Suitable bio-pesticide may be used in the event of ear/cob damage

iii. Cultural control

- Summer ploughing in deep to expose pupae of FAW to predatory birds, heat *etc.*
- Control is largely achieved in the northern and central India through a winter kill by exposing larvae and pupae within the upper soil surface. Freezing temperatures cause high larval mortality
- Clean and weed free cultivation to destroy the alternate hosts and balanced use of fertilizers
- Dig trench around the field and fill with water and insecticide to avoid migration of FAW larvae from one to another field
- Early, synchronized sowing of maize to reduce the availability of crop for increase of population of FAW and further outbreak. Avoid staggered sowings
- Intercropping of maize with suitable pulse crops of particular region. (*eg.* Maize + pigeon pea/black gram / green gram)
- Sowing of 3-4 rows of trap crops (*eg.* Napier) around maize field and spray with 5% NSKE or azadirachtin 1500 ppm as soon as the trap crop shows symptom of FAW damage
- Apply charcoal, soil, ash, local plant extract on the whorl of maize,

FAW monitoring

Source: SAWBO

Scouting in 'W' path

Source: SAWBO

Maize intercropped with Napier grass

Source: Farmbiz Africa

Collection and destruction of larvae

Source: thehindu.com

Egg mass collection and destruction

as an ITK method

- Cultivation of maize hybrids with tight husk cover will reduce ear damage by FAW

iv. Mechanical control

- Hand picking and destruction of egg masses and neonate larvae in mass by crushing or immersing in kerosine water
- Application of dry sand in to the whorl of affected maize plants soon after observation of FAW incidence in the field
- Application of Sand + lime in 9:1 ration in whorls in first thirty days of sowing
- Mass trapping of male moths using FAW specific pheromone traps @ 15/acre

v. Traps

- Spread blue cloth measuring 2 m^2 in places randomly in an acre area to attract and kill the larvae
- Install FAW pheromone trap @ 5 numbers/ac and light trap @ 1 number/ha at early stage of crop

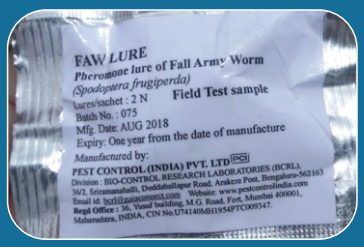
B. Curative Methods

i. Biological control

- *In situ* protection of natural enemies by habitat management: Increase the plant diversity by intercropping with pulses, oil seeds and ornamental flowering plants which help in build-up of natural enemies
- Augmentative release of egg parasitoid *Trichogramma pretiosum* or *Telenomus remus* @ 50,000 per acre at weekly intervals or based on trap catch of 3 moths/trap
- Bio-pesticides: If infestation level is at 5% damage in seedling to early whorl stage and 10% ear damage, then use following entomopathogenic fungi and bacteria: *Metarhizium anisopliae, Nomuraea rileyi, Beauveria bassiana, Verticilium lecani* (1×10^8cfu/g) @ 5g/litre whorl application. Repeat after 10 days if required
- *Bacillus thuringiensis* var. *kurstaki* formulations @ 2g/l (or) 400g/acre
- Apply Azhadirachtin 1% EC @ 10,000 ppm or neem oil @ 5 mL/lit. as oviposition deterrent on one week after sowing

Pheromone trap

Source: kiran.nic.in



FAW lure

Light trap

Trichogramma pretiosum

Source: © Heraldo Negri

Telenomus remus

Source: © L. Buss, University of Florida

- Erect bird perch @ 25-50 numbers/ha to attract predatory birds during early stage of the crop (up to 30 days) on feeding various larval stages of FAW

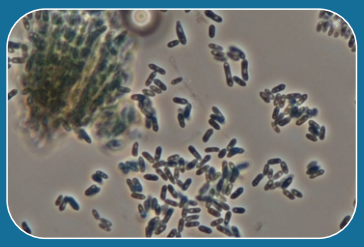
ii. Chemical control

- Seed treatment: Cyantraniliprole 19.8% + Thiamethoxam 19.8% FS @ 6 ml/kg of seed will be effective for 15-20 days
- First Window (seedling to early whorl stage): To control FAW larvae at 5% damage to reduce hatchability of freshly laid eggs, spray 5% NSKE / Azadirachtin 1500ppm @ 5ml/l of water.
- Second window (mid whorl to late whorl stage): To manage 2nd and 3rd instars larvae having more than 10% foliar damage the following chemicals may be used upto early tasselling stage: Spinetoram 11.7% SC or Chlorantraniliprole 18.5% SC or Thiamethoxam 12.6% + Lambda cyhalothrin 9.5% ZC
- Poison baiting: Poison baiting is recommended for late instar larvae of second window. Keep the mixture of 10 kg rice bran + 2 kg jaggery with 2-3 litres of water for 24 hours to ferment. Add 100g Thiodicarb just half an hour before application in the field. The bait should be applied into the whorl of the plants
- Third Window (8 weeks after emergence to tasseling and post tasseling): Insecticide management is not cost effective at this stage. Bio-pesticides as recommended above to be applied. Hand picking of the larvae is advisable
- All the sprays should be directed towards whorl and either in the early hours of the day or in the evening time

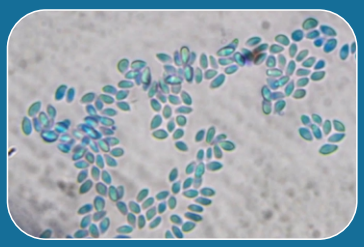
Capacity building and mass awareness

- Application and timely plant protection measures to avoid spread of the insect from the abandoned crop.
- Creation of awareness among important stake holders through trainings / group discussions.
- Community based and area-wide approach for implementing management strategies

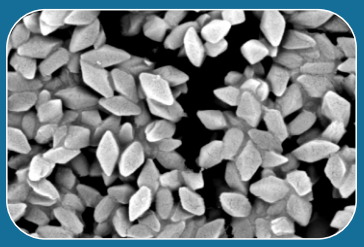
Source: MoA & FW, DACFW, GoI
TNAU, Coimbatore
ICAR, New Delhi



Metarhizium anisopliae spores
Source: naro.affrc.go.jp



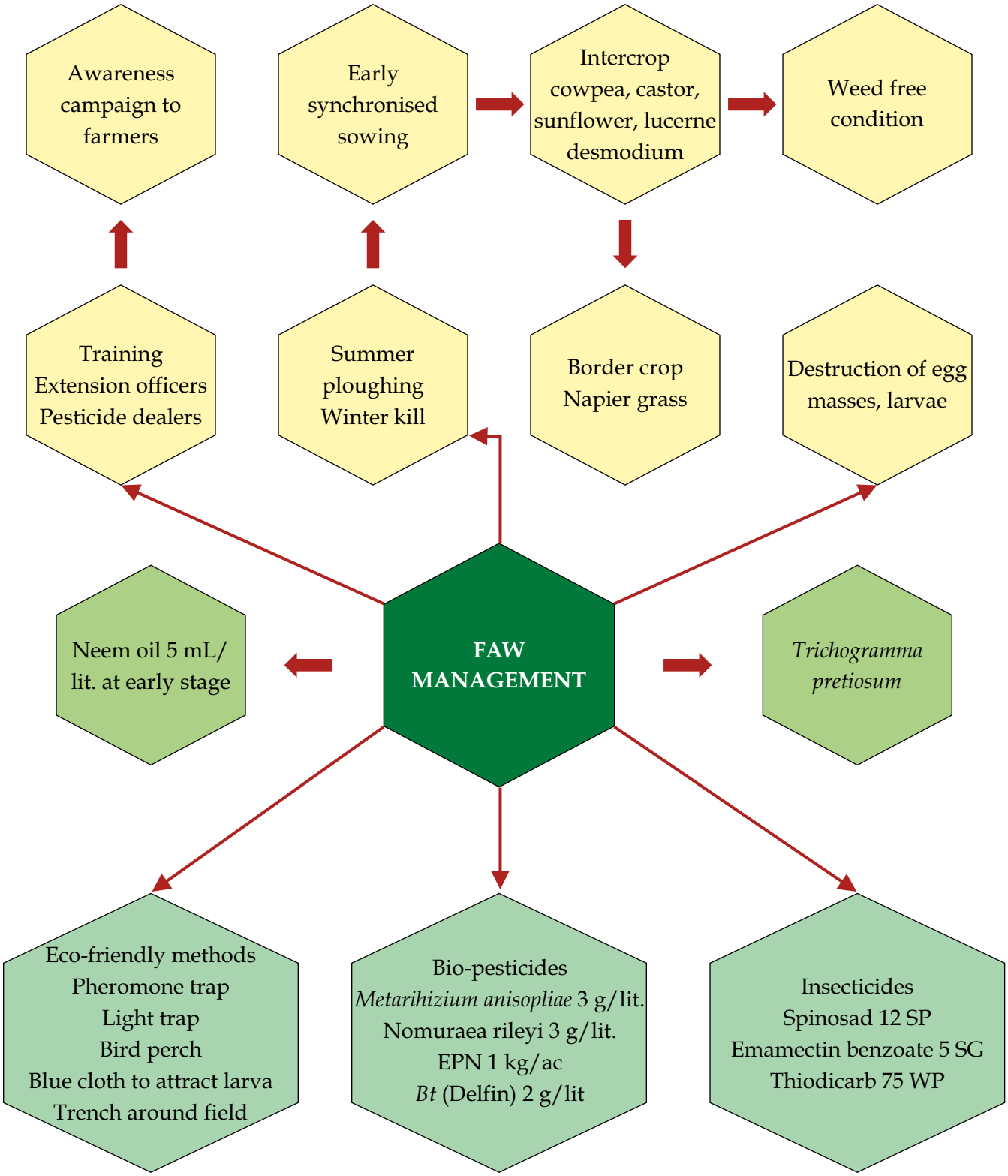
Nomuraea rileyi spores
Source: Reyna Torres



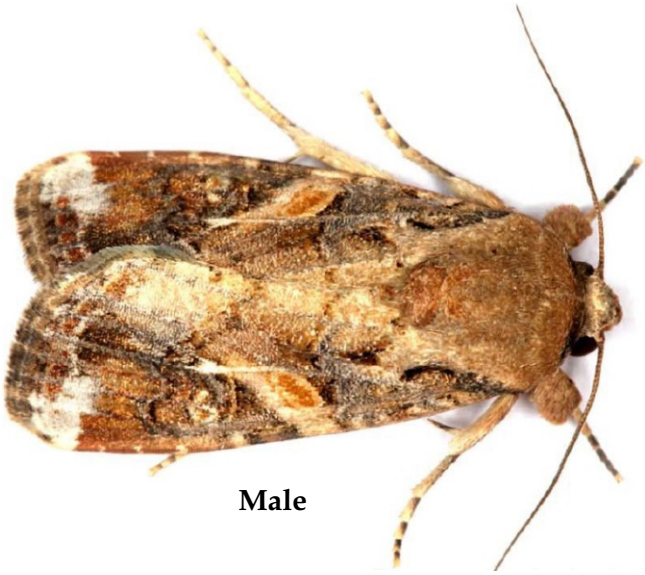
Bacillus thuringiensis spores
Source: Jim Buckman

Bird perch

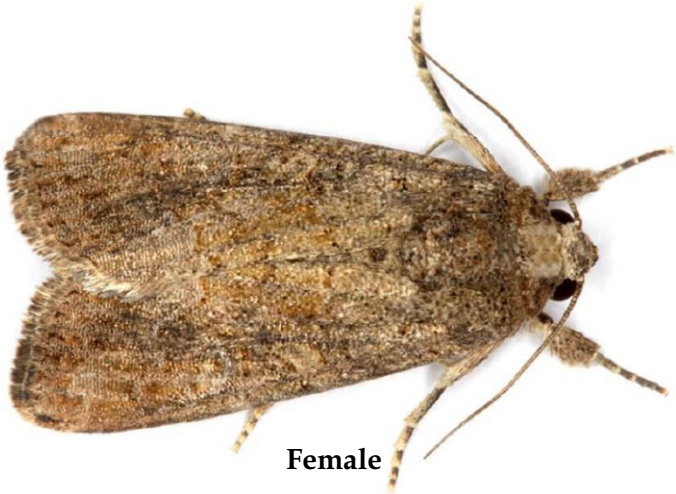
Integrated FAW management flow chart



Taxanomic keys for identification of FAW



Male



Female

Fall armyworm moth
Source: © D Visser ARC-VOP Roodeplaat

Male

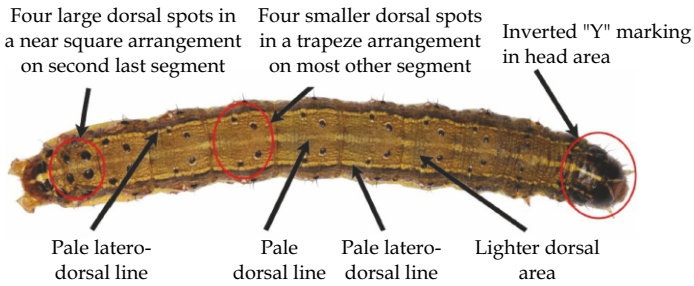
Female

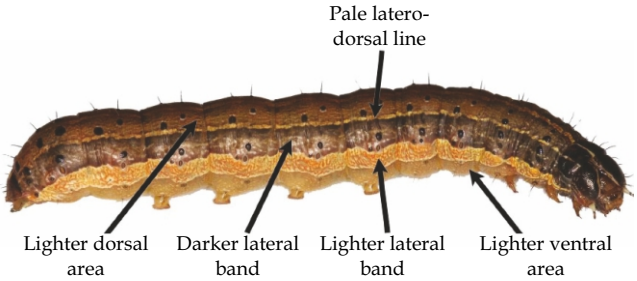
Fall armyworm adult
Source: © D Visser ARC-VOP Roodeplaat

Fall armyworm egg masses
Source: © D Visser ARC-VOP Roodeplaat

Instars of Fall armyworm
Source: ICAR-IIMR, Ludhiyana

Fall armyworm characteristic marks
Source: © D Visser ARC-VOP Roodeplaat





Fall armyworm characteristic spots
Source: © D Visser ARC-VOP Roodeplaat

Fall armyworm pupa
Source: © D Visser ARC-VOP Roodeplaat

Fall armyworm pupa in earthern cocoon
Source: © D Visser ARC-VOP Roodeplaat

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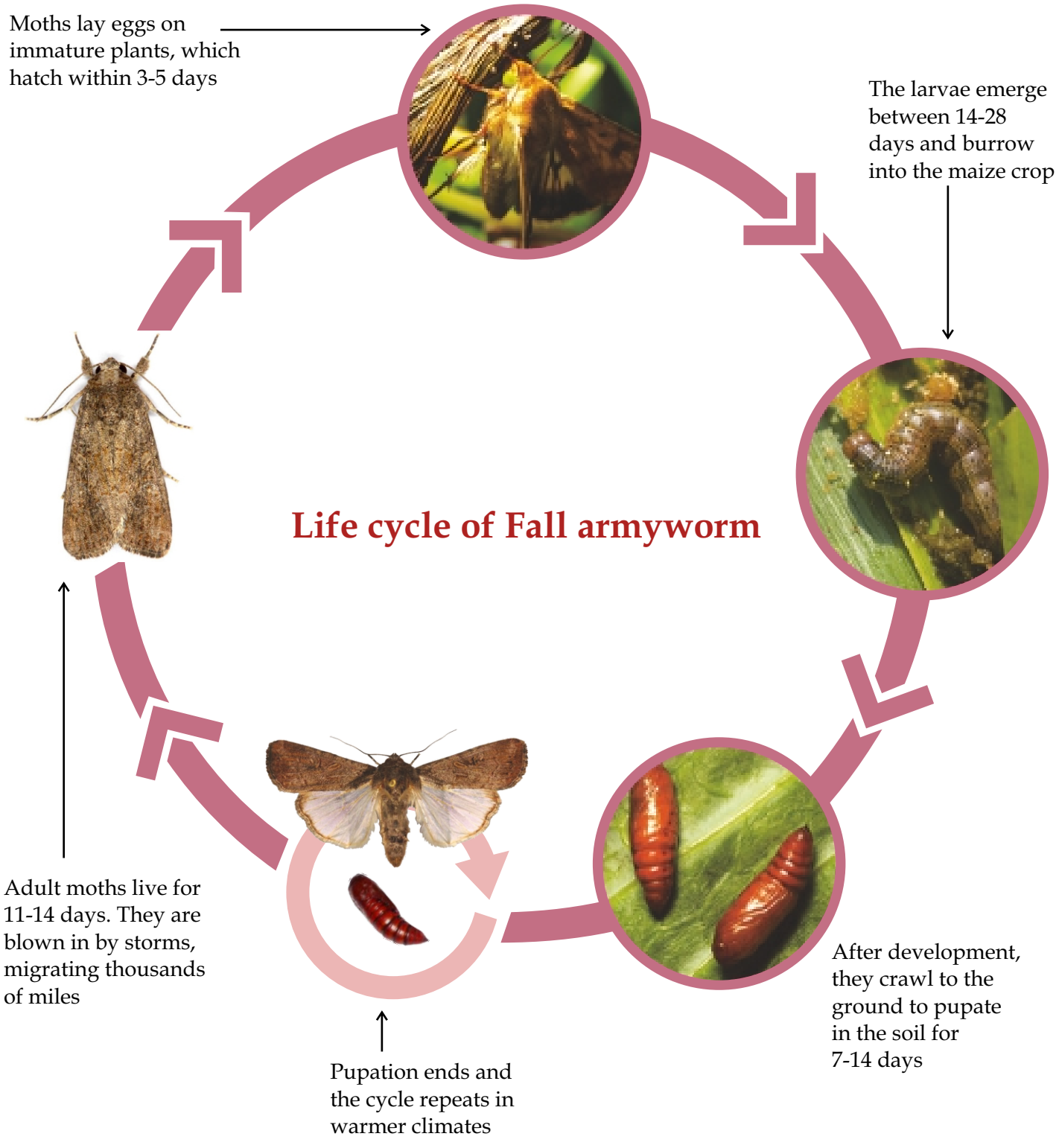
Fall armyworm symptoms of damage

1. Cob damage Source: pinterest.com
2. Scrapping Source: theconversation.com
3. Shot hole Source: caixinglobal.com
4. Whorl damage Source: vtnews.edu
5. Stem damage Source: plantvillage.psu.edu
6. Cob tip damage Source: iita.org



Source: International Maize and Wheat Improvement Center Photo: Dreamstime; Alamy

Predators / pathogens of FAW around world

Doru luteipes

Source: Maria Fachini Agostinho

Euborellia annulipes

Source: © Elliotte Rusty Harold

Coleomegilla maculata

Source: © Owen Davids

Olla v-nigrum

Source: © Randy Hardy

Cycloneda sanguinea

Source: Dianakc

Eriopis connexa

Source: alchetron.com

Hippodamia convergens

Source: © Gary McDonald

Calosoma granulatum adult

Source: Stanislav Krejčík

Calosoma granulatum larva

Source: pybio.org

Assassin bug (*Zelus* spp.)

Source: Andreas Kay

Zelus renardii

Source: © Pete Moulton

Podisus sp. (Pentatomidae)

Source: José Roberto Peruca

Orius insidiosus

Source: naturalenemiesbiocontrol.com

Geocoris punctipes

Source: Xpda

Fungus infected larvae

Source: © Albert Changaya and © Ken Wilson

NPV infected larvae

Source: Raghunandan BL *et al.*, 2019

Common parasitoids of FAW found worldwide

Parasitoid	Type	Country
Telenomus spp. Hymenoptera: Platygastridae	Egg	Antigua, Barbados, Brazil, Colombia, Dominican Republic, Guadeloupe, Ecuador, Guyana, Honduras, Nicaragua, Puerto Rico, Suriname, Trinidad, U.S., Venezuela, Israel, Cuba, Mexico, India
Trichogramma spp. Hymenoptera: Trichogrammatidae	Egg	Barbados, Nicaragua, Brazil, Chile, Colombia, Argentina, Cuba, U.S., Guadeloupe, Mexico, India
Chelonus spp. Hymenoptera: Braconidae	Egg, Larval	Barbados, Nicaragua Honduras, Mexico, Trinidad, Argentina, Brazil, Chile, Colombia, Cuba, Haiti, Puerto Rico, U.S., Uruguay, Venezuela
Agathis stigmatera Hymenoptera: Braconidae	Larval	Argentina, Peru, U.S.
Archytas spp. Diptera: Tachinidae	Larval	Argentina, Barbados, Honduras, Mexico, Nicaragua, U.S., Venezuela, Brazil, Chile, Puerto Rico, Suriname, Trinidad, Uruguay, Cuba, Ecuador, Guadeloupe, Lesser Antilles, Peru
Campoletis grioti (Hymenoptera: Ichneumonidae)	Larval	Argentina
Cotesia marginiventris Hymenoptera: Braconidae	Larval	Honduras, Barbados, Nicaragua, Argentina, Brazil, Chile, Lesser Antilles, Mexico, Puerto Rico, Suriname, U.S., Uruguay, Venezuela, Trinidad & Tobago, Colombia, Guyana
Euplectrus spp. Hymenoptera: Eulophidae	Larval	Nicaragua, U.S., Argentina, Puerto Rico, Panama, Honduras, Barbados, Brazil, Chile, Colombia, Cuba, Guyana, Lesser Antilles, Mexico, Trinidad, Venezuela, Honduras
Lespesia spp. Diptera: Tachinidae	Larval	Brazil, Honduras, U.S., Argentina, Brazil, Chile, Cuba, Guadeloupe, Guatemala, Honduras, Lesser Antilles, Mexico, Nicaragua, Puerto Rico, Uruguay, Venezuela, Colombia
Ophion spp. Hymenoptera: Ichneumonidae	Larval	Argentina, Uruguay, Chile, U.S., Brazil, Honduras, Mexico, Nicargua, Peru
Brachymeria spp. Hymenoptera: Chalcididae	Pupal	Argentina, U.S.

Parasitoid	Type	Country
Cryptus albitarsis Hymenoptera: Ichneumonidae	Pupal	U.S.
Diapetimorpha introit Hymenoptera: Ichneumonidae	Pupal	Honduras, U.S.
Ichneumon promissorius, *I. ambulatorius.* Hymenoptera: Ichneumonidae	Pupal	U.S.
Trichospilus pupivora Hymenoptera: Eulophidae	Pupal	Barbados

Source: Innovation Lab for Integrated Pest Management, USAID

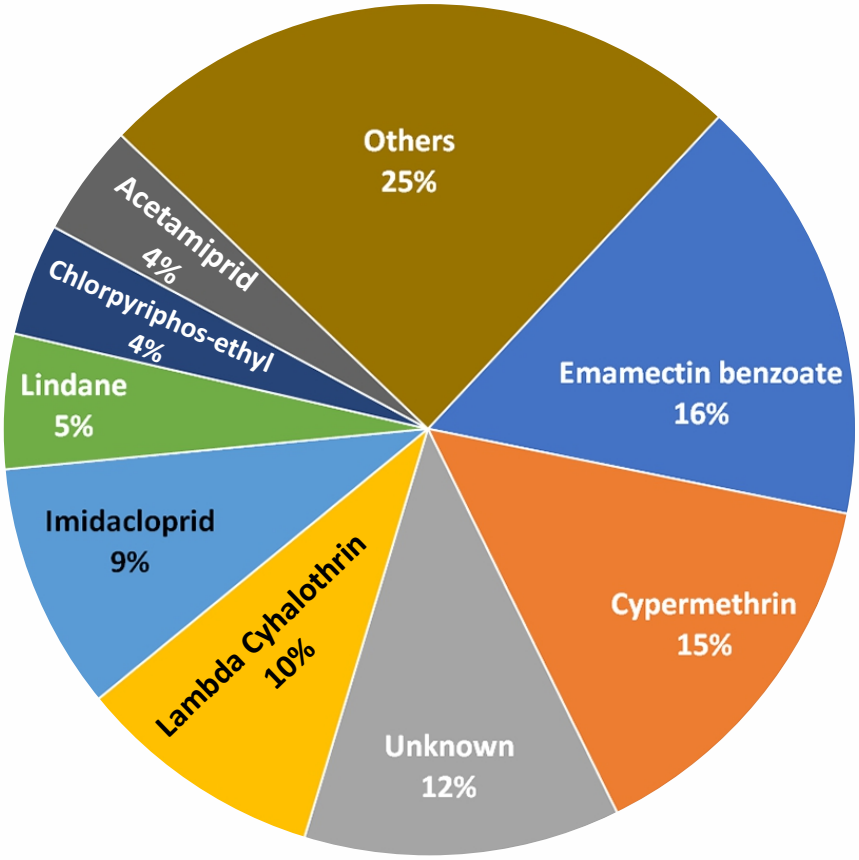
Conclusion

The fall armyworm incidence was first reported in Karnataka state on maize during 2018, thereafter it spread all over southern states except Telangana in a short span of time. Since it is an invasive pest in India, identification of the pest seemed to be difficult due to lack of reference materials or type specimens. The pest is rapidly spreading in India due to few characteristic behaviours like voraciousness, fast and rapid flying capacity, more 80 alternate hosts *etc*. Development of IPM to manage the pest is in infancy in India for want of basic information about this pest. The infestation of FAW has been reported during *kharif* 2019 in Karnataka, Andhra Pradesh, Tamil Nadu, Maharashtra, Rajasthan, Madhya Pradesh, Uttar Pradesh and Bihar. However, the FAW has been effectively managed in North Eastern states like Mizoram, Manipur, Nagaland, Assam, Arunachal Pradesh, Tripura, Sikkim and Meghalaya due to scouting and monitoring at early stage of the crop. To achieve such freedom from FAW in other parts of country, periodical awareness training to maize growers and capacity building on early scouting, surveillance and monitoring of FAW incidence to extension officers and input dealers are highly required.

For further reading

- Fall armyworm: An identification guide in relation to other common caterpillars, a South African perspective, www.grainsa.co.za/upload/Fall-Armyworm-Identification-Presentation.pdf
- FAO, www.fao.org/fall-armyworm/en/
- CABI, www.cabi.org/isc/fallarmyworm
- CIMMYT, www.cimmyt.org/tag/fall-armyworm/
- Management of Fall Armyworm in maize, GoI, www.ppqs.gov.in/sites/default/files/faw_do.pdf
- FAW training manual, FAO, www.livestockzimbabwe.com
- The Life Cycle of Fall Armyworm, blog.plantwise.org/2017/07/17/the-life-cycle-of-fall-armyworm/
- Fall armyworm photo guide – identification, www.cabi.org

Active ingredients of insecticides used by farmers to control *Spodoptera frugiperda* infestation on maize



Source: Fotso Kuate A. *et al.* 2019

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