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FALL ARMYWORM (FAW), *SPODOPTERA FRUGIPERDA* AND IPM STRATEGIES FOR MANIPUR

J. Konsam[1], N. Nongmaithem[1], S. Dayananda[1], N. Karam[1], P. Senjam[1], R. Thokchom[1] and S. M. Haldhar[2]

[1]Central Agricultural University (Imphal), Lamphelpat 795004, Manipur

[2]College of Agriculture (CAU, Imphal), Iroisemba 795004, Manipur

Fall Armyworm (FAW), *Spodoptera frugiperda* (Lepidoptera: Noctuidae) is a major pest of maize. The pest is a highly polyphagous migratory lepidopteran pest native to tropical and subtropical regions of the Americas causing significant damage to crop and is the key insect pest of maize in tropical (Sisay *et al.*, 2019). It was detected in central and western Africa in early 2016. In northeast India, this invasive pest was reported for the first during late March 2019 in Lunglei district of Mizoram and West Tripura district of Tripura state. Subsequently, it has detected causing massive outbreaks during April in Mizoram state and Nagaland state. Later, it was detected causing damage to maize crop during early May in Meghalaya, Manipur, Sikkim and Arunachal Pradesh states of northeast India. FAW was first detected in Manipur on 7th May, 2019 in Chandanpokpi village of Chandel district and subsequently reported from all the districts of Manipur. The pest is suspected to have arrived from Myanmar via Chandel district of Manipur, which borders Myanmar.

FAW being a polyphagous by nature attacks more than 180 spp. of plant in 42 families. However, this species prefers corn, sorghum, bermuda grass which are C4 plant as opposed to cotton, soybean. There are two strains of the fall armyworm, namely, R-strain which prefer rice (*Oryza sativa* L.), Bermuda grass and other graminae where C-strain prefers cotton and corn (*Zea mays* L.) (Adamczyk *et al.*, 1997). Among those two strains, the maize strain is more prevalent and feeds on maize leaves and stem. In Nicaragua, Huis, 1981 found a 33% increase in maize yield when plants were protected with an insecticide. According to (Hruska and Gould, 1997), infestations during the mid-to-late corn stage resulted in yield losses of 15-73% when 55-100% of the plants were infested with *S. frugiperda.*

SYMPTOMS ACCORDING TO THE STAGE OF LARVAL INSTARS

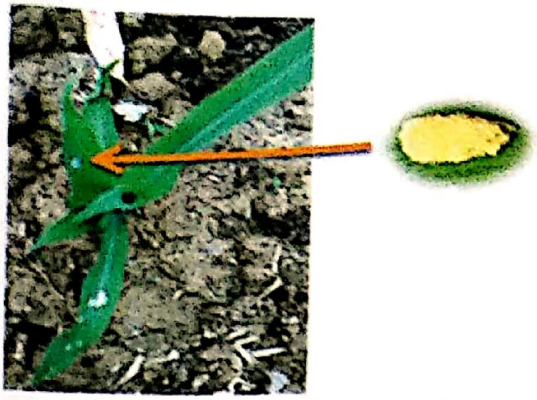


Fig. 1 Egg mass of FAW

Fig. 2 First instars larvae

Fig. 3 Initial damaged symptoms (Papery window)

Fig. 4 Damaged caused by 2nd instars larvae

Fig. 5 Ragged-edged holes caused by 3rd and 4th instar larvae

Fig. 6 Extensive leaf damage caused by 5th instar larvae

Fig. 7 Damaged caused by 6th instar larvae (extensively defoliate the leaves and produce large amount of faecal matter)

Fig. 8 Larvae damaged on tassel

Fig. 9 FAW Larval damage during reproductive stage

Fig. 10 FAW damaged maize Field

Fig. 11 Collection of FAW Larvae

Fig. 12 FAW 5th instar larva with identification marks viz., three creamy yellow lines (2, 3 & 4), white Y-shaped suture (1), bigger spots arranged in square (5) and trapezoid (6) formation.

Difference between Male and female moths

Fig. 13 Male moth (A) has fawn coloured spot (a) and whites a patch (b) at the apical margin of the wing. Female (B) is dull with faint markings

LIFE CYCLE OF FALL ARMYWORM

FAW being a lepidopteran pest, life cycle completes in four phases viz. egg, larva, pupa and adult. The pest requires 30 days in summer, 60 days in autumn and spring to complete its life cycle. However, the duration may be prolonged to 80 to 90 days during winter season (Luginbill, 1928). Every stage of the pest metamorphosis is described as,

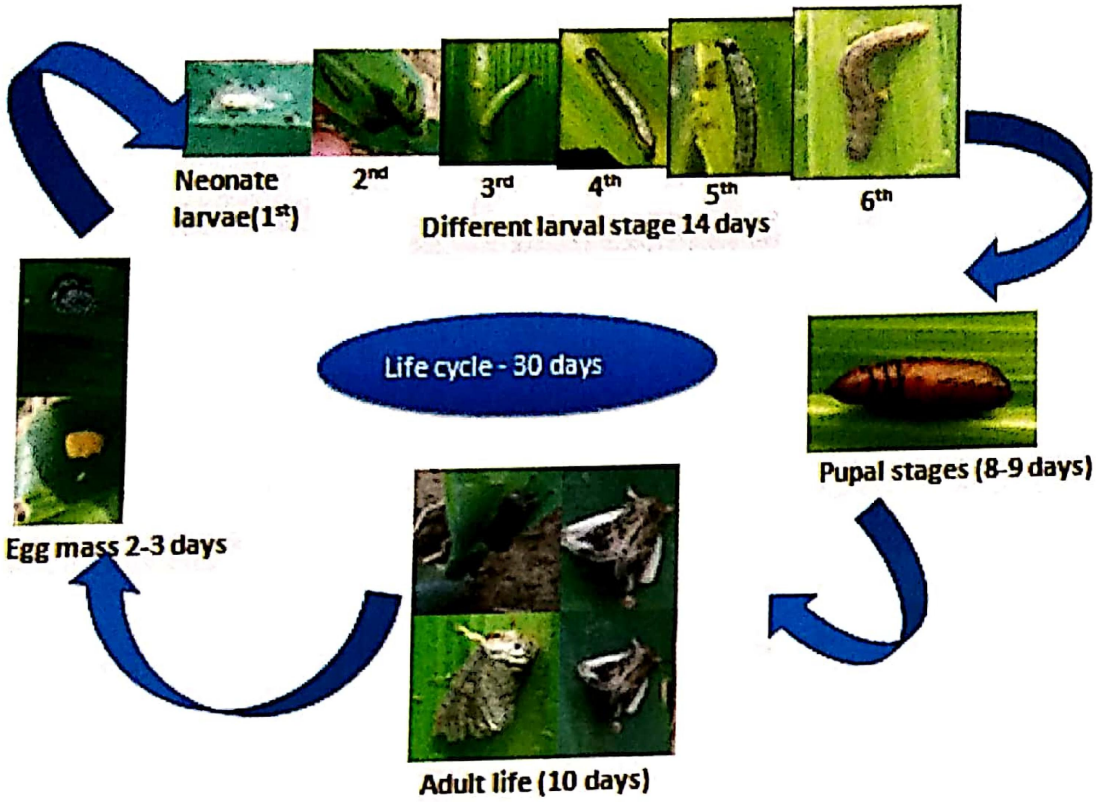


Fig. 14 Life cycle of Fall armyworm

INTEGRATED PEST MANAGEMENT (IPM) STRATEGY FOR FALL ARMYWORM

Integrated Pest Management (IPM) is the best and preferred method of FAW management (Day *et al.*, 2017).

1. Monitoring

Installation of FAW pheromone traps @ 5 acre on or before germination of the crop to monitor pest and population build-up. If 3 moths are detected per trap spraying is recommended.

2. Scouting

1. Start scouting in "W" pattern in the field after leaving 3-4 outer rows as soon as maize seedlings emerge.

2. At Seedling to early whorl stage (0-2 weeks after emergence): Action can be taken if 5% plants are infested or first catch of 3 moths trap^{-1}.
3. At early whorl to mid-whorl stage (2-4 weeks after emergence): Action can be taken if 5-10% plants are infested
4. At mid whorl to late whorl stage (4-7 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.
5. Late-whorl stage (7 weeks onwards of emergence): Action can be taken if more than or equal to 20% plants are infested.
6. At tasseling to harvest stage: Do not spray any insecticides (No insecticide application), but manually pick and destroy larvae.

3. Cultural Measures

1. Deep summer ploughing is recommended before sowing to expose FAW pupae to predatory birds and heat.
2. Timely sowing is recommended and avoids staggered sowings (Planting in same field at different times).
3. Follow clean cultivation and balanced use of fertilizers.
4. Intercropping of maize with non host crop (eg. Maize + pigeon pea/black gram /green gram).
5. Erection of bird perches @ 10 acre^{-1} as soon as sowing is completed (up to 30 days).
6. Planting of 3-4 rows of Napier grass (FAW trap crop) in maize field and spray with 5% NSKE or azadirachtin 1500 ppm @ 5 ml l^{-1} as soon as the trap crop shows symptom of FAW damage.
7. Selection of single cross hybrids and planting of maize hybrids with tight husk cover will reduce ear damage by FAW.
8. Push-pull strategy is also one of the strategies of cultural management of the pest in which maize is intercropped with pest-repellent "Push crop" (*Desmodium* spp.), surrounded by pest-attractive "pull crop" (Napier Grass, *Pennisetum purpureum* or *Brachiaria* spp.) (Dively, 2018).

4. Mechanical Measures

1. Hand picking and destruction of egg masses and neonate larvae in mass by crushing or immersing in kerosine water.

OR

Picking of FAW larvae and feed them to chicks for poultry production as FAW larvae are good complementary source of protein.

OR

FAW are also edible for human consumption. In countries where insects are consumed, they are good complementary source of protein for local population.

2. Application of sand or ash into plant whorl of affected maize plants soon after observation of FAW incidence in the field.

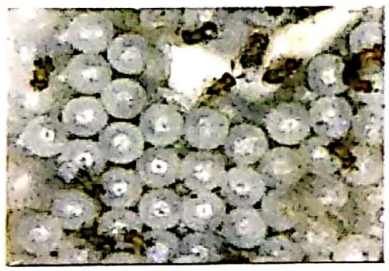
3. Application of soil or soil slurry to the leaf whorl

4. Mass trapping of male moths by using pheromone traps @15 traps acre^{-1}

5. Biological Control Strategies

1. *In situ* protection of natural enemies by habitat management.

2. Increase the plant diversity by intercropping with pulses and ornamental flowering plants which help in build-up of natural enemies.



Trichogramma sp.

Telenomus remus on FAW eggs

3. Augmentative release of *Trichogramma pretiosum* or *Telenomus remus* @ 50,000 acre^{-1} at weekly intervals or based on trap catch of 3 moths trap^{-1}.

Table 1 Parasitic natural enemies of fall armyworm

S. No.	Natural Enemy	Life Stage	Host
1.	*Archytas incertus*	Larva	Maize
2.	*Archytas marmoratus*	Larva/pupa	Maize/Sorghum
3.	*Campoletis flavicincta*	Larva	Maize
4.	*Chelonus curvimaculatus*	Eggs/Larva	Maize
5.	*Chelonus insularis*	Eggs/Larva	Maize/Sorghum
6.	*Cotesia marginiventris*	Larva	Maize

7.	*Cotesia ruficrus*	Larva	Maize
8.	*Euplectrus platyhypenae*	Larva	Maize
9.	*Glyptapanteles creatonoti*	Larva	Maize
10.	*Lespesia archippivora*	Larva	Maize
11.	*Microchelonus heliopae*	Eggs/Larva	Maize
12.	*Brachymeria ovata*	Pupa	
13.	*Telenomus remus*	Eggs	Maize/Vegetables
14.	*Trichogramma achaeae*	Eggs	Maize
15.	*Trichogramma chilotraeae*	Eggs	Maize
16.	*Trichogramma pretiosum*	Eggs	Maize
17.	*Trichogramma rojasi*	Eggs	Maize

Source: (CABI, 2019)

6. Microbial biopesticides

Microbial biopesticides are suitable at 5% damage in seedling to early whorl stage and 10% ear damage with entomopathogenic fungi and bacteria

Microbial biopesticide formulations

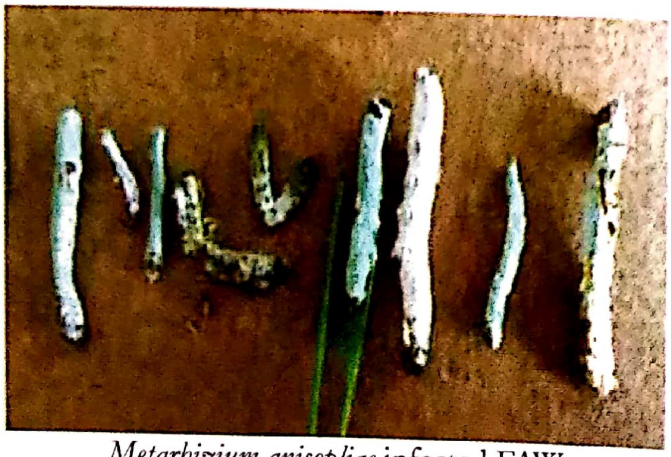
a. Application of *Metarhizium anisopliae* talc formulation (1×10^8 cfu g^{-1}) @ 5 g l^{-1} whorl application at 15-25 days after sowing. Another 1-2 sprays may also be given at an interval of 10 days depending on pest damage

OR

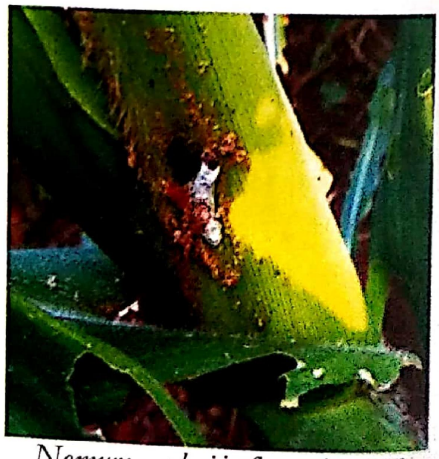
b. Application of *Nomuraea rileyi rice* grain formulation (1×10^8 cfu g^{-1}) @ 3 g l^{-1} whorl application at 15-25 days after sowing. Another 1-2 sprays may also be given at an interval of 10 days depending on pest damage

OR

c. Application of *Bacillus thuringiensis* v. *kurstaki* formulations @ 2 g l^{-1} (or) 400 g $acre^{-1}$



Metarhizium anisopliae infected FAW



Nomurea releyi inf[illegible] FAW

Particularly for FAW larvae infected with baculovirus, the dead larvae will generally be observed in the upper parts of the maize plant and will hang upside down (Prasanna *et al.*, 2018). The major entomopathogens that are helpful in the management of FAW in maize are listed below in the **Table 2.**

Table 2 Pathogenic natural enemy of fall Armyworm

S. No.	Natural Enemy	Life Stage
1.	*Bacillus cereus*	Larvae
2.	*Bacillus thuringiensis*	Larvae
3.	*Bacillus thuringiensis alesti*	Larvae
4.	*Bacillus thuringiensis darmstadiensis*	Larvae
5.	*Bacillus thuringiensis thuringiensis*	Larvae
6.	*Bacillus thuringiensis kurstaki*	Larvae
7.	*Beauveria bassiana*	Eggs/Larvae
8.	*Granulosis virus*	Larvae
9.	*Metarhizium anisopliae*	Eggs/Larvae
10.	*Nucleopolyhedrosis virus*	Larvae

Source: CABI (2019)

7. Chemical Control According to Stage of Crop

1. Seed treatment

Seed treatment with *Cyantraniliprole* 19.8% + *Thiomethoxam* 19.8% @ 4 ml kg^{-1} of seed reported to offer protection upto 2-3 weeks after germination.

2. Seedling to early whorl stage (0-2 weeks after emergence)

To control FAW larvae at this stage or at 5% damage, spray 5% neem seed kernel emulsion (NSKE) or Azadirachtin 1500 ppm @ 5 ml l^{-1} of water to kill eggs and neonate larvae.

3. Early whorl to mid-whorl stage (2-4 weeks after emergence)

To manage 1st instar 3 mm) larvae at 5-10% damage spray Chlorantraniliprole18.5% SC @ 0.4 ml l^{-1} or Thiamethoxam 12.6% + lambda cyhalothrin 9.5% @ 0.25 ml l^{-1} of water or Spinetoram 11.7% SC @ 0.5 ml l^{-1} of water.

Mid-whorl to late whorl stage (4-7 weeks after emergence)

To manage 2nd and 3rd instar larvae at 10-20% damage spray Chlorantraniliprole 18.5% SC @ 0.4 ml l^{-1} or Thiamethoxam 12.6% + lambda cyhalothrin 9.5% @ 0.25 ml l^{-1} of water or Spinetoram 11.7% SC @ 0.5 ml l^{-1} of water.

5. **Late-whorl stage (7 weeks onwards of emergence)**

Poison baiting is recommended for late instar larvae i.e. from 4th to 6th instars larvae. Keep the mixture of 10 kg jeerb just half an hour before application in the field. The bait should be applied into the whorl of the plants.

6. **Tasseling stage to harvest**

At this stage Hand picking and destruction of the larvae is advisable. Insecticide management will not be cost effective.

CONCLUSION

Fall armyworm is a highly damaging pest of maize. It has a very rapid spreading capacity. It is becoming a major threat in India as well as in north Eastern states. Proper quarantine measures should be strengthened to control the further entry of pest through different medium. Regular monitoring and scouting for the presence of the pest should be done. The spreading of FAW should be managed at the primary level using the integrated pest management methods like cultural control, biological control and use of chemicals below the economic injury level. However, the use of chemicals during the initial phase of pest spreading is not suggested as it can harm the natural enemies of the pest too.

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