Food and Agriculture Organization of the United Nations

MINISTRY OF AGRICULTURE AND FARMERS' WELFARE
GOVERNMENT OF INDIA

Integrated Pest Management (IPM) Farmer Field School (FFS)

A guide for facilitators of FFS on maize with special emphasis on Fall Armyworm

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Message

Maize is most important food crop after rice and wheat contributing towards national food security with an annual production of 28.7 million M.T. The Major maize producing states are Karnataka, Madhya Pradesh, Rajasthan Maharashtra and Andhra Pradesh. Maize is a relatively less water demanding crop and gives higher yield /hectare among other cereal. Due to development of newer varieties which are tolerant to extreme temperatures, the area under maize cultivation is increasing in northern parts of India. In India about 15 million farmers are engaged in farming and processing of maize.

Maize crop is attacked by number of pest & diseases which if not managed effectively and efficiently could adversely affect the maize productivity. Hence, the Integrated Pest Management (IPM) approach is being promoted to mitigate the pest problems with limited reliance on chemical pesticides.

The recent invasion of Fall Armyworm (FAW) is causing economic damage to maize cultivation. The pest is new, it is important to understand its behaviour in the agro ecosystem and its interactions with predators, parasitiods and entomo-pathogens in diverse agro ecosystem.

The Food and Agriculture Organization of the United Nations (FAO) in collaboration with MoAFW is implementing a project on "Time critical measures to support early warning and monitoring for sustainable management of Fall Armyworm in India".

This illustrative guide on IPM-FFS is developed by experts from Food and Agriculture Organization of the United Nations (FAO) and Directorate of Plant protection Quarantine & Storage (DPPQS), MoAFW for promoting IPM in maize cultivation with special emphasis on FAW management.

I wish that this guide will be useful to all extension functionaries in popularising the IPM Practices, evolving and adopting indigenous technical knowledge in pest management.

Dr. Ravi Prakash

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Foreword

The Food And Agriculture Organization of United Nations (FAO) is working to eradicate hunger and poverty, and to ensure sustainable management of natural resources, FAO has contributed to India's economic growth by supporting the Government of India and its partners in the areas like rural development, agriculture and livelihoods, crops, livestock, food security, environment, agriculture sustainably and management of natural resources in the past over seven decades.

Improvements in agriculture productivity have come with social and environmental costs including Water Scarcity, Soil Degradation, Biodiversity Loss, and High Greenhouse Gas Emissions. FAO is working to ensure food and nutritional security and end of all forms of malnutrition, in line with the Sustainable Development Goal (SDG-2) of zero hunger. This involves transformation of food systems and inclusive development while sustaining natural resources and protecting biodiversity.

In India, Maize is the third most important food crop after Rice and Wheat. It has attained a position of industrial crop globally as 83 percent of its production in the world and 76 percent in India is used in feed, starch and biofuel industries. Further, it is an important industrial raw material where more than 3 000 products are being made using Maize directly or indirectly providing wide opportunity for value addition.

The Fall Armyworm (Spodoptera Frugiperda), an economically crucial polyphagous insect pest native to tropical and subtropical regions of America has reached Asia and noticed first time in Maize fields of South Karnataka in the Indian subcontinent during May 2018, causing substantial damage to the crop. The pest has invaded most of the Maize growing area in India within a short period of two months posing a severe threat to livelihoods of Maize growers.

In the context of its economic losses caused by the destructive nature of FAW, the identification, biology and life cycle, nature of damage and extent of yield loss, and management of Fall Armyworm through cultural practices, mechanical and local controls, biological and synthetic pesticides have been reviewed in detail in the present IPM FFS manual. Government of India has been taking several steps to control the spread of FAW to minimize the crop losses.

This IPM – FFS Manual helps Master Trainers/ Facilitators to organize Farmer Field Schools for a season long to create awareness amongst farmers on sustainable management of FAW in the context of Indian smallholder cropping systems.

FAO gratefully acknowledges MoAFW for providing this wonderful opportunity. We will continue to support the government's efforts to successfully implement the recommendations to enhance food and nutritional security and increase farmer incomes.

Tomio Shichiri

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We gratefully acknowledge the role of the Ministry of Agriculture and Farmer's Welfare, Government of India, in providing an opportunity to present scenario of Maize cultivation in India and suggesting sustainable management options for management of Fall Armyworm through Farmer Field Schools Approach.

We would like to thank the Director-IIMR, Director-NBAIR, Director-NIPHM for their support in successful completion of the IPM-FFS Manual for the management of Fall Armyworm.

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Abbreviations and acronyms

AESA	Agro-ecosystem Analysis
CIPMC	Central Integrated Pest Management Centre
RCIPMC	Regional Integrated Pest Management Centre
FFS	Farmer Field School
IPM	Integrated Pest Management
IIMR	Indian Institute of Maize Research
PAR	Participatory Action Research
ICAR	Indian Council for Agriculture Research
FAW	Fall Armyworm
FAMEWS	Fall Armyworm Early Monitoring Warning System

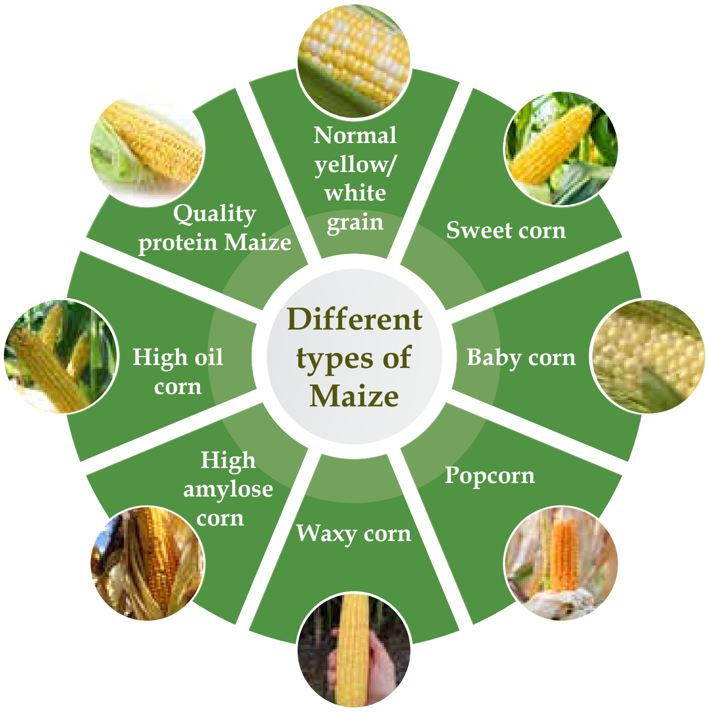
Chapter 1

Basic information of Maize Crop, Cultivation in India, Major Insect Pests and Diseases of Maize with Special Emphasis on Invasive Insect Pest, Fall Armyworm in Maize in India

1.1 Introduction

Maize, one of the most important cereal crops in the world, contributes to food security in many of the developing countries. Globally, Maize is known as the Queen of Cereals, because of its highest genetic yield potential. The crop is less water demanding than other similar cereals and being a C4 as well as day-neutral plant, it has the highest genetic yield potential among the cereals and can be grown in several agro-ecosystems.

- Multi-faceted use of Maize as a food, fodder and feed crop makes it more demand friendly.
- The crop is suitable for enhancing farmers' income and livelihoods in India.
- Maize qualifies as a potential crop for doubling farmers' income in India as several improvements can be done in crop protection and crop production technologies.



Maize: Economic facts

- *Contributes nearly 9 percent in the national food basket and shares good quantum in the national agricultural GDP.*
- *Not less than 15 million farmers are cultivating Maize and generating employment for more than 650 million person-days at farming and its related business.*
- *Two-thirds of the produce is consumed for feed and other industrial uses mainly starch.*
- *For a long period, India is exporting Maize to different AESEAN countries, Vietnam, Bangladesh and other neighbouring countries.*
- *Feed industry accounts a compound annual growth rate (CAGR) of 6-7 percent globally and 9 percent within India presents a huge opportunity for Maize growers*
- *In India Maize is used as feed (60 percent) followed by food (24 percent), industrial (starch) products (14 percent) beverages and seed (1 percent each).*

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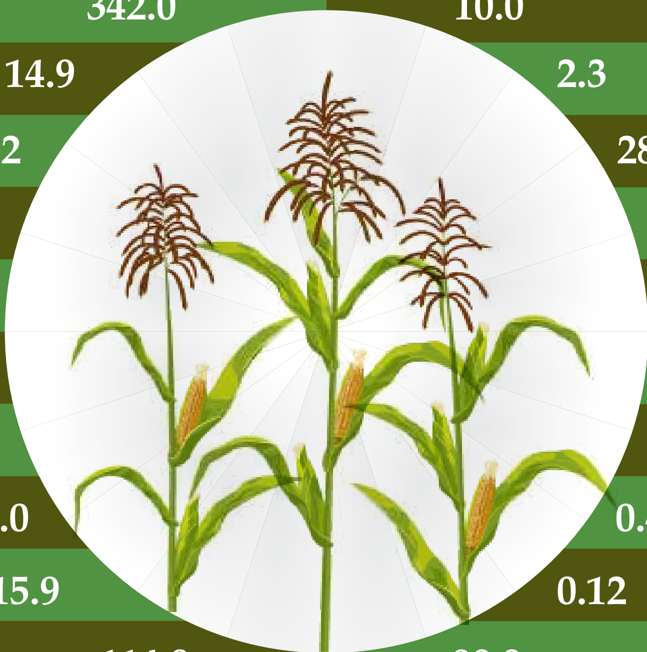
1.2 Maize Production Scenario in India

In India, Maize is the third important food crop after Rice and Wheat. Maize, predominantly a *Kharif* crop, is the only food cereal crop that can be grown in diverse seasons. *Kharif* crop area of Maize constitutes about 85 percent and remaining is cultivated in other seasons. The *Kharif* Maize is cultivated almost across the country while winter or *Rabi* Maize is cultivated more in Bihar, West Bengal and Peninsular India. Summer Maize is gaining popularity in Punjab, Haryana and Western Uttar Pradesh. The Maize is cultivated in India as a field crop in most of the states. However, it is also cultivated for home consumption as a garden crop in some areas. The small and marginal farmers are also actively growing Maize for their livelihood.

- The Maize growing predominant states are Karnataka (14.8 percent), Maharashtra (10.9 percent), Madhya Pradesh (10.8 percent), undivided Andhra Pradesh (10.4 percent), Rajasthan (10.6 percent), Uttar Pradesh (8.3 percent), Bihar (7.9 percent), Gujarat (5.0 percent) and Tamil Nadu (3.6 percent); accounting for nearly 80 percent of the total Maize area of the country.
- Karnataka, Andhra Pradesh, Maharashtra, Rajasthan and Bihar states together account for almost two-thirds of the national Maize production.
- Maize is also grown in Tamil Nadu, Uttar Pradesh, Himachal Pradesh, Punjab, West Bengal, Jharkhand, Gujarat, Jammu and Kashmir and North-Eastern states.
- The Maize production was 27.72 million MT during 2018-19.
- About 65-70 percent area is covered under hybrid Maize.

1.3 Uses of Maize and Nutritional Contents

- *Maize can be consumed as food, feed and fodder.*
- *Source of more than 3 500 products including specialized Maize, like quality protein Maize (QPM), baby corn, sweet corn etc.*
- *Maize contains high level of starch, oil, rich in protein, calcium, potassium, zinc, iron, selenium, manganese, magnesium, fibre, sugar etc.*



Calories	342.0	10.0	Calcium (mg)
Moisture (g)	14.9	2.3	Iron (mg)
Carbohydrates (g)	66.2	286.0	Potassium (mg)
Protein (g)	11.1	139.0	Magnesium (mg)
Fat (g)	3.6	0.14	Copper (mg)
Fibre (g)	2.7	1.78	Amino acids (mg)
Minerals (g)	1.5	0.10	Riboflavin (mg)
Phosphorus (mg)	348.0	0.42	Thiamine (mg)
Sodium (mg)	15.9	0.12	Vitamin C (mg)
Sulphur (mg)	114.0	90.0	Carotene (µg)

Table 1. Composition per 100 g of the edible portion of Maize (dry)

©Gopalan et al., 2007

1.4 Maize Consumption in India

Maize consumption in India can broadly be divided into three categories viz. feed, food and industrial non-food products (mainly starch). The Maize consumption pattern in India is– feed accounts for about 60 percent ; the most important use and demand driver of Maize is poultry feed 47 percent ; livestock feed 13 percent ; food consumption 20 percent (direct consumption 13 percent and processed food 7 percent); non-food industrial products 20 percent (Figure 1). Starch is the most important in this category accounting for 14 percent of the total Maize consumption.

According to industry estimates, India would require 45 million MTs of Maize by the year 2022, out of which 30 million MT will be for feed and 15 million MT will be demanded by FSI (food, seed and industry).

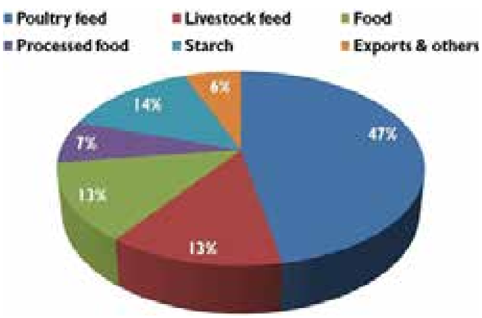


Figure 1. The usage pattern of Maize in India

1.5 Export Potential of Maize

About 6-7 million MT is exported to the South East Asian countries Indonesia, Vietnam, Malaysia, Taiwan, Bangladesh, Nepal, Bhutan etc.

1.6 Ecologies for Maize Cultivation in India

Based on the agro-ecological conditions, the entire India is divided in five major zones – Northern Hill Zone (Zone I), North West Plains Zone (Zone II), North East Plains Zone (Zone III), Peninsular Zone (Zone IV) and Central Western Zone (Zone V), for effective evaluation and identification of suitable hybrids and breeding materials of Maize. The Maize growing states included in these zones are given in Table 1.

1.7 Botany, Plant Anatomy and Physiology

Maize (*Zea mays* L) has distinct growth form, it is tall, determinate annual C4 plant varying in height from 1 to 4 m, producing large, narrow, opposite leaves wide as they are borne alternately along the length of a solid stem (Figure 2).

The botanical features of various plant parts are as follows.

Root: Normally Maize plants have three types of roots (Figure 3):

1. **Seminal Roots** – Develop from radicle and persist for long period
2. **Adventitious Roots** – Fibrous roots developing from the lower nodes of stem below ground level, which are the effective and active roots of plant
3. **Brace or Prop Roots** – Produced by lower two nodes.

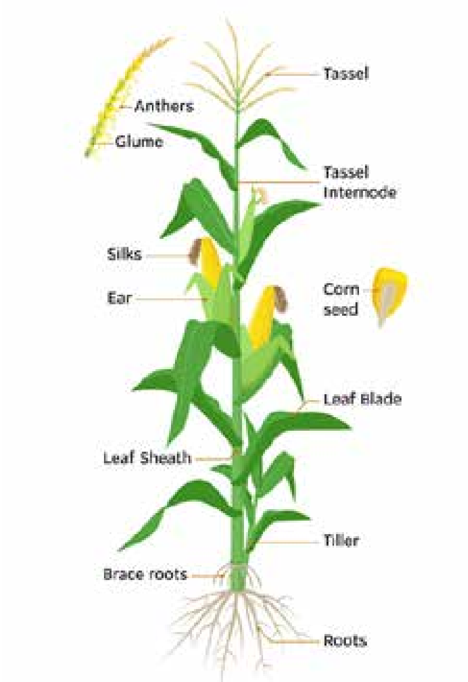


Figure 2. Maize plant

©FAO/India

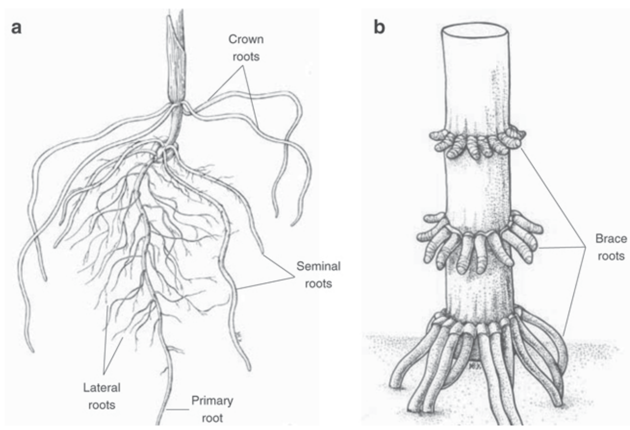


Figure 3. Root system of Maize

©CIPMC/Benguluru

The roots grow very rapidly and almost equally outwards and downwards. Favourable soils may allow root growth up to 60 cm laterally and in depth.

Stem: Its thickness is 3-4 cm; inter nodes short and fairly thick at the base of the plant, become longer and thicker higher up the stem and taper again; ear bearing internodes longitudinally grooved to allow proper positioning of the ear head (cob); and upper leaves more responsible for light interception and major contributors of photosynthesis activity.

Flower: Maize is a monoecious plant (Figure 4). The apex of its stem ends in tassel, an inflorescence of male (staminate) flowers– a loose panicle, produces pairs of free spikelets each enclosing a fertile and a sterile floret.

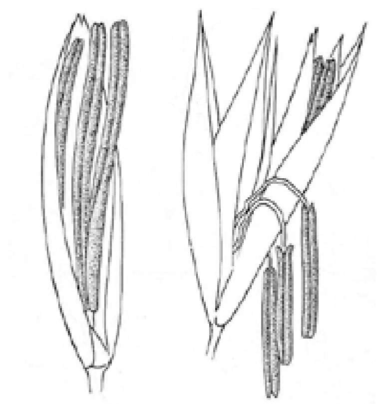


Figure 4. Maize female and male flower

©CIPMC/Benguluru

The female inflorescences pistillate (cobs or ears) are borne at the apex of condensed lateral branches (shanks protruding from leaf axils). The female (pistillate) inflorescence, a spike, produces pairs of spikelet on the surface of a highly condensed Rachis (central axis or cob). The silks are the elongated stigmas that look like tufts of hair initially and later turn green or purple. Each female spikelet encloses two fertile florets, one of whose ovaries will mature into a Maize kernel once sexually fertilized by wind-blown pollen.

The Maize is generally protandrous i.e. male flower matures earlier than female flower.

Grain: The individual Maize grain is botanically a caryopsis (Figure 5), a dry fruit containing a single seed fused to inner tissues of fruit case. The seed contains two sister structures, a germ (plumule and radical) from which a new plant develops, and an endosperm that provides nutrients for germinating seedling until the seedling establishes sufficient leaf area to become autotroph.

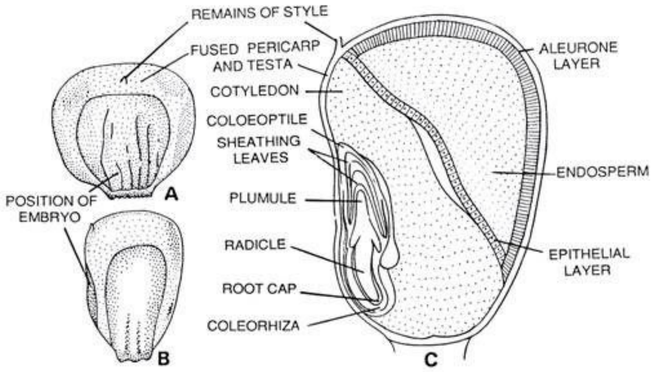


Figure 5. An individual Maize grain

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1.8 Maize Crop Growth Stages

Typical Maize is a monoecious plant with determinate type of plant habit; usually, develops 18 to 22 leaves in total; silk appears about 55 days after emergence; and matures in around 125 days after emergence (Figure 6) (Ritchie et al., 1993). The specific time interval, however, can vary among hybrids, environments, planting date, and location. These circumstances decide the length of time between each growth stage. For example, early maturing hybrids may produce fewer leaves or progress through the different growth stages at a faster rate.

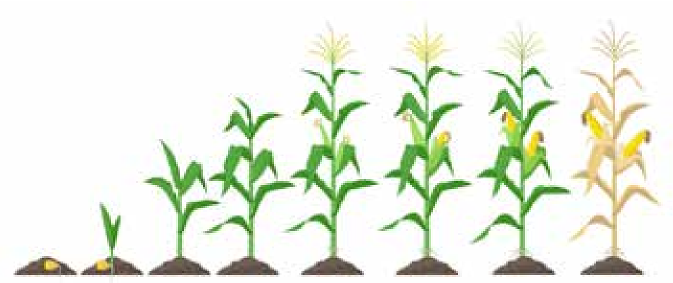

Figure 6. Different developmental stages in plants

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The growth stages of Maize are as follows:

VE-Emergence
Coleoptile reaches the soil surface and exposure to sunlight stops elongation of Coleoptile and Mesocotyl. Embryonic leaves rapidly develop and grow through the coleoptilar tip. Seminal root growth begins to slow and nodal roots are initiated at the crown.

V1-First leaf collar
Lower most leaf (short with rounded tip) has a visible leaf collar. Nodal roots begin elongation.

V3-Third leaf collar
The growing point remains below the soil surface as little stalk elongates. Lateral roots begin to grow from the nodal roots and growth of the seminal root system ceases. All leaves and ear shoots that the plant will produce are initiated at this stage. Since the growing point remains below the soil surface, cold soil temperature may increase the time between leaf stages, increase the total number of leaves formed, delay tassel formation, and reduce nutrient uptake.

V7 – Seven leaf collar
During the V7 and V8 growth stages the rapid growth phase and kernel row determination begins. Senescence of lower leaves may occur if plant is stressed, but must still be counted when staging plants.

V10 – Ten leaf collar
At the V9 and V10 growth stages the stalk is in a rapid growth phase a accumulating dry matter as well as nutrients. The tassel begin growing rapidly as the stalk continues to elongate. Many ear shoots are easily visible when the stalk is dissected.

VT – Tasselling
Initiation of the VT stage begins the last branch of the tassel is visible and silks have not emerged. This stage begins about 2-3 days before emergence. The plant is almost at its full height and pollen shed (anthesis) begins. Pollen shed typically occurs in the morning or evening. Plants at the VT/R1 are most vulnerable to moisture stress and leaf loss (hail).

R1 – Silking
This stage begins when any silk is visible outside the husk. Falling pollen grains are captured by the silk and grow down the silk over a 24 hour period ultimately fertilizing the ovule. The ovule becomes a kernel. It takes more than three days for all silks on a single ear to be exposed and pollinated. The number of fertilized ovules is determined at this stage. If an ovule is not fertilized, it will not produce a kernel and degenerates eventually. Environmental stress at this time is detrimental to pollination and seed set, with moisture stress causing desiccation of silks and pollen grains. Nutrient concentration in the plant is highly correlated with final grain yield as nitrogen and phosphorus uptake are rapid.

R2 to R6 stages
Active grain filling takes place during these stages and it is the final critical production stage. Any stress at this point can reduce the number, size and weight of the harvestable kernels. This stage of kernel development is directly linked to production levels of crop.

R6-Physiological maturity
Occurring approximately 45 days after silking, all kernels on the ear attain maximum dry weight. A black or brown layer is formed where the kernel attaches to the cob, indicating that physiological maturity has been attained. The stalk of the plant may remain green, but leaf and husk tissue lose its green colour at this stage. Kernel moisture content ranges from 30-35 percent at this stage, with much variation among hybrids and environmental conditions.

Almost all pest management decisions for Maize are based on the vegetative stage. These are identified by the number of collars present on the corn plant. The leaf collar is the light – color collar – like band located at the base of an exposed leaf blade, near the spot where the leaf blade comes in contact with the stem of the plant. Leaves within the whorl, not fully expanded and with no visible leaf collar are not included. For example, a plant with 3 collars would be called a V3 plant, however, there may be 6 leaves showing on the plant.

Maize crop stage	Days after sowing (DAS)
Germination Stage	5
Seedling Stage	6-15
Early Vegetative (whorl) Stage	16-25
Mid Vegetative (whorl) Stage	26-35
Late Vegetative (whorl) Stage	36-45
Tasseling and Silking Stage	46-65
Cob Formation and Development Stage	66-85
Cob Maturity stage	86-110
Harvesting Stage	>110

1.9 Cultivation of Maize Crop in India

Climate and soil
Maize, a day neutral crop, is grown under extremely divergent climatic conditions in different parts of India, ranging from subtropical to low temperature regions. Crop requires moderate temperature and cannot withstand frost and water logging at any stage of its growth.

Maize requires fertile, deep and well drained soils. However, it can be grown on any type of soil, ranging from deep heavy clays to light sandy soil. Soils with good organic matter content and having high water holding capacity with neutral pH are considered good for higher productivity. It is desirable to avoid low lying fields having poor drainage and also the field having higher salinity.

Land preparation
Maize requires well prepared flat beds; free from stubbles and weeds; 4-5 deep ploughing provide an ideal condition for sowing the crop. During *Kharif* cultivation, it is essential that adequate drainage is provided. It may be provided in the form of very shallow surface drains at 40-50 m apart (depending on the slope and the texture of the soil) across the slope and connected to main outlet.

Application of manures and fertilizers
FYM or compost – 5 tonnes/ha– should be ploughed into the soil before sowing. For raising good *Kharif* season crop the application 150:75:50 kg/ha of N:P_2O_5:K_2O required for hybrids of medium and late duration while for early duration hybrids and composites can be grown with 100:40:25 kg/ha of N:P_2O_5: K_2O. During *Rabi* season for cultivation of medium and late duration Maize hybrid, it requires180:80:60 kg/ha of N:P_2O_5: K_2O However, these recommendations vary in different agro-ecological situations as given in Table 2.

One-third of the nitrogen (N) and total quantity of potash (K_2O) and phosphorus (P_2O_5) should be applied before sowing, while the remaining nitrogen should be applied in two equal doses at the knee high and tasseling stages.

Application of zinc sulphate ($ZnSO_4$) @ 25 kg/ha at the time of sowing is also recommended since Maize is susceptible to Zn deficiency.

The nutrient hunger symptoms of Maize – stunted growth in general and the typical symptoms are small (stunted) plants, pale green leaves, and spotting or striping on leaves. Deficiency symptoms for most important nutrient elements are identifiable (Figure 7); however, in some complex cases, with no clear distinction, a specialist needs to identify the

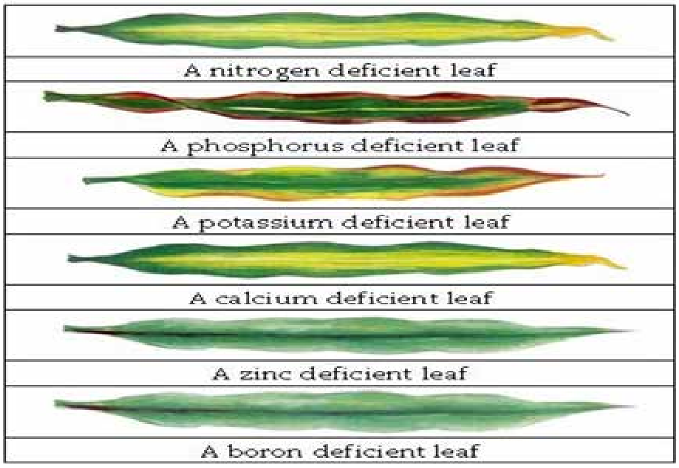

Figure 7. Nutrient deficiency symptoms in Maize

©Maize doctor.cimmyt.org

Table 2. Recommended dose of nutrients for Maize cultivation in various states			
S. No.	**Season**	**RDF (N: P2O5:K2O kg/ha)**	**States**
1.	*Kharif*	100:60:40	Odisha, Bihar and Madhya Pradesh
2.	*Kharif*	120:40:0	Rajasthan and Gujarat
3.	*Kharif*	120:60:40	Himachal Pradesh, Maharashtra, Punjab, Uttar Pradesh and Uttarakhand
4.	*Kharif*	150:80: 60	Chhattisgarh, Haryana, Karnataka, Jammu and Kashmir, West Bengal and Tamil Nadu
5.	*Rabi*	120:75:50	Bihar and Rajasthan
6.	*Rabi*	175:60:50	West Bengal
7.	*Rabi*	225:80:80	Andhra Pradesh and Tamil Nadu
8.	Spring	80:40:30	Bihar
9.	Spring	120:75:50	Punjab and Uttar Pradesh

problem. Some times insect pest and disease damage symptoms are quite similar to those of nutrient deficiencies (e.g. striping or spotting), so it is important to differentiate these symptoms for timely intervention.

Cropping season
There are three distinct seasons for the cultivation of Maize:

1. **Kharif:** The main season for cultivation of Maize is *Kharif*. Early March in North eastern hills, April to early May in North western hills, May-June in Peninsular India.

2. **Rabi:** Middle of October to middle of November.

3. **Spring Season:** Late January to the end of February.

Spacing and seed rate
Maize is sown in rows 60-75 cm apart, whereas the plants in the row are spaced at 20 to 25 cm. A population of 60-75 thousand plants/ha at harvest is required for obtaining the optimum yield. Healthy seeds @ 20-22 kg/ ha are required for the grain crop and @ 35-40 kg/ha for the fodder crop.

Inter cultivation
During initial crop stage, weeds suppress the growth of Maize plants. Weeding may be done between and within the rows. At knee-high stage the crop plants should be earthed up followed by hand weeding. No inter cultivation is advisable after flowering, as it is likely to damage the lateral roots.

Water management
Most of the Maize varieties grown in India are harvested between 80 and 110 days, hence, to sustain the rapid rate of growth, an adequate supply of soil moisture is essential. As per estimates Maize crop requires about 50 percent of the total water requirement in a short period of 30-35 days after tasseling. Lack of adequate moisture during the grain filling stage adversely affects the yield.

The water management depends on the season for the Maize, which is cultivated during monsoon season particularly under rainfed conditions. However, in areas with assured irrigation facilities, depending upon the rains and moisture holding capacity of the soil, irrigation should be applied as and when required by the crop.

Kharif irrigation required at early knee-high, tasseling and 50 percent silking stages. For winter Maize, it is advisable to keep soil wet.

Harvesting
Cobs to be utilized as grain, should be harvested when the grains are almost dry or containing roughly 15-20 percent moisture. The cobs are removed from the standing crop and should be preferably sun dried for 3-4 days to improve the grain recoveries and reduce breakage losses during shelling, otherwise retained in their jackets.

Yield
Considerable variation in grain yield is observed. The yield levels depend upon the variety, the amount of the fertilizer used, and the rainfall pattern etc. Under irrigated conditions and recommended cultural practices, an average yield is 4 tonnes/ha.

1.10 Biotic Stresses in Maize Production in India

Irregularity in agro-climatic conditions is directly affecting the yield, besides emergence of new biotic and abiotic factors is also affecting Maize production in India. Maize crop is attacked by wide range of pests like insects, nematodes, vertebrate pests, weeds, and diseases etc. adversely affecting the Maize productivity.

1.10.1 Major insect pests of Maize

Among the factors adversely affecting Maize productivity, ubiquitous prevalence of diseases and insect pests in the pre harvest stage are prominent. In India, the total economic loss of the crop due to insect pests and diseases is estimated to be 13.2 percent . Since there is practically no possibility of increasing Maize area, the productivity can only be raised by providing seed of improved cultivars, better agronomic practices and protection against diseases and pests.

Insect pests of Maize: Maize crop is prone to several insect pests, which may significantly cause crop loss, if not protected. The major/ minor insect pests of Maize are enumerated in Table 3.

i) Spotted stem borer: *Chilo partellus* (Swinhoe)
Spotted stem borer (*Chilo partellus*), the most important insect pest of Maize during *Kharif*, is causing yield losses in the range of 26-80 percent in different agro-climatic regions of India. Eggs are flat, oval, yellowish, laid in overlapping clusters; larvae creamy pink to yellowish brown with 4 rows of dotted stripes along the back with reddish brown head; and larval period about 14-28 days. The forewing of adult female moth is brown-yellowish with darker scale patterns forming longitudinal stripes.

Table 3: Major and minor insect pests of Maize			
Pest	**Scientific name**	**Family**	**Order**
Major insect pests of Maize			
Fall Armyworm	*Spodoptera frugiperda* (J. E. Smith)	Noctuidae	Lepidoptera
Spotted stem borer	*Chilo partellus* (Swinhoe)	Pyralidae	Lepidoptera
Pink stem borer	Sesamia inferens Walker	Noctuidae	Lepidoptera
Shoot fly	Atherigona soccata (Rond), A. orientalis Schiner and A. naqvii Steyskal	Muscidae	Diptera
Oriental Armyworm	*Mythimna separata* (Haworth) and *Mythimna loreyi* (Duponchel)	Noctuidae	Lepidoptera
Cut worm	Agrotis ipsilon Rott.	Noctuidae	Lepidoptera
Tobacco and Lucerne caterpillar	*Spodoptera litura* (Fabricius), *S. exigua* (Hubner)	Noctuidae	Lepidoptera
Cob worm/ Earworm	*Helicoverpa armigera* (Hubner)	Noctuidae	Lepidoptera
Aphid	*Rhopalosiphum maidis* (Fitch)	Aphididae	Hemiptera
Shoot bug	*Peregrinus maidis* (Ashmead)	Delphacidae	Hemiptera
Minor insect pests of Maize			
Maize leafhopper	*Cicadulina bipunctata* (Matsumura)	Cicadellidae	Hemiptera
Sugarcane Leafhopper	*Pyrilla perpusilla* (Walker)	Lophopidae	Hemiptera
Flower eating beetles	*Chiloloba acuta* (Weidemann); *Oxycetonia versicolor* (Fabricius)	Scarabaeidae	Coleoptera
Termites	*Odontotermes obesus* (Rambur)	Termitidae	Isoptera
Grasshopper	*Hieroglyphus nigrorepletus* Bol.	Acrididae	Orthoptera

Hind wings are pale straw-colour in male moths and white in females. The life cycle is completed in about 5-6 weeks.

Nature of damage

Adult of moth of spotted stem borer prefers 3-5 leaf stage Maize for egg laying; eggs generally laid on lower surface of leaves and hatch in 3-4 days; and newly hatched larvae crawl inside leaf whorl and feed in groups. When the rolled leaves of whorl unfurl series of pin holes and papery windows are visible, which is the first symptom of spotted stem borer attack. After a week onwards, larvae move out of whorl and bore upwards the developing stalk, often reaching meristem. When

Larvae and Pupae Papery window Bore hole Dead heart

Figure 8. Spotted stem borer–nature of damage

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meristem is fed upon, the leaf whorl dries up known as dead heart, and the plant usually dies often giving rise to tillers (Figure 8).

ii) Shoot fly (Antherigona spp.)
Eggs of A. *soccata* and A. *orientalis* are elongated like a small rice grain, milky white with two wing-like projections and those of A. naqvii are cylindrical with fine ridges on surface. The incubation period is 1-3 days. Larval period is 7-10 days with 3-4 instars. Full grown maggot is yellow. Pupation takes place inside the stem. The pupae is dark brown, barrel-shaped. The pupal period lasts for about a week. The adult lives for 3-4 days (Figure 9a). The life cycle is completed in about 3 weeks.

Nature of damage
Maggots on hatching from eggs bore into central shoots of seedlings and kill the growing point, producing dead hearts (Figure 9b). They feed on decaying core of shoots, subsequently on the death of central shoot plant gives out tillers and plants gets a bushy appearance.

(a)

(b)

Figure 9. Shoot fly – (a) Shoot fly adult, (b) Dead hearts

©CIPMC/Ranchi

iii) Pink stem borer (Sesamia inferens Walker)
Pink stem borer is the most important pest during *Rabi* (winter) causing yield losses from 25.7 to 78.9 percent . Eggs are creamy white, bead-like laid in 2-4 longitudinal rows inside the sheath of 1-2 lower leaves. Larvae of this pest is light pink with a purplish tinge. The larval period varies from 22-36 days. The adult female is medium size, stout, straw colour moth, coppery tinged shining scales with brown streaks. Forewings have three small black dots on the dorsal side and an intermediate brown strip. Hind wings are white (Figure 10). The antennae were pectinate in males and filiform in female moths. The total life cycle varies from 40-53 days.

Nature of damage
Infested plants exhibit the characteristic dead heart symptom, with the central shoot drying up, red mining in the midribs, windows in the leaves, shot holes on the whorl leaves and boreholes at the base of the stem (Figures 11,12).

Figure 11. Dead heart

Figure 12. Larval tunnel with excreta
©CIPMC/Benguluru

Egg

Larvae

Pupae

Adult

Figure 10. Life cycle of Pink stem borer

©ICAR/National Bureau of Agricultural Insect Resources

iv) Corn worm/Ear worm: *Helicoverpa armigera* (Hubner)

Helicoverpa armigera is an emerging pest of Maize, especially in sweet corn. Eggs are spherical in shape and creamy-white, laid singly on silk. There are five or six larval stages. The larvae shows colour variation from greenish to brown. It has dark brown-grey lines on the body with lateral white lines. Pupae is brown, rounded both in anterior and posterior part, with two tapering parallel spines at posterior tip. Forewings of adult moth contain line of seven to eight blackish spots on the margin and a black comma-shaped marking in the middle underside of each forewing. There is a distinguished colour pattern between male and female moths. Forewings of males are greenish-grey which later fade to straw yellow while the hind wings are cream to light yellow with dark brown outer marginal band. In females, forewing are light brown while the hind wings are cream to light yellow with pronounced dark brown bands. Females are also identified by the presence of tuft of hairs on the tip of abdomen.

Nature of damage

Larvae first feed on silk and may tunnel into ears, especially if the ear tip is exposed and/or covered loosely (Figures 13-15).

Figure 13. Ear damaged by cob borer

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Figure 14. Larvae

©CIPMC/Benguluru

Figure 15. Cob borer feeding on cob

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v) Tobacco and Lucerne Caterpillar *Spodoptera litura* (Fabricius), *S. exigua*

Spodoptera litura and *S. exigua* are distributed throughout India. Females lay eggs in masses of about 200 to 300 on the underside of leaves and covered with brown scales. Eggs are laid in 2-3 layers. The larvae is variable in colour, sides of body with dark and light longitudinal bands; dorsal side with two dark semilunar spots laterally on each segment, except for the prothorax; spots on the first and eighth abdominal segments larger than others, interrupting the lateral lines on the first segment. A bright-yellow stripe along the length of the dorsal surface is characteristic of *S. litura* larvae.

The larvae feed in group when they are young but spread out as larvae grow. Grown-up larvae fell from plants and pupate in a small cell in the soil/cobs. In males, forewing contains reniform brown spot, elongate orbicular spot, white fork in the median area, a row of dark brown glass markings along outer margin and a large yellowish or light brown patch on the median area adjacent to inner margin. The forewing of female moth is grey to reddish brown with a strongly variegated pattern and paler lines along the veins. The hind wing is greyish white with grey margins. The lifecycle takes about 25-30 days (Figures 16-18).

Figure 16. Egg mass

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© Luis Miguel Constantino

Figure 17. Larvae

©FAO/Lekha Edirisinghe

Figure 19. C. Acuta

©FAO/Lekha Edirisinghe

© Luis Miguel Constantino

Fig 18 FAW Adult

©SANMI

Figure 20. O. versicolor

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Nature of damage

On hatching, the larvae feed on tender leaves in groups. They scrape the surface but do not actually perforate it, creating a window pane effect. Under severe infestation, the entire young plant may be consumed. Later on the larvae migrate and feed on the leaves which give thin papery appearance.

vi) Flower eating beetle *Chiloloba acuta* (Weidemann) & *Oxycetonia versicolor* (Fabricius):

Chaffer beetle, *Chiloloba acuta*, adults are bright metallic green with prominent eyes and covered with yellow hairs above and beneath (Figure 19). The adults O. *versicolor* adults mostly brilliantly coloured and mostly red with black markings. The upper surface of the body is smooth with a metallic sheen and striking color patterns. The prothorax and elytra are brick red. A pair of black spots is present on the prothorax and lateral margins reveal a white border (Figure 20).

Nature of damage

This pest is serious on Maize at the time of flowering. The adult beetles feed on the pollen and results in poor seed set (Figures 19-20).

vii) Armyworm (*Mythimna spp.*)

Mythimna separata and *Mythimna loreyi* are the predominant species in Maize ecosystem, its larval stages are difficult to distinguish. Eggs are shiny, greenish-white, spherical with fine reticulations which turn black before hatching. The incubation period is about 5 days. Mature larvae vary from greenish to greyish brown, predominantly white inverted Y-shaped suture on the head and dorsal or sub dorsal longitudinal light grey to black stripes or clear yellow stripes lines running along the entire length of the body. The larval period is about 3 weeks. The larvae is found in the leaf whorl or at the surface of the soil. The pupae is dark brown; pupal period is about 8-13 days. The adult moth is pale brown with dark specks. Hind wings are pale brown with dark external margin. Males lack paired tufts on the basal segment of the abdomen below. The life cycle is completed in one month. The alternate hosts are paddy, wheat, sorghum, sugarcane, oats, barley, bajra, ragi, legumes and some other grasses.

Nature of damage

Larvae feed on tender leaves and skeletonize them. In case of severe attack, leaves including midribs are eaten away and fields look as if grazed by the cattle. Larvae excrete faecal matter in the form of pellets which are seen in the plant whorls. Larvae also damage immature ears (Figure 21).

Figure 21. *Mythimna* sp. larvae

©IIMR,/Hyderabad

viii) Cut worm (*Agrotis ipsilon* Rott.)

Females lay about 300 creamy white dome-shaped eggs. Freshly hatched larvae is slightly yellowish with black head. The fully grown larvae is greasy in appearance, plump and dark brown with red head (Figure 22). The larval period is about 4-5 weeks. The pupal stage lasts for about 10 days. The pupae is reddish brown and pupation takes place underground. Forewings of adults are long and narrow, darker than the hind wings and marked with black dashes: the basal two-thirds of the forewing is dark, with the outer third pale grey to brown; orbicular is tear-shaped; reniform has a distinct black wedge or dagger-shaped black marking on its outer margin. There is a zigzag line of pale scales on a dark background in the sub terminal area. The antennae of males are plumose (feathered), while the female antennae are filiform type. The life cycle is completed in 8-12 weeks.

Nature of damage

The larvae feed on leaves and also cut the tender stems of young and growing plants either below the surface or above the ground.

Figure 22. Cut worm larvae

©IIMR/Hyderabad

ix) Termites (*Odontotermes obesus* (Rambur)]

Termites are common throughout the tropics and subtropics (Figure 23). The queen lays 70 000 to 80 000 eggs in 24 hours. The eggs hatch after one week; within 6 weeks, larvae develop to form soldiers or workers. There is only one queen in the colony and normally lives for 5-10 years. The king's life is much shorter than that of queen and when he dies he is replaced by a new one. The workers develop from fertilized eggs but remain stunted as they are reared on ordinary food. The soldiers develop from unfertilized eggs and remain comparatively under developed.

Nature of damage

Termite invasion initiates from dry leaves. Later roots and lower part of the stem are destroyed resulting in lodging. Vascular tissues might be damaged and wilting would occur especially under water stress conditions. In extreme cases, the ears are invaded by termites. Severely damaged plants may lodge and get completely destroyed by termites.

Figure 23. Termites

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x) Grasshopper (*Hieroglyphus nigrorepletus* Bol.)
It is a sporadic pest distributed all over India but more prevalent in Rajasthan. The alternate hosts are sorghum, *ragi*, red gram, cotton, rice and other grasses. Eggs are laid in batches under the soil (egg pods) consisting of 30 elongate eggs cemented together. Most nymphs start feeding within one day after egg hatch, and usually feed on the same plant as the adult. The nymphal stage requires about 6 weeks. Total development takes about 2.5 to 3.5 months; adults live for 45 to 50 days.

Nature of damage
Injury may start at leaf edge or in centre of a leaf adjacent to midrib. Defoliation is the primary injury to plants, but damage often exceeds the amount of foliage eaten. Grasshoppers may feed on ripening kernels of grain causing shattering. They also feed on the green silk, preventing fertilization or filling of the ear (Figures 24-26).

Figure 24. Adult Grasshopper

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Figure 25. Foliar damage

©FAO/ G. Tortoli

Figure 26. Cob damage

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xi) Aphid [*Rhopalosiphum maidis* (Fitch)]
The aphids are bluish green, 2 mm long, with black legs, antennae and cornicles. The females give birth to apterous forms that moult four times to become adults. Under crowded conditions, or when the host plants are under stress, aphids produce winged adults, which mould five times to become adults. Nymphal development is completed in 12-15 days.

Nature of damage
Aphid sucks the sap from the leaves during the vegetative stage of the crop (Figures 27-28). Honey dew excreted by aphids results in sooty moulds on leaves. It is also a transmitter of Maize mosaic virus. In general its infestations rarely reach damaging proportions. Aphid infestation results in the yellowing, tanning, and drying up of leaves. Infested young plants seldom produce ears. The aphid colony sometimes completely covers the flag leaf cover of tassel, preventing tassel opening. Heavily damaged tassel may become sterile. If the ears and shoots are infested, seed set may be affected.

Figure 27. Aphids infested tassel

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Figure 28. Aphids on leaf

©ICAR/IIMR/Ludhiyana

xii) Leafhoppers: *Pyrilla perpusilla* (Walker)
Pyrilla adult females lay elongate pale white to slightly bluish eggs in loosely arranged elongated clusters of 20-50, which are covered by white waxy filaments of the caudal tuft. Nymphs emerge from eggs and start sucking the plant sap and develop into adult through five nymphal instars. The egg and nymphal stages occupy 7-12 days and 24-65 days, respectively, during April-October (Figures 29-30).

Figure 29. Pyrilla perpusilla

Figure 30. Cicadulina bipunctata

©CIPMC/Gauhati

Nature of Damage
Both adults and nymphs of both the species suck the cell sap from the leaves and secrete honey dew. Due to this feeding, the leaves turn yellow and finally look withered.

1.10.1 Major Diseases of Maize

Maize crop is prone to several plant pathogens. Turcicum leaf blight, maydis leaf blight, downy mildews, post-flowering stalk rots, ear rot and, banded leaf and sheath blight are important diseases, which affect yield of Maize. Bacterial stalk rot and, brown spot are reported from northern India, whereas, downy mildews are more prominent in the peninsular India and Udaipur region of Rajasthan (Table 4).

Table 4: Major Diseases and Casual Agents

Sl. No.	Disease	Causal agents
1	Turcicum Leaf Blight	*Exserohilum turcicum* (Pass) Leon. & Suggs
2	Maydis Leaf Blight	*Cochliobolus heterostrophus* Nikado & Miyake
3	Polysora Rust	*Puccinia polysora* Underw
4	Brown Spot	*Physoderma maydis* Shaw Teleomorph: *Cladochytrium maydis* Miyabe
5	Banded Leaf and Sheath Blight	*Thanatephorus sasakii* (Shirai)
6	Common Rust	*Puccinia sorghi* Schw
7	Brown Stripe Downy Mildew	*Sclerophthora rayssiae* var. zeae
8	Rajasthan Downy Mildew	*Peronosclerospora heteropogoni*
9	Sorghum Downy Mildew	*Peronosclerospora sorghi*
10	Bacterial Stalk Rot	*Dickeya zeae* Samson
11	Fusarium Stalk Rot	*Fusarium verticillioides* Sacchardo
12	Charcoal Rot	*Macrophomina phaseolina*

1.10.2 Major diseases of Maize in India

i) Turcicum leaf blight: ***Exserohilum turcicum*** (Pass) Leon. & Suggs

Distribution: Jammu & Kashmir, Himachal Pradesh, Sikkim, West Bengal, Meghalaya, Tripura, Assam, Rajasthan, Uttar Pradesh, Bihar, Madhya Pradesh, Gujarat, Maharashtra, Andhra Pradesh, Telangana, Karnataka and Tamil Nadu.

Figure 31 Tursicum leaf blight

©FAO/India

An early symptom is easily recognized with this coloration of slightly oval, water-soaked, small spots produced on the leaves (Figure 31). These grow into elongated, spindle-shaped necrotic lesions. They may appear first on lower leaves and increase in number as the plant develops, and can lead to complete burning of the foliage. Turcicum leaf blight (or northern leaf blight) occurs in areas with high humidity and moderate temperatures during the growing season. When infection occurs prior to and at silking and conditions are optimum for pathogen it may cause significant economic damage.

ii) Maydis leaf blight: *Cochliobolus heterostrophus* Nikado & Miyake Young lesions are small and diamond shaped (Figure 32). As they mature, they elongate. Growth is limited by adjacent veins, so final lesion shape is rectangular and 2 to 3 cm long. Lesions may coalesce, producing a complete burning of large areas of the leaves. Maydis leaf blight (or southern Maize leaf blight) is prevalent in hot, humid, Maize-growing areas. The fungus requires slightly higher temperatures for infection than; however, both species are often found on the same plant.

Figure 32. Maydis leaf blight

©FAO/India

iii) Downy mildews: Brown stripe downy mildew (*Sclerophthora rayssiae* var. *zeae* Payak and Renfro)

Sorghum downy mildew (*Peronosclerospora sorghi* Weston & Uppal Shaw)

Rajasthan downy mildew (*Peronosclerospora hetropogoni* Siradhana *etal.*)

These diseases (Figures 33, 34) are of serious concern to Maize producers. Symptom expression is greatly affected by plant age, pathogen species, and environment. Usually, there is chlorotic striping or partial symptoms in leaves and leaf sheaths, along with dwarfing. Downy mildew becomes conspicuous after development of a downy growth on or under leaf surfaces. This condition is due to conidia formation, which commonly occurs in the early morning. These diseases are most prevalent in warm, humid regions. Some species causing downy mildew also induce tassel malformations, blocking pollen production and ear formation. Leaves may be narrow, thick, and abnormally erect.

Figure 33. Sorghum downy

Figure 34. Brown stripe mildew

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iv) Banded leaf and sheath blight: Rhizoctonia solani f. sp. sasakii Exner

True to the name, this disease develops on leaves and sheaths (Figures 35,36). Symptoms are characteristic concentric spots that cover large areas of infected leaves and husks. The main damage in the humid tropics is a brownish rotting of ears, which shows conspicuous, light brown, cottony mycelium with small, round, black sclerotia.

Figure 35. Banded Leaf

©CIPMC/Vijayawada

Figure 36. Sheath blight

Source: CIPMC – Vijayawada

Common rust *Puccinia sorghi Schw.*

The disease is found in subtropical, temperate, and highland environments with high humidity. Common rust (Figure 37) is the most conspicuous when plants approach tasselling. It may be recognized by small, elongate, powdery pustules over both surfaces of the leaves. Pustules are dark brown in early stages of infection; later, the epidermis rupturs and the lesions turn black as the plant matures.

Figure 37. Common rust

©CIPMC/Vijayawada

Polysora rust *Puccinia polysora* Underw

Pustules are smaller, light orange, and more circular than those produced by P. sorghi (Figure 38). They are also present on both leaf surfaces, but the epidermis remains intact longer than it does in P. sorghi-infected leaves. Pustules turn dark brown as plants approach maturity. No alternate host of the fungus is known. Polysora rust (or southern rust) is common in hot and humid lowland tropical conditions.

Figure 38. Polysora rust

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vi) Charcoal stalk rot *Macrophomina phaseolina* (Goid) Tassi

Charcoal stalk rot (Figure 39) is most common in hot, dry environments. Incidence increases rapidly when drought and high temperatures prevail near tasseling stage. The pathogen invades seedling roots. After flowering, initial symptoms are the abnormal drying of upper leaf tissue. When plants approach maturity, the internal parts of stems show a black discoloration and vascular bundles shred mainly in lower stalk internodes. Careful examination of rind and vascular bundles reveals small, black, fungal structures known as sclerotia that can overwinter and infect the next crop. The fungus may also infect kernels, blackening them completely. Many crops can serve as hosts for this pathogen. No alternate host of the fungus is known. Polysora rust (or southern rust) is common in hot and humid lowl and tropical conditions.

Figure 39. Charcoal stalk rot

©CIPMC/Benguluru

Apart from these diseases Fusarium stalk rot: *Fusarium moniliforme* Sheld, Post flowering stalk rot (PFSR)-Late wilt (*Cephalosporium maydis*) etc.also affect the Maize crop. Example

1.10.3 Major Nematodes infesting Maize

Plant parasitic nematodes viz. cyst nematodes (*Heterodera spp.*), lesion nematodes (*Pratylenchus spp.*), root knot nematodes (*Meloidogyne spp.*), stunt nematode (*Tylenchorhynchus spp.*) and spiral nematode (*Helicotylenchus spp.*) are associated with Maize. *H. zeae* is considered as one of the most important nematode pests of Maize in India. Maize cyst nematode, *Heterodera zeae* is widely distributed in Maize growing areas of Rajasthan, Delhi, Punjab, Haryana, Himachal Pradesh, Uttar Pradesh, Bihar, Madhya Pradesh, Gujarat, Tamil Nadu, Karnataka, Andhra Pradesh and Maharashtra.

1.10.4 Major vertebrate pests of Maize

The major vertebrate pests of Maize are wild boar, nilgai, monkey, rose ringed parakeet, pigeon and rodents.

1. **Wild boar *Sus scrofa***
   Wild boars are more active during early morning and evening hours than in the daytime. The damage of wild boar is more pronounced in crop fields which are in close proximity with adjoining forest areas and more damage due to trampling.

2. **Nilgai *Boselaphus tragocamelus***
   The Nilgai is one of the most commonly seen wild animals of central and northern India. Maize crop is also damaged by blue bull.

3. **Monkey and langur *Macaca mulatta* and *Semnopithecus entellus***
   Monkeys are distributed widely across the country and cause damage to the Maize crop from milky stage till harvesting stage.

4. **Rose ringed parakeet *Psittacula krameri***
   Rose ringed parakeet is a problem in Maize crop causing damage mainly during milky stage and grain formation stage.

5. **Pigeon *Columbia livia***
   Pigeons cause severe damage at the time of sowing and also during storage.

6. **Rodents: lesser bandicoot *Bandicota bengalensis*; grass rat *Millardia meltada***
   Rodents are one of the major production constraints in majority crop fields and more damage to cereal crops. Extensive burrowing by rodents lead to soil erosion, damage to irrigation channels and loss of irrigation water and attack lodged Maize plants causing damage to Maize ears.

1.10.5 Major weeds of Maize

The critical stage of crop weed competition in Maize crop is first 30 to 45 days. In India, the presence of weeds, in general reduces the Maize yield by 27-60 percent , and the magnitude of losses largely depends upon the composition of weed flora, period of crop-weed competition and weed intensity. The major weeds in Maize field (Figure 40) were *Cyperus rotundus* L. among the sedges, *Digitaria* spp, *Dactyloctenium aegyptium* L., *Dinebra aRabica* L., *Cynodon dactylon* L., and *Eleusine indica* L. and *Rottboellia* spp among grasses; *Parthenium hysterophorus* L., *Melilotus alba* L., *Trianthema portulacastrum* L., *Euphorbia geniculate* L., *Commelina* spp, *Tridax procumbens* L. and *Amaranthus viridis* L. among broad leaf weeds (Madhavi et al., 2014).

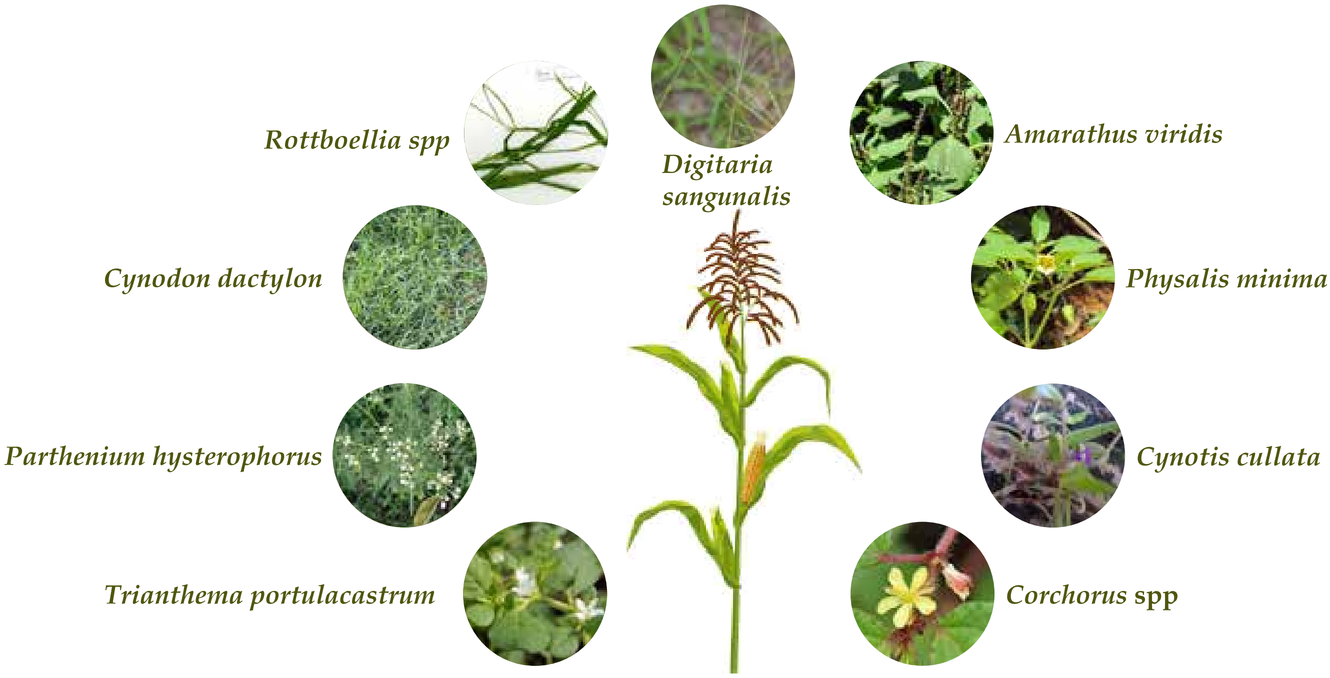

Figure 40. Common weeds in Maize fields

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1.10.6 Stored grain pests of Maize

Storage pests are categorized into two types namely primary and secondary pests. Primary pests including rice weevil, angoumois grain moth, khapra beetle are capable of infesting intact kernels of grain. Larval stages completely develop inside the grain kernel. Secondary pests such as red flour beetle, rice moth are unable to infest sound kernel but feed on broken kernels and debris. Larval stages are found external to the grain.

i) Rice weevil (*Sitophilus oryzae* L.)

The adult is tiny weevil about 2.5 mm long, dark brown or reddish brown. Females lay about 150-300 eggs , which hatch in about 3 days. The grub is short, stout C-shaped that is creamy-white, curved, translucent, with yellow or brown head and biting jaws. The larvae feed inside the grain kernel for 18–20 days. The pupae is naked and the pupal stage lasts for 6-7 days. Adults live for 4-5 months. The new adult will remain in the seed for 3 to 4 days while it hardens and matures. The lifecycle is completed in 40–45 days.

Nature of damage

As it is an internal feeder, both adults and larvae attack the grains and feed voraciously (Figures 41, 42). In case of heavy infestation only pericarp of the kernel is left behind, while rest of the mass is eaten up. The insect can infest crop at maturing stage in the field or while storing.

Figure 41.Weevil damaged kernel

©*CIPMC/Hyderabad*

Figure 42. Adult weevil

©*CIPMC/Hyderabad*

ii) Angoumois grain moth: *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechidae)

Only larvae damage grains, adults are harmless. The larvae after hatching, begins to feed on endosperm due to which grains are hollowed out resulting into loss of viability. On damaged grains, a circular hole with a characteristic flap or trap door appears. Pest attack is both in fields and stores. In stored bulk grain, infestation remains confined to upper 30 cm depth only.

iii) Rice moth: *Corcyra cephalonica* Stainton (Lepidoptera: Pyralidae)

Young larvae feeds on the broken grains make webbings resulting in grain pollution with large quantities of frass and silken cocoons.

iv) Red flour beetle: *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae

It feeds on broken grains resulting in dust formation. Infested flour emits sour and pungent smell, which is due to secretions of beetles. The presence of larval stage, dead and live adults and odour represent damaged material.

v) Lesser grain borer *Rhyzopertha dominica* (Fab) (Coleoptera:Bostrichidae)

Heavily attacked grains become hollowed out and only thin shell remains. After severe infestation adults produce frass and spoil more than what they eat. Profuse powdery substance is the characteristic of its damage.

vi) Khapra beetle *Trogoderma granerium* (Everts.) (Coleoptera: Dermestidae)

The grub feeds on internal part of grain. Adults are harmless. Visible mould occurs. Shed skins and faeces can also contaminate grain and cause allergic reactions.

Management strategies for storage pests

- Cleanliness and sanitation is the most important and first step towards prevention of insect infestation. Dusts, grains, and chaffs should be removed from transport system, storage area as well as threshing yard before using them for new produce after harvest.
- Crop should be harvested at the proper time to prevent egg laying by storage pests.
- Moisture content of grain should be less than 10 percent .
- Newer grains should not be mixed with older ones.
- Seed stored gunny bags should be kept few inches above the ground.
- Walls and floor of the storage area should be painted/ white washed or sprayed with solution of deltamethrin 2.8EC @ 1.5 ml/l of water/100 sqm. Malathion 50 EC @ 15ml /4.5 litres of water or 5 percent NSKE should be sprayed as a thin film on bags before use.
- Through mechanical devices monitoring and mass trapping of stored product insects can be done.
- Staggered sun drying with short exposure to sun spread reduces insect infestation
- By modified atmospheric storage, insects can be controlled.

1.10.7 Insect pests and diseases at different crop growth stages in Maize

Table 5. Major insect pests and diseases at different growth stages in Maize

Crop growth stage	Major insect pests and diseases
Germination Stage	Cutworms, wireworms
Seedling Stage	Seedling blight, Cutworms, White grubs, Fall Armyworm (FAW), Shoot fly, Stem borers, Tobacco caterpillar
Vegetative Stage	Downy mildew, Common rust, Polysora rust, Turcicum leaf blight, Maydis leaf blight, Banded leaf and sheath blight, FAW, Spotted stem borer, Pink stem borer, Shoot fly, Chafer beetle, Aphids, Termite, etc.
Tasseling and Silking Stage	Fusarium, stalk rot, Late wilt, Aphids, Grasshoppers, FAW, Chaffer beetles, Cob borer, Termites
Cob Formation to Maturity Stage	FAW, Earworm, Cob borers

1.11 Fall Armyworm-A Major Challenge for Maize Cultivation

Recently, the Maize crop was reported invaded by an exotic invasive alien pest viz. Fall Armyworm (FAW)-*Spodoptera frugiperda*. This new report warranted special vigilance in Maize pest management. The brief information on FAW is compiled here followed by advice on FAW management protocol.

The Fall Armyworm (FAW) (*Spodoptera frugiperda*) is an invasive, polyphagous lepidopteran pest. FAW larvae can feed primarily on Maize, but was also recorded on sorghum. The pest is native to tropical and sub-tropical regions of the America. However, it has moved out and entered into Africa in 2015, where it caused significant damage to Maize crop, thereafter within a span of 2 years it has spread in 40 other countries in Africa.

1.11.1 Occurrence and distribution of FAW (Spodoptera frugiperda) in India

In India, it was first noticed in July 2018 in Karnataka, thereafter FAW was also reported from the states of Andhra Pradesh, Telengana, Odisha, Tamil Nadu, West Bengal, Gujarat and Maharashtra. In 2019 it was also reported from Chhattisgarh, Andaman & Nicobar Islands, Mizoram, Manipur, Nagaland, Assam, Meghalaya, Tripura, Bihar, Uttar Pradesh, Madhya Pradesh, Rajasthan, Punjab, Haryana and in July 2020 in Himachal Pradesh and Jammu & Kashmir.

1.11.2 Life cycle and identification of FAW

Identifying any pest is the first step of management. The life cycle of FAW includes egg, larvae (6 instars), pupae and adults (Figures 43-49).

Figure 43. Egg mass

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Eggs: The female adult moth lays 100-200 eggs in batches, deposited in layers on the inner side of whorl and also on under surface of leaves typically near the base of plant close to junction of a leaf and stem. Eggs are pale green or white at the beginning and covered with scale, later turn clear brown to brown before hatching. They hatch within 2-3 days.

Figure 44. Neonate larvae

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Larvae: There are six larval stages. Young larvae are pale and become brown to pale green, turn darker at the later stages. The larval stage completes in 12-20 days. The later stages of the larvae are easiest to identify. They may contain characteristic marks and spots. The marks that are often used for identification includes the upside down 'Y' mark on the head region and four larger dorsal spots on a second last segment of the abdomen.

Figure 45. Typical identification spots of larvae

Figure 46 Typical identification spots of larvae

Figure 47. Pupae

Moths: The moth is 3-4 cm wide. The male moth's forewings are generally shaded grey and brown with triangular spots at the tip and near center of the wing. The forewing of the females are less distinctly marked ranging from uniform greyish brown to fine mottling grey and brown. The hind wing is iridescent silver white with narrow dark boarder in both the sexes. Adults live for 2-3 weeks

Figure 48. Adult moth

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Pupae: The matured larvae drops on to the ground, burrows shallowly 2-8 cm into the soil and makes earthen cells by constructing filmy cocoon. More rarely pupation takes place in stalks. Pupae is dark brown and remains in pupation for 12-14 days.

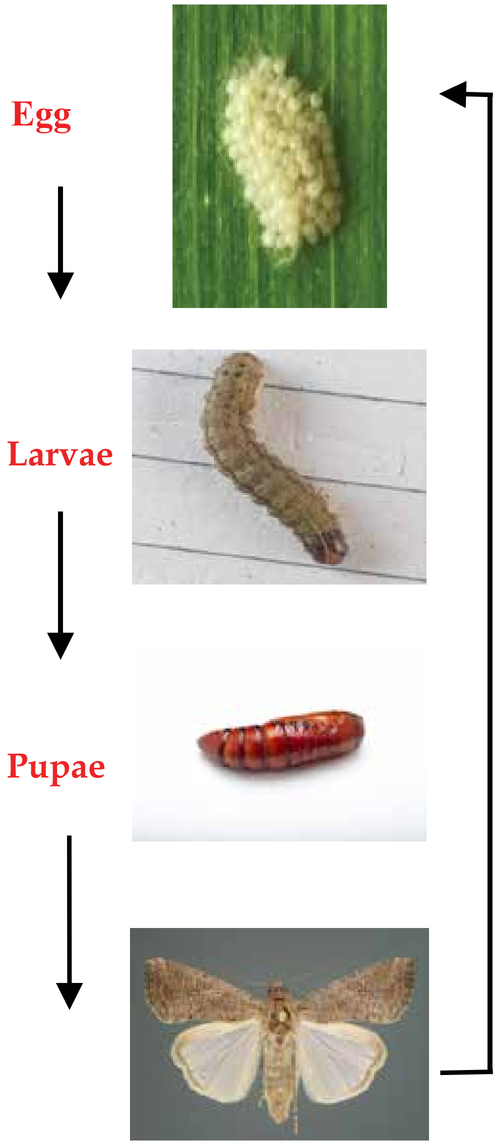

Figure 49. Life stages in sequence

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1.11.3 FAW damage symptoms

After hatching from cluster of eggs young larvae feed superficially on leaves by scrapping the leaf tissues leaving silvery transparent membrane on the leaves. Young larvae spin silken threads, which catch the wind and transport them to a new plant where it causes damage. Grown up larvae feed on basal region of the whorl where it does the maximum damage, which looks irregular scissor shot holes, characterized by ragged feeding and moist faecal matter near whorl and upper leaves of a plant (Figure 51-53).

Feeding on growing points of the young plants result in its stunted and irregular growth and there is no cob formation.

The favourite spot of the FAW larvae is curled part of whorl of a Maize plant, where it feels protected, chews and grows on its favourite tender, young Maize leaves (Figure 50 a,b,c & 51). This also provides good microclimate for FAW larvae. The maximum damage is caused by later instar larvae especially when growing points of a plant are eaten. Fortunately, Maize plant has the compensation ability to significantly recover from the early growth damage of leaves. FAW population is high enough on a plant, matured larvae even may move and feed on the tassel and ears cause damage that lead to a considerable yield loss (Figures. 52, 53).

(a) Scraping (silvery patches)

(b) Whorl damage

(c) Plant damgae

Figure 50. (a,b,c). The favourite spot of the FAW larvae and damage it causes

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Figure 51. Damage by the early instar larvae during initial stage of the crop

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Figure 52. Damage during the later stage of crop (reproductive stage)

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Figure 53. Cob damage by fall armwork

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1.11.4 Management Strategies of Fall Armyworm

IPM strategy aims to manage the pest through combination of all available techniques in a compatible manner. The components of IPM are maneuvered by cultural, physical, biological and chemical methods besides best utilization of prevailing agro-ecosystems pertaining to the crop biology and pest phenology. Since FAW is a recently noted invasive pest, so its establishment of population and host preference to the local agro-climatic conditions provide a challenge to manage the pest before pest becomes a major pest to several crops. In the recent past ravages of the pest were found restricted in the Maize growing areas from 15 DAS to 80 DAS. Considering this, its management strategy in Maize is designed to arrest the population flare up in the mid vegetative to cob formation stages of the Maize crop. Based on the reports from several CIPMCs the larvae are infected with locally available entomopathogens and number of natural enemies were found antagonistic to FAW.

Sustainable management of FAW starts with the prevention, and it needs a multi-dimensional and multi stakeholders' approaches. Farmers need a thorough knowledge about the pest biology and agro-ecological interactions of the pest incidence besides plant protection tools. Since Maize is grown in different seasons across the country so there is an ample scope for the pest migration to continue its life cycle throughout the year. It is evident from the available pest reports that it has established its population in Karnataka, Andhra Pradesh and some Maize growing areas of peninsular India as its incidence is reported this year also. Further, its population is also extended to sub-tropical to semi-temperate Maize growing areas of North eastern states.

The FAW larvae prefer early stage of the crop when tissues are succulent and soft. Immediately after hatching the larvae start sluggish movement around the cluster of eggs in search of habitat, shaded area with maximum humidity, optimum temperature and small microclimatic niches. To get a suitable habitat most of the larvae migrate to the nearby plants through silken threads secreted by the larvae and wind helps to carry over to the nearby plants. However, a few larvae remain in the same plant and migrate to whorl region of the growing point and start feeding (Figure 54). It is also noticed that in this migratory process some larvae die due to incapacitation to search suitable habitat and food. It is also noted that cannibalism occurs during the early instars of larvae.

Figure 54. Larvae find a good habitat and food, and starts to feed epidermal tissue

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Once the first instar larvae found good habitat and food, it starts to feed epidermal tissue and then penetrate to the unrolled leaf of the apical region. This type of damage is evident in the leaf with sequential holes when it emerged out. The larvae after initial cosmetic damage start moulting in the closed chamber of rolled leaf. Second instar larvae feed on the growing protuberance of the leaf buds or the meristematic tissues. This type of damage symptoms is particularly found when the plants are in early vegetative to mid vegetative stage. After moulting the third instar larvae start feeding the surrounding tissue of the growing region with external symptoms of drying up of the apical region. Fourth instar also restricts its feeding potentiality in same micro habitat. The fifth and sixth instar are the most damaging life stages of the FAW. They are in search of further food in the same plant comparatively more mature plant parts. All the stages of larvae are photonegative and prefer to remain within the whorl and avoid shifting of habitat at frequent intervals. The larvae were also found in ear in the apical region feeding on immature corn with tightly covered leaves, and also in growing part of tassel. Once larvae are mature enough become sluggish and drop down on soil. Total larval period is 12-20 days.

Pupation undertakes 2-8 cm below loose soil. On emergence adult female moths lay eggs in clusters on inner side of whorl and also on the under surface of leaves, typically near the base of a plant close to the junction of leaf and stem.

The damage is significant during seedling to tasseling/ silking stage. FAW do not prefer to feed on older plants. The critical damaging stage of the insect is generally fifth and sixth instar larvae, which cause maximum economic damage to crop by reducing the photosynthetic tissue of a plant and emerging cob.

FAW Management

A. Cultural practices

- **Clean cultivation:** Removal of alternate hosts helps to breakdown the life cycle of the FAW as well as mature larvae cannot take refuge under the dense weed
- **Timely and uniform sowing:** Staggered sowings/ sowing crop with different dates helps the FAW to continue the life cycle by providing susceptible or favorable stages of the crop. Late sowing Maize attracts more incidence of FAW from already built up populations in the early-sowing plants. Hence, late sowing and staggered sowing should be avoided.

  Uniform sowing helps to break the life cycle of FAW by not providing preferred stage of the host. FAW larvae do not prefer to feed on older crops and incidence gets reduced due to unavailability of preferred host stage and habitat.

B. Mechanical measures

- Installation of Pheromone traps @ 15/acre for mass trapping and destruction of male moths
- Erection of Bird perches @ 10/acre during early stage of the crop (up to 30 days). Birds act as good predator of lepidopteran larvae.
- Application of sand-lime in 9:1 ratio in whorl of affected Maize plant soon after the observation of FAW incidence restricts larval feeding
- Hand picking and destruction of egg masses and neonate larvae in mass by crushing or by immersing in water.

C. Biological control

- Augmentative release of *Trichogramma pretiosum* or *Telenomus remus*

  @ 5 0000 per acre at weekly intervals or based on trap catch of 3 moths/trap
- Biopesticides suitable at 5 percent damage in seedling to early whorl stage and 10 percent ear damage

1. Spraying @ 5 percent NSKE/azadirachtin 1 500 ppm @ 5ml/litre of water can reduce the hatchability of freshly laid eggs and help manage FAW larvae
2. Entomopathogenic fungal formulations: Application of *Metarhizium anisopliae* talc formulation (1 × 108cfu/g) @ 5 g/litre 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 Application of *Metarhizium rileyi* rice grain formulation (1 × 108 cfu/g) @ 3 g/ litre whorl at 15-25 days after sowing. Another 1-2 sprays may also be given at an interval of 10 days depending on pest damage.
3. *Bacillus thuringiensis* var. *kurstaki formulations* @ 2 g/l (or) 400 g/acre

Fall Armyworm has many natural enemies or biological control agents having the potential to substantially reduce its populations. The biological control agents include predators, parasitoids and microbial pathogens.

i) Predators: A natural enemy that preys and feeds other organisms by predating or supplementing host as food. Eggs, larvae, pupae or adult FAW are considered as preys. Predators are non-selective, they feed opportunistically on more than one host species. Predator includes ear wigs, ladybird beetles, green lacewings, ground beetles, assassin and flower bugs, spiders, ants, birds, bats etc (Figure 55 a-e).

Ants are important insect predators and potent biocontrol agents in Maize ecosystem. In tropical agro-ecosystems, ants may play an important role because of their greater relative abundance and diversity. These are essentially carnivores, generalist predators and significantly reduce populations of FAW. The most abundant species are Solenopsis geminata (F.) (Hymenoptera; Formicidae), Lespesia archippivora (Riley) (Diptera; Tachinidae) and Doru taeniatum (Dorhn) (Dermaptera; Forficulidae). Rove beetle, Paederus fuscipes Curtis (Coleoptera: Staphylinidae) was also found predating the larvae

(a) Ladybird beetle

(b) Grub

(c) Earwig

(d) Spider

(e) Green lacewing

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Figure 55 (a-e). Potential predators in Maize crop ecosystem

of Fall Armyworm in Andhra Pradesh, India.

ii) Parasitoids: Parasitoids is an organism that lives on or in a host organism and ultimately kills the host. Parasitoids that have undergone an adoption process to the FAW display narrow host range. Such host specificity of parasitoids to FAW is of greater significance for management FAW. Parasitoids can be released against egg and larval stage of FAW.

Egg parasitoids kill the pest in the egg stage itself before the pest could emerge and damage the crop. *Trichogramma pretiosum* and *Telenomus remus* (Figure 56 a&b) are potential egg parasitoids of FAW. The females of the egg parasitoids first locate the host eggs by using chemical and visual signals. After finding suitable eggs, females determine if the egg was previously parasitized by using her ovipositor and antennal drumming and tapping on the egg surface. Females also use antennal drumming to determine the size and quality of the target egg, which determine the number of eggs a female may insert or fecundity rate of the parasitoid. A single female can parasitize up to 10 host eggs a day. Larval parasitoids deposit eggs in host larvae and eggs hatch within the host larvae and consume host tissues and complete life cycle within host and come out by killing the host larvae. Example *Cotesia* spp(Figure 56c).

The natural enemy complex of FAW, including egg parasitoids viz., *Telenomus* sp. (Hymenoptera: Platygastridae) and *Trichogramma* sp. (Hymenoptera: Trichogrammatidae), gregarious larval parasitoid *Glyptapanteles creatonoti* (Viereck) (Hymenoptera: Braconidae), solitary larval parasitoid *Campoletis chlorideae* Uchida (Hymenoptera: Ichneumonidae), and two braconid larval parasitoids *Phanerotoma* sp. (Hymenoptera: Braconidae) and *Chelonus* sp. (Hymenoptera: Braconidae) (Figure 56d) , a solitary + indeterminate larval-pupal parasitoid (Hymenoptera: Ichneumonidae: Ichneumoninae) and pupal parasitoid *Trichomalopsis* (Hymenoptera: Pteromalidae) were reported first time from India by ICAR-NBAIR. FAW is the first host record for *Glyptapanteles creatonoti* across the globe being a well established parasitoid of various noctuids in India and Malaysia. *Coccygidium transcaspicum* (Kokujev) (Hymenoptera: Braconidae) (Figure 56e) was also identified for the first time across the globe as a larval parasitoid of Fall Armyworm. Besides these, several predators (Figure 55, a-e) like earwig, *Forficula* sp, predatory bugs like *Andrallus spinidens* and *Eocanthecona furcellata* were identified. In addition to this, one dipteran parasitoid, Pseudgourax sp. was also recorded on the egg mass of Fall Armyworm. The maggots were found feeding on the eggs thereby showing a potential for the management of FAW (ICAR-NBAIR *Annual Report*, 2018-19).

When FAW eggs were exposed to both parasitoids, *T. remus* resulted in 92.73 percent parasitism and *T. pretiosum* caused 45.51 percent parasitism. Percent adult emergence in *T. remus* was 95.01 percent while 68.13 percent adults emerged from *T. pretiosum* parasitized FAW eggs. Four releases of *T. pretiosum* @ 50 000/ha in FAW infested fields along with other IPM interventions (Pheromone traps, entomopathogenic fungi and entomopathogenic bacteria) resulted in 76.14 percent reduction in FAW egg mass at 60 days after first release (ICAR-NBAIR *Annual Report*, 2019-20).

(a) *Trichogramma pretiosum* parasitizing eggs of FAW

(b) *Telenomus remus Nixon*

(c) *Cotesia marginiventris (Cresson)*

Figure 56 (a-e). Potential parasitoids in Maize crop ecosystem

(d)*Chelonus insularis (Cresson)*

(e) *Coccygidium transcaspicum* Kokujev

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iii) Microbial Pathogens or Entomopathogens: Entomopathogens are the micro-organisms that infect through pathogenicity and kill insects and can attack larvae, pupae and adult stages (Figure 58 a-c). Though larvae are the target life stage to use entomopathogens. FAW is naturally infected by different types of the pathogens in the field condition. So collection, isolation and mass production of such pathogens will be of immense use for FAW management.

Entomopathogenic fungi: ***Metarhizium anisopliae, M. rileyi and Beauveria bassiana***

Entomopathogenic bacteria: ***Bacillus thuringiensis var kurstaki***

Entomopathogenic viruses: ***Nuclear polyhedrosis virus***

FAW larvae naturally infested by entomopathogenic fungi and virus are easily identified in the field. Fungal-killed larvae turn rigid and appear frozen on the leaves eventually turning white or light green as the fungal spores matures. Virus-killed larvae become soft and many hang from the leaves, eventually oozing viroid particle and fluids.

The host specificity is very high and usually restricted to few closely related insect species. These pathogens do not affect other groups of natural enemies.

(a) Infected by Metarhizium anisopliae (fungus)

(b) Infected by Metarhizium anisopliae (fungus)

Figure 57 (a-c). Natural infection to FAW larvae by entomopathogens

(c) Infected by NPV (virus)

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Figure 58. Recycling of entomopathogens at field level

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Farmers practice of management or recycling of pathogens: When naturally killed fungi or virus are observed in the field can be collected and grounded, strained and diluted with water. The diluted fungal spores or virus particles can be sprayed back to infested plants (Figure 59).

D. Habitat management

Habitat management is an important strategy for pest control in integrated pest management (IPM). Various categories of habitat management such as trap cropping, intercropping, cover cropping for natural enemy refuges such as beetle banks, and floral resources for parasitism and predators are used in applied insect ecology for many years by the farmers in their own fields. In a broader sense, two mechanisms, the enemy hypothesis and the resource concentration hypothesis were identified as acting independently or combined in pest population dynamics. The enemy hypothesis, alternative food sources, and pollen (SNAP) to improve conservation biological control. The resource concentration hypothesis emphasizes how the host selection behaviour of herbivores in a diverse habitat can reduce pest colonization in crops.

i) Trap cropping

Trap crops are deployed or manipulated to attract, divert, intercept, and/or retain insect pests to reduce their damage within the main crop. Once the pest is aggregated in a trap crop, it can be managed by using much more localized applications of pesticides or by the physical destruction of the added vegetation and the pest along with. Although trap cropping is usually deployed to target one pest species, sometimes it can be useful against more than one. The selection of host plants by herbivores is influenced by crop species and cultivar, and by plant and pest phenology. Additionally, the attractiveness of the trap crop and its spatial coverage/ arrangement are critical in successful and effective pest management schemes.

Different modalities of trap cropping are used as a traditional practice in North-Eastern Maize growing areas and dead end trap cropping is one of the most effective systems against pests. In dead end trap cropping, the selected trap plants are attractive to insects on which their off-springs cannot survive for a long time. A famous example of dead-end trap cropping is the push–pull system. In that, molasses grass, legume like Desmodium in association with Napier grass (Pennisetum purpureum), sorghum may be a valuable biological agent to control Maize stem borers and FAW. When it is sown around Maize field the molasses grass emits two chemical signals: one chemical has a repellent effect on the stem borers, and the other chemical attracts the wasp Cotesia spp, a stem borer parasitoid.

For managing FAW, sowing 3-4 rows of trap crop i.e. Napier grass around the Maize crop attracts the FAW moths to lay eggs and eggs laying in target crop Maize is the minimum. Emerging larvae did not survive on the Napier grass because the plant produces a gummy substance that immobilizes the larvae, preventing their feeding and also the FAW larvae do not develop on it due to poor nutrition. This strategy also increased the abundance and diversity of natural enemies, partly because pesticides were no longer used to control the FAW.

ii) Intercropping towards better gain

Intercropping of Maize with suitable pulse crops in particular regions viz. Maize + Pigeon pea/Black gram /Green gram.

Intercropping acts on herbivores by partitioning their population between the crop and the intercrop, reducing pest pressure on the main crop (Figure 60). It also deters or repels pests because non-crop visual or chemical cues change insect behaviour, potentially reducing pest damage. This form of habitat management also acts by creating a physical barrier, restricting inter-plant pest movement or providing floral resources for the pests' natural enemies. Young larvae transported from one plant to another plant by spinning the silken thread and which catch the wind and establish to a new Maize plant. This movement can be minimised by intercropping with pulses.

Figure 59. Intercropping system in Maize

©ICPMC/Benguluru

Habitat Management of Fall Armyworm

a. Destruction of Egg Masses

Eggs (100-200) are laid in batches on the under surface of the leaves typically near the base of plant close to the junction of the leaf and stem in batches and also deposited in layers on the inner side of the whorl. Collecting and crushing of egg masses reduce the further population build up. Planting Napier grass around the Maize field attracts the FAW to lay eggs on it, but it does not allow larvae to develop due to poor nutrition

b. Larval Management

Larval cannibalism is observed in FAW. When larvae become larger, they eat each other and reduce the competition of food and habitat often only 1 or 2 larvae found in whorls. Young larvae transport from one plant to another plant by spinning the silken thread, which catch the wind and establish to a new Maize plant. Intercropping with pulses and also increasing the diversity of other plants within Maize field minimise this movement.

c. Pupae Management

Pupation takes place within the soil or at the base of the plant in dried leaf litter so, deep ploughing before sowing may expose FAW puape to predators, and also periodical weeding exposes larvae to predators besides disturbance of habitat. Larvae sometimes conceal in the weed during day time.

d. Adult Trapping

Adults are not the damaging life stage of the crop. Installation of Pheromone traps (Figure 61) for mass trapping and destruction of male moths reduces incidence of population of FAW besides it helps in monitoring.

Figure 60. Demonstration of Pheromone trap CIPMC Hyderabad

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e. Bird perches

Erection of bird perches helps birds to perch and prey over the FAW larvae. The bird perches, however, must be removed at the time of the cob formation.

1.11.5 A guide for the management of Fall Armyworm

1. Pre-sowing

- Creation of awareness among the farming community and stakeholders through trainings /group discussions on importance of FAW and its management strategies
- Clean cultivation: Removal of alternate hosts helps to breakdown the life cycle of FAW and mature larvae cannot take refuge under the dense weed.

2. Sowing to six leaf stage

- Timely and uniform sowing over a larger area
- Follow ridge and furrow planting method instead of flat bed sowing
- Apply only the recommended dosage of NPK as basal dose
- Plant 3-4 rows of Napier grass/hybrid napier as trap crop around Maize fields
- Intercrop Maize with legumes, viz. pigeonpea, cowpea, black gram, kidney bean etc. in 2:1 to 4:1 ratio
- Erect bird perches @10/acre to encourage natural FAW predation by birds
- Install Pheromone traps @ 4/acre soon after sowing and monitor moth catches#
- Adopt clean cultivation to eliminate possible alternate hosts
- Destruction of egg masses and larvae by crushing
- Application of sand or soil mixed with lime in 9:1 ratio into whorl of Maize plants
- First spray should be with 5 percent Neem Seed Kernel Extract (NSKE) or azadiractin, 1 500 ppm (1 litre/acre) @ 5 ml /litre after observation of one moth/trap/day or 5 percent FAW infestation on trap crop or main crop
- If monitoring indicates more than one moth/ trap/day install Pheromone traps @ 15/acre for mass trapping [*Note: For success of mass trapping go for community action*] OR release egg parasitoids viz. *Telenomus remus* @ 4 000/ acre or *Trichogramma pretiosum* @ 16 000/acre. Two releases of parasitoids at weekly interval should

be done. [*Note: Release of parasitoids should not be opted if mass trapping is followed*]

- At 5-10 percent infestation whorl application of *Bacillus thuringiensis* var *kurstaki* formulations (400 g/acre) @ 2 g/litre or *Metarhizium anisopliae* or *Beauveria bassiana* with spore count of 1×108cfu/g (1 kg/acre) @ 5 g/litre or SfNPV (600 ml/acre) @ 3 ml/litre or entomopathogenic nematode (EPN) (4 kg/acre) @ 20 g/litre of water is recommended
- If infestation is more than 10 percent , whorl application of any one of the recommended insecticides for FAW viz. Chlorantraniliprole 18.5 SC (80 ml/acre) @ 0.4 ml/litre; Chlorantraniliprole 9.3 percent + Lambda cyhalothrin 4.6 percent ZC (35 g a.i/ha-23.42+11.58) (100 ml/acre) @ 0.5ml/litre; Spinetoram 11.7 percent SC (100 ml/acre) @ 0.5 ml/litre; Emamectin benzoate 5 percent SG (80 g/acre) @ 0.4 g/litre is recommended

3. Seven leaf stage to flowering

- Monitoring of FAW using Pheromone traps @ 4/acre should be continued#
- Spray 5 percent NSKE or azadiractin, 1 500 ppm (1 litre/acre) @ 5 ml /l after observation of one moth/trap/day or 5 percent of fresh FAW infestation
- If infestation is more than 10 percent , whorl application of *Bacillus thuringiensis* var *kurstaki* formulations (400 g/acre) @ 2 g/litre or *Metarhizium anisopliae* or *Beauveria bassiana* with spore count of 1×108 cfu/g (1 kg/acre) @ 5 g/litre or SfNPV (600 ml/acre) @3 ml/ litre or entomopathogenic nematode (EPN) (4 kg/acre) @ 20 g/litre of water is recommended
- If infestation is more than 20 percent , whorl application of any one of the recommended insecticides for FAW, viz., Chlorantraniliprole 18.5 SC (80 ml/acre) @ 0.4 ml/litre; Chlorantraniliprole 9.3 percent + Lambda cyhalothrin 4.6 percent ZC (35 g a.i/ha-23.42+11.58) (100ml/acre) @ 0.5ml/litre; Spinetoram 11.7 percent SC (100 ml/acre @ 0.5 ml/litre) @ 0.5 ml/litre; Emamectin benzoate 5 percent SG (80 g/acre) @ 0.4 g/litre is recommended.

4. Flowering to harvest

- Hand picking and destruction of larvae boring into ears
- At 10 percent ear damage, application of *Bacillus thuringiensis* var *kurstaki* formulations (400 g/acre) @ 2 g/litre or *Metarhizium anisopliae* or *Beauveria bassiana* with spore count of 1×108cfu/g (1 kg/acre) @ 5 g/litre or SfNPV (600 ml/acre)@ 3 ml/ litre or Entomopathogenic nematode (EPN) (4 kg/acre) @ 20 g/litre of water is recommended.

1.11.5.1 Guide on action thresholds and management of Fall Armyworm on grain corn

Crop stage	Action threshold	Intervention options
Sowing to six leaf stage	One moth/ trap/day or 5 percent infestation on trap or main crop	Application of 5 percent Neem Seed Kernel Extract (NSKE) or azadirachtin 1 500 ppm @ 5 ml/litre (1 litre/acre) of water
	One moth/trap/day caught in traps kept for monitoring	Install Pheromone traps @ 15/acre for mass trapping of male moths [For success of mass trapping go for community action] [Mass trapping should not be an option if parasitoid releases are planned]
		Release egg parasitoids viz. *Telenomus remus* @ 4 000/ acre or *Trichogramma pretiosum* @ 50 000/acre. Two releases of parasitoids at weekly interval should be done. [Release of parasitoids should not be opted if mass trapping is followed]
	5-10 percent infestation	Whorl application of *Bacillus thuringiensis* var *kurstaki* formulations (400 g/acre) @ 2 g/litre or *Metarhizium anisopliae* or *Beauveria bassiana* with spore count of 1×10^8 cfu/g (1 kg/acre) @ 5 g/litre or SfNPV (600 ml/acre) @ 3 ml/litre or entomopathogenic nematode (EPN) (4 kg/acre) @10 g/litre of water is recommended

Crop stage	Action threshold	Intervention options
	>10 percent infestation	Whorl application of anyone of the recommended insecticides with label claim, viz. Chlorantraniliprole 18.5 SC (80 ml/acre) @ 0.4 ml/litre or Chlorantraniliprole 9.3 percent + Lambda cyhalothrin 4.6 percent ZC (35 g a.i/ha-23.42+11.58) (100 ml/acre) @ 0.5 ml/litre or Spinetoram 11.7 percent SC (100 ml/acre) @ 0.5 ml/litre
Seven leaf stage to flowering	5-10 percent infestati on	Application of 5 percent Neem Seed Kernel Extract (NSKE) or azadirachtin 1 500 ppm @ 5 ml/l (1 litre/acre) of water
	>10 percent infestation	Whorl application of *Bacillus thuringiensis* var *kurstaki* formulations (400 g/acre) @ 2 g/litre or *Metarhizium anisopliae* or *Beauveria bassiana* with spore count of 1×10^8 cfu/g (1 kg/acre) @ 5 g/litre or SfNPV (600 ml/acre) @ 3 ml/litre or entomopathogenic nematode (EPN) (4 kg/acre) @ 10 g/litre of water
	>20 percent infestation	Whorl application of anyone of the recommended insecticides with label claim, viz., Chlorantraniliprole 18.5 SC (80 ml/acre) @ 0.4 ml/litre or Chlorantraniliprole 9.3 percent + Lambda cyhalothrin 4.6 percent ZC (35 g a.i/ha-23.42+11.58) (100 ml/acre) @ 0.5 ml/litre or Spinetoram 11.7 percent SC (100 ml/acre) @ 0.5 ml/litre
Flowering to harvest	10 percent ear damage	Application of *Bacillus thuringiensis* var *kurstaki* formulations (400 g/acre) @ 2 g/litre or *Metarhizium anisopliae* or *Beauveria bassiana* with spore count of 1×10^8 cfu/g (1 kg/acre) @ 5 g/litre or SfNPV (600 ml/acre) @ 3 ml/litre or entomopathogenic nematode (EPN) (4 kg/acre) @ 10 g/litre of water

1.11.5.2 Guide on action thresholds and management of Fall Armyworm on baby corn

Crop stage	Action threshold	Intervention options
Sowing to six leaf stage	One moth/trap/day or 5 percent infestation on trap or main crop	Application of 5 percent Neem Seed Kernel Extract (NSKE) or azadirachtin 1 500 ppm @ 5 ml/litre (1 litre/acre) of water OR Release egg parasitoids viz. *Telenomus remus* @ 4 000/ acre or *Trichogramma pretiosum* @ 16 000/acre. Two releases of parasitoids at weekly interval should be done
	5-10 percent infestation	Whorl application of *Bacillus thuringiensis* formulations @ 2 g/litre (400 g/acre) or *Metarhizium anisopliae* or *Beauveria bassiana* (1×10^8 cfu/g) @ 5 g/litre (1 kg/acre) or SfNPV (1.5×10^{12} POBs/ha) @4 ml/litre (800 ml/acre) or entomopathogenic nematode (Heterorhabditis indica) @ 20 g/litre of water (4 kg/acre) is recommended.
	>10 percent infestation	Whorl application of any one of the recommended insecticides for FAW, viz., Chlorantraniliprole 18.5 SC (80 ml/acre) @ 0.4 ml/litre; Chlorantraniliprole 9.3 percent + Lambda Cyhalothrin 4.6 percent ZC (100 ml/acre) @ 0.5 ml/litre; Spinetoram 11.7 percent SC (100 ml/acre) @ 0.5 ml/litre; Emamectin benzoate 5 percent SG (80 g/acre) @ 0.4 g/litre
Seven leaf stage to baby corn harvest	5 percent infestation	Application of 5 percent Neem Seed Kernel Extract (NSKE) or azadirachtin 1 500 ppm @ 5 ml/l (1 litre/acre) of water
	>10 percent infestation	Whorl application of *Bacillus thuringiensis* formulations @ 2 g/litre (400 g/acre) or *Metarhizium anisopliae* or *Beauveria bassiana* (1×10^8 cfu/g) @ 5 g/litre (1 kg/acre) or SfNPV (1.5×10^{12} POBs/ha) @ 4 ml/litre (800 ml/acre) or entomopathogenic nematode (*Heterorhabditis indica*) @20 g/litre of water (4 kg/acre) is recommended

1.11.5.3 Guide on action thresholds and management of Fall Armyworm on sweet corn

Crop stage	Action threshold	Intervention options
Sowing to six leaf stage	One moth/trap/day or 5 percent infestation on trap or main crop	Application of 5 percent Neem Seed Kernel Extract (NSKE) or azadirachtin 1 500ppm @ 5 ml/litre (1 litre/acre) of water OR Release egg parasitoids viz.*Telenomus remus* @ 4 000/ acre or *Trichogramma pretiosum* @ 16 000/acre. Two releases of parasitoids at weekly interval should be done
	5-10 percent infestation	Whorl application of *Bacillus thuringiensis* formulations @ 2 g/litre (400 g/acre) or *Metarhizium anisopliae* or *Beauveria bassiana* (1×10^8 cfu/g) @ 5 g/litre (1 kg/acre) or SfNPV (1.5×10^{12} POBs/ha) @ 4 ml/litre (800 ml/acre) or entomopathogenic nematode (*Heterorhabditis indica*) @ 20 g/litre of water (4 kg/acre) is recommended
	>10 percent infestation	Whorl application of any one of the recommended insecticides for FAW, viz. Chlorantraniliprole 18.5 SC (80 ml/acre) @ 0.4 ml/litre; Chlorantraniliprole 9.3 percent + Lambda Cyhalothrin 4.6 percent ZC (100 ml/acre) @ 0.5 ml/litre; Spinetoram 11.7 percent SC (100 ml/acre) @ 0.5 ml/litre; Emamectin benzoate 5 percent SG (80 g/acre) @ 0.4 g/litre
Seven leaf stage to flowering	5 percent infestation	Application of 5 percent Neem Seed Kernel Extract (NSKE) or azadirachtin 1 500ppm @ 5 ml/l (1 litre/acre) of water
	>10 percent infestation	W Whorl application of *Bacillus thuringiensis* formulations @ 2 g/litre (400 g/acre) or *Metarhizium anisopliae* or *Beauveria bassiana* (1×10^8 cfu/g) @ 5g/litre (1 kg/acre) or SfNPV (1.5×10^{12} POBs/ha) @ 4 ml/litre (800 ml/acre) or entomopathogenic nematode (*Heterorhabditis indica*) @ 20 g/litre of water (4 kg/acre) is recommended
Flowering to sweet corn harvest	10 percent ear damage	Whorl application of *Bacillus thuringiensis* formulations @ 2 g/litre (400 g/acre) or *Metarhizium anisopliae* or *Beauveria bassiana* (1×10^8 cfu/g) @ 5 g/litre (1 kg/acre) or SfNPV (1.5×10^{12} POBs/ha) @ 4 ml/litre (800 ml/acre) or entomopathogenic nematode (*Heterorhabditis indica*) @ 20 g/litre of water (4 kg/acre) is recommended.

1.11.5.4 Guide on action thresholds and management of Fall Armyworm on Maize for fodder and silage

Crop stage	Action threshold	Intervention options
Sowing to six leaf stage	One moth/trap/day or 5 percent infestation on trap or main crop	Application of 5 percent Neem Seed Kernel Extract (NSKE) or azadirachtin 1 500ppm @ 5 ml/litre (1 litre/acre) of water or Release egg parasitoids viz. *Telenomus remus* @ 4 000/acre or *Trichogramma pretiosum* @ 16 000/acre. Two releases of parasitoids at weekly interval should be done
	5-10 percent infestation	Whorl application of *Bacillus thuringiensis* formulations @ 2 g/litre (400 g/acre) or *Metarhizium anisopliae* or *Beauveria bassiana* (1×10^8 cfu/g) @ 5 g/litre (1 kg/acre) or SfNPV (1.5×10^{12} POBs/ha) @ 4 ml/litre (800 ml/acre) or entomopathogenic nematode (*Heterorhabditis indica*) @ 20 g/litre of water (4 kg/acre) is recommended.

Crop stage	Action threshold	Intervention options
	>10 percent infestation	Whorl application of any one of the recommended insecticides for FAW, viz. Chlorantraniliprole 18.5 SC (80 ml/acre) @ 0.4 ml/litre; Chlorantraniliprole 9.3 percent + Lambda Cyhalothrin 4.6 percent ZC (100ml/acre) @ 0.5 ml/litre; Spinetoram 11.7 percent SC (100ml/acre) @ 0.5 ml/litre; Emamectin benzoate 5 percent SG (80 g/acre) @ 0.4 g/litre
Seven leaf stage to fodder harvest for silage	5 percent infestation	Application of 5 percent Neem Seed Kernel Extract (NSKE) or azadirachtin 1 500 ppm @ 5 ml/l (1 litre/acre) of water
	>10 percent infestation	Whorl application of *Bacillus thuringiensis* formulations @ 2 g/litre (400 g/acre) or *Metarhizium anisopliae* or *Beauveria bassiana* (1×10^8 cfu/g) @ 5 g/litre (1 kg/acre) or SfNPV (1.5×10^{12} POBs/ha) @ 4 ml/litre (800 ml/acre) or entomopathogenic nematode (Heterorhabditis indica) @ 20 g/litre of water (4 kg/acre) is recommended.

POP for the management of FAW, grain corn, baby corn, sweet corn in silage and fodder Maize prepared by ICAR-IIMR and ICAR-NBAIR in coordination with DPPQ&S.

Pheromone traps– Funnel trap with FAW lure should be installed at a height adjusted each week matching with crop canopy. Traps should be separated by a minimum distance of 75 feet. Observe traps for number of moths caught twice or once in a week and work out the catch/day. FAW lures should be changed once in 30 days in case of monitoring and no lure change is required for mass trapping.

Preparation of Neem Seed Kernel Extract (NSKE) for one acre – 10 kg of need seed kernel is required for one acre. Grind 10 kg of need seed kernels to make powder. Soak the powder in 50 litre water overnight. Stir and filter the contents using cotton cloth. Add 200g detergent powder or 200 ml of soap solution to the filtered solution. Make up the volume to 200 litre by adding water.

Caution upon release of egg parasitoids-Minimum of oneweek interval should be followed between parasitoid release and application of neem or chemical insecticides

Precautions for pesticide use: Not more than two chemical sprays are to be used in entire crop duration. Same chemical should not be chosen for second spray. Sprays should always be directed towards whorl and applied either in early hours of the day or in the evening. Use protective clothing, facemask and gloves during preparation and application of pesticides. Enter the field only 48 hours after spraying pesticide. Interval between application of chemical insecticide and harvest of corn should be minimum 30 days.

Note: Apart from the popular formulations of biopesticides available in market, Fall Armyworm specific formulations of indigenous strains of *Bacillus thuringiensis* (NBAIR Bt 25 percent formulation (4 litre/acre) @ 20 ml/litre), *Metarhizium anisopliae*, *Beauveria bassiana*, *Heterorhabditis indica* and SpfrNPV are available with ICAR-NBAIR

1.12 FAW Landscape Approach

Preserving and restoring semi natural habitats not only increases densities of natural enemies but also enhances pest control services. In particular, increasing habitat diversity at the landscape level (e.g., through the preservation or cultivation of patches of natural vegetation, tree cover, or hedgerows) can increase the abundance of insectivorous birds and bats.

Although individual farmers and practitioners may also implement landscape level interventions, landscape approaches typically also require involvement of communities, governments, or other organizing bodies to coordinate action across a sufficient scale to achieve impact on pest populations.

1.12.1 FAW Characteristics

Fall Armyworm (FAW), *Spodoptera frugiperda*, is a dangerous transboundary insect (Figure 62) with a high potential to spread rapidly due to its natural distribution capacity and opportunities presented by international trade. FAW represents a real threat to food security and livelihoods of millions of smallholder farmers. It prefers Maize but also feeds on more than 80 other crops, including wheat, sorghum, millet, sugarcane, vegetable crops and cotton. Considering that FAW is a new pest, recommendations for pest management are evolving.

Figure 61. Fall Armyworm (FAW)

©FAO/India

1.12.2 Need to enhance farmers' awareness

Given the above, farmers will need to seek information, advice, tools and resources on how to cope. Farmers need to understand the different stages of FAW and how FAW attacks different growth stages. They need to know how to monitor FAW using appropriate scouting methods, and how to monitor (observe and analyze) and make informed management decisions based on the observed biotic factors (pests, weeds, diseases and natural enemies) and abiotic factors that influence the health of the crop and pest incidence (e.g. soil fertility and weather conditions).

1.12.3 Current pest management strategies and impacts

The key weakness with our current pest management strategies is not so much the products but our central operating philosophy. Pest management strategies often use silver bullet[1] products. The use of therapeutic tools, whether biological, chemical, or physical, as the primary means of controlling pests rather than as occasional supplements to natural regulators to bring them into acceptable bounds violates fundamental unifying principles and cannot be sustainable. We are aware that use of conventional pesticides results in toxic residues, pest resistance, emergence of secondary pests, and pest resurgence. Thus, therapeutic interventions into these systems are met by countermoves that neutralize their effectiveness. We need to recognize that agricultural ecosystems interact and maintain balance within functional fluctuating bounds. Therefore, we must turn more to developing farming practices that are compatible with ecological systems and designing cropping systems that naturally limit the elevation of an organism to pest status.

1.12.4 Multipronged strategy

Early detection and implementation of control measures, deploying biological and low-risk solutions, are critical for sustainable management of the pest. Monitoring, surveillance and scouting are necessary for the quick detection of presence of FAW and control before outbreaks occur. This is critical to reduce yield losses, preserve needed ecosystem services[2] and minimize harm to the environment. Considering the above, there is a need for multistakeholder[3] engagement to pool in resources and expertise (agronomic, ecological, and social/ institutional) to innovate and comprehensively address the challenge (Figures 62 & 63). Surveillance of FAW should be done throughout the year because there are several generations, which attack Maize at different stages; they also attack other host plants. During the dry season, irrigated areas become host reservoirs of FAW populations, from which migration occurs at the beginning of the rainy season. Monitoring and controlling the populations on off-season crops can be critical in reducing infestation on rain-fed crops.

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[1] *one that instantly solves a long-standing problem ; a simple and seemingly magical solution to a complicated problem*

[2] *Ecosystem services can be categorized into four: (1) provisioning (goods and products obtained from ecosystems such as food, water, timber, or medicines); (2) regulating (benefits obtained from an ecosystem's control of natural processes, for instance pollination or pest control by natural enemies); (3) cultural (the nonmaterial benefits obtained from ecosystems such as recreation in forests); and (4) habitat.*

[3] *farmers, scientists, extension service advisors, agribusiness representatives, consumer associations, and others*

Figure 62. Early detection of FAW is must for further action

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Figure 63. Engagement of multi stakeholders

©Victorian State Department of Environment and Industries.

Considering the nature of the pest and need for year-round monitoring, surveillance, scouting and control operations, adoption of a multipronged strategy that begins with soil preparation and covers all crop stages can be very effective in the control of FAW. The multipronged strategy should include a combination of cultural, biological and chemical measures with use of chemical option as a last resort (Figure 64).

Figure 64. Multipronged strategy to tackle FAW

©Sathguru/2019

Here below is an indicative list of measures for operationalizing this strategy:

- Soil preparation: Improved soil health and adequate moisture are essential to grow healthy plants, which can better withstand pest infestation and damage. Deep ploughing before sowing would expose the insect stages hiding underground to birds and other natural enemies
- Planting: Avoid late planting and staggered planting
- Weather forecasting: Atmospheric conditions are the major driver for the development and spread of crop pests and diseases. Satellite imagery and forecasting of weather conditions provide a probability for future outbreaks, and also identify the regions that are most at risk
- Pest trapping: The presence and build-up of FAW in a particular area can be detected by using Pheromone traps. Traps are useful monitoring tools for FAW populations
- Monitoring: It is important to monitor your Maize crop frequently after germination for presence of the pest and or signs/damage symptoms. Early detection of the pest allows quick and timely response, which will minimize damage to your Maize crop and reduce harvest losses
- Thresholds: Control needs to be considered when egg masses are present on 5 percent of the plants or when 25 percent of the plants show damage symptoms and live larvae are still present. Controlling larger larvae, typically after they are hidden under the frass plug, will be much more difficult.

1.12.5 Landscape / ecosystem management: An alternate strategy

The multipronged strategy is most effective when adopted alongside landscape approaches. Landscape approaches harness inherent strengths within the ecosystem to bring pest populations into acceptable bounds rather than eliminating them (Figure 65). The objective is to control and promote natural enemies for control of the pest and avoid mass use of pesticide.

Figure 65.

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Different numbers in the picture indicate the different Agro-ecological approaches to the pest management.

1. **Minimum soil disturbance** enhances biological properties of soil, thereby improving soil fertility management and plant nutrition;

2. **Mulching of crop residues** protects the soil surface and adds carbon to improve soil fertility management, and in addition provides habitat for insect predators especially spiders, earwigs, beetles and ants;

3. **Planting leguminous inter-crops** or cover crops improves soil fertility management through nitrogen fixation, diversifies the field environment for beneficial insects, including insect predators and parasitoids.

4. **Shrubs/trees** with flowers or extra flora nectaries support populations of ants and small wasps;

5. **Boundary trees** (e.g. fodder trees, fuelwood trees, shelter trees) provide perches and roosts for birds and bats and increase the structural diversity of the farm habitat through shade and shelter;

6. **Crop rotation** – improves soil fertility management and diversifies the farm environment;

7. **Regular scouting** by the farmer to identify pests and assess damage enables informed pest management decisions;

8. **Weeds** allowed to grow between the Maize rows and along field margin can provide habitat for insect predators and encourage parasitoids and predatory wasps through provision of nectar (however, weeds can also compete with the crop and sometimes provide alternative hosts for pests, hence detailed understanding of their effects is required);

9. ***Diverse field margins*** provide habitat for generalist predators, such as spiders, beetles, earwigs and ants;

10. ***Insectivorous birds*** and bats provide an important role in reducing pest abundance in diverse Agro-ecological systems;

11. **Nest site provision** for predatory wasps or ants could be used to enhance the local abundance of insect predators;

12. **Predatory wasp** – these wasps hunt pest caterpillars to provision their larvae. (For interpretation of the references to colour in this Figure legend, the reader is referred to the Web version of this article.)

For this, non-cultivable habitats including hedgerows, grassy margins of fields, and wildflower strips provide essential resources for natural enemies and insect pollinators. So, it is important to manage non-cultivated habitats to boost natural enemy populations and reduce the pests. Effectiveness of landscape approaches are dependent on multi stakeholder engagement, i.e. engaging local authorities, communities, and agripreneurs to undertake and sustain monitoring and control operations for effective management of the pest. Two effective methods that can aid landscape approaches are: Farmer Field Schools (FFS)) and FAW Monitoring and Early Warning System (FAMEWS).

FFS serves as an important mechanism to facilitate collective processes at the local level, build individual and collective capacities using discovery learning methods, and create/strengthen institutional processes at the local level for building/ sustainable landscape management approaches for control of FAW (Figure 66). Synchronized implementation of FFS across a large landscape can build the necessary institutional base for effective surveillance and control FAW operations in a larger landscape.

Figure 66. Farmer Field Schools (FFS)

©RySS/Guntur

Figure 67. AESA in the field

©FAO/RySS

Agro-ecosystem Analysis (AESA), which is considered as the heart of FFS builds critical decision-making skills on crop and ecosystem management. It involves observing biotic (plant and pest) and abiotic factors and interplay between them for informed decision making. AESA observations in FAW FFS should go beyond crop to

Figure 68. FAO FAMEWS mobile application

©CIPMC/Benguluru

larger ecosystem—hedgerows, grassy margins of fields, and wildflower strips as they provide essential resources for natural enemies and insect pollinators. Additional details of the FFS methodology and process are covered in the FFS section.

FAO FAMEWS is a mobile application for Android users for the real-time monitoring of the Fall Armyworm (FAW) in a macro landscape and at the global level (Figure 68).

This multi-lingual tool allows farmers, communities, extension agents and others to record standardized field data whenever they scout a field or check Pheromone traps for FAW.

Data from the FAMEWS app provide valuable insights on how FAW changes over time with ecology, to improve knowledge of its behaviour and guide best management practices. FAW data can be collected at the farm level and collated for sharing at local, national and global levels to manage the pest, identify priority areas, and foster early warning mechanisms for all stakeholders. Additional information about FAMEWS is provided in relevant section.

Chapter 2

Basic concepts of Integrated Pest Management-Farmers Field Schools (IPM-FFS)

2.1 Background of Farmers Field School

Farmers Field School (FFS) is a process oriented extension approach that grew out of the formal training process at the end of 1980s in Indonesia in response to Brown Plant Hopper (BPH) outbreak in rice affecting the entire country. The extension workers when started to deliver information on IPM, using methods similar to those they had used in the past to transfer information about pesticides, they realized that the information on IPM is more complex and difficult to transfer through conventional methods. The formal training methods of delivering messages were often inappropriate and too simple to deal with the complex information. The informal training was found suitable to reach the core issues of problem and eradicate the bottleneck of the solution delivery channel. This happened through hands-on practical learning in FFS, building on principles of adult education and experiential learning emerged as a means of facilitating critical decision making skills among farmers.

FFS, a school without walls, has group of farmers who meet regularly during the course of the crop growing seasons to experiment as a group with new production options. FFS aims to increase capacity of group of farmers to test new technologies/ideas in their own fields, assess results and their relevance to their local context. They interact on a more demand driven basis with the researchers and extension workers and seek assistance in most cases when they are unable to solve a specific problem amongst themselves.

Why FFS ?

In general, the FFS aims to empower farmers with knowledge and skills to– make them experts in their own fields; sharpen their ability to make critical and informed decisions that render farming profitable and sustainable; sensitise farmers in new ways of thinking and problem solving; and guide them to organize themselves and their communities. A field school, therefore, is a process and not a goal.

India officially adopted IPM as a measure of Plant Protection tool in 1985, and its different approaches have been considered since then. In 1991, erstwhile Central Biological Control Stations (CBCS), Plant Protection Stations (CSS) and Central Surveillance Stations (CSS) were merged to form Central IPM Centres (CIPMCs). To disseminate the IPM technology, several initiatives were taken through training and demonstration. Season Long Training Programme (SLTP) for a particular crop was launched to produce IPM master trainers. Besides 5-day and 2-day orientation training programme, Farmers Field Schools (FFS) are in operation targeting different crop pests and to popularise IPM technology to farmers.

FFS operates through group of farmers with a common interest, who meets on a regular basis to study the "how and why" (Ws?) of a particular topic. The topics covered can vary considerably; from time of plant protection approach to decision making for pest management in their own fields.

Apart from technical issues, group dynamic exercises and sessions addressing special topics relating to major pest and its ravages are integrated in the learning approach. Tools for adult education are used to internalize learning in a way that it can be expressed to others. A skilled facilitator can guide the FFS learning activities (Figures 69-71).

Figure 69. FFS activity

©CIPMC/Ranchi

FFS Objectives are

1. *Grow healthy crops,*
2. *Conserve natural enemies,*
3. *Conduct regular field survey, and*
4. *Make farmers competent in their own field.*

Figure 70. FFS activity

©CIPM/Vijayawada

Figure 71. FFS activity

©CIPM/Bengaluru

2.2 The Learning Process in FFS

The learning process in FFS is undertaken based on some key principles related to attitude of farmers, type of farmers engaged with the problem, type of pest management and its magnitude and source of information for learning.

Several key learning tools and exercises are available in the FFS as means of enhancing learning, and as an aid for the facilitators to ensure participation, dialogues etc. in the groups.

The way key features of the FFS approach are described and classified varies across sources though the main features remain the same. The features listed in Box 1 are mainly based on the observation of practice over time as well as the elaborated non-negotiable principles.

Box 1. Special features of FFS

1. What is relevant and meaningful is decided by the learner and must be discovered by the learner. Learning flourishes in a situation in which teaching is seen as a facilitating process that assists people to explore and discover the existing problem.
2. Learning is a consequence of experience. People become responsible when they assume responsibility and experience success in overcoming a problem.
3. Cooperative approaches are enabling. As people invest in collaborative group approaches, they develop a better sense of their own worth, which can deliver as a remedial measure for the gross problem.
4. Learning is an evolutionary process and is characterized by free and open communication, confrontation, acceptance, respect and the right to make mistakes.
5. Each person's experience of reality is unique. As they become more aware of how they learn and solve problems, they can refine and modify their own styles of learning and action.

2.3 General Learning Principles

The field is the learning ground

The field with standing crops or pest problems is the main learning ground (Figure 72), around which all FFS activities are organised. Farmers learn directly from what they observe and experience in their surrounding instead of through textbooks. Participants also develop their own learning materials based on what they observe. They identify objects from phenotypic characters of a pest, disease symptoms, type of damages, etc. with their own explanations.

Discovery based learning

To a large extent, technical information is brought out through discovery based exercises rather than in lecture style. These exercises are usually one hour long to fit into a regular FFS session and address the learning topic of the day in a practical manner. Discovery based learning is an essential part of the FFS (Figure 73). It helps participants to develop a feeling of ownership and to gain the confidence that they are able to reproduce the activities and results on their own. Problems are

Figure 72. The field is the learning ground

©CIPMC/Benguluru

presented as challenges and not as constraints. Groups learn different analytical methods to help them gain the ability to identify and solve problems.

The process of learning adheres to principles of adult education and learning by doing. FFS recognises that farmers do not change their behaviour and practices just because someone tells them. They learn better through experience than from passive listening to lectures or formal education or demonstrations. Therefore, in FFS, learning is by doing and testing new ideas and practices in the field.

FFS is discovery-based approach

If I hear	**-**	**I can forget**
If I see	**-**	**I can believe**
If I do	**-**	**I can learn**
If I discover	**–**	**I own it**

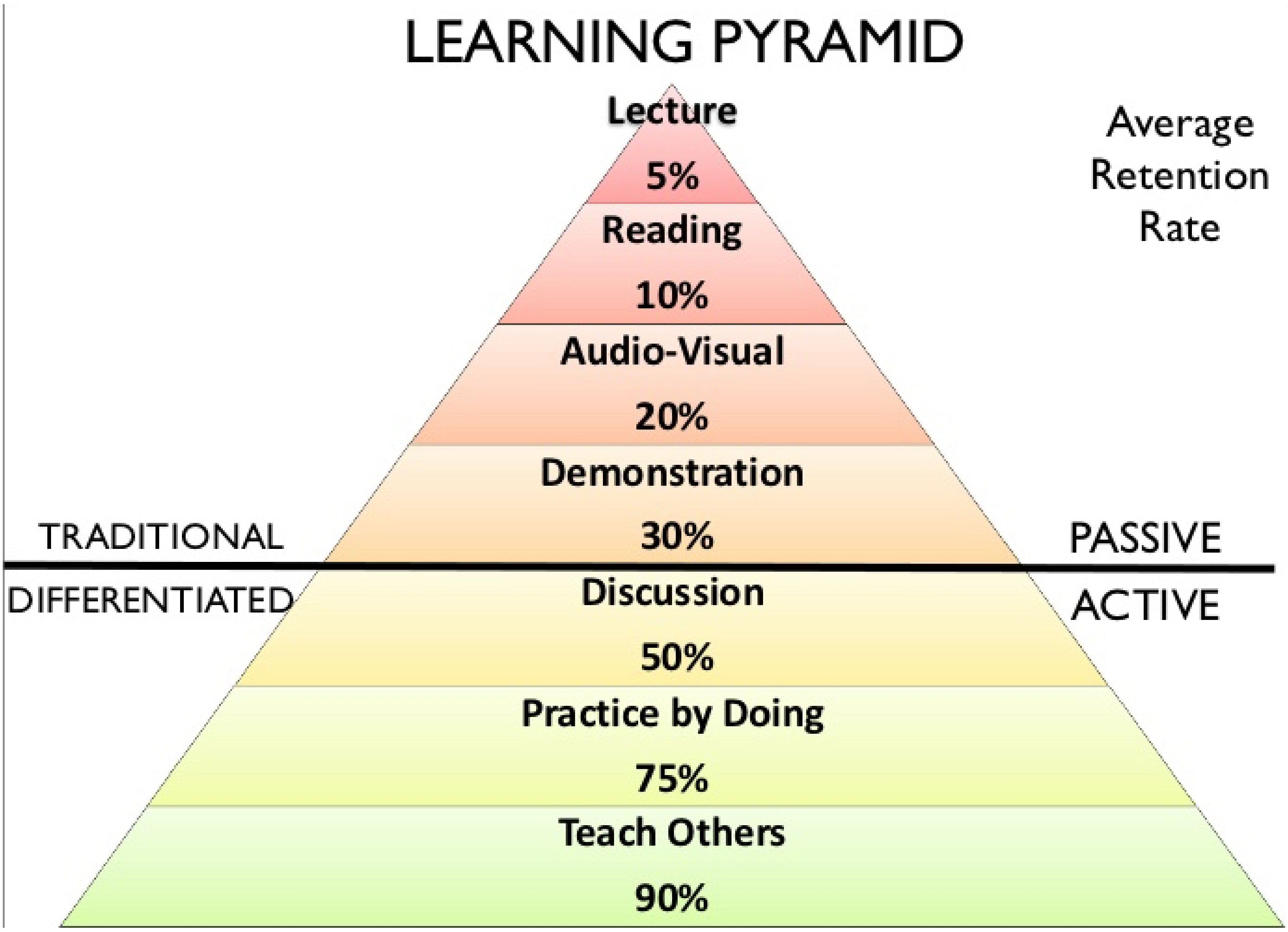

Figure 73. Learning pyramid

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2.4 Farmer "Owned" Curriculum

Farmers are the managers of the programme to decide what topics are relevant to them and what they want in the FFS to address in their learning curriculum. The facilitator only guides the learning process by creating opportunities to engage with new experiences through simple ways. This ensures that the information is relevant and tailored to participants' actual needs.

Training activities must be based on existing gaps in the community knowledge and skills. Every group is different, has its own needs and realities with pest problems. As participants develop their own content, each FFS is unique. Agriculture farming is usually closely connected to other livelihood aspects, hence the curriculum will also include collateral farming issues defined by farmers such as availability of seeds, factors of productivity, recurring pest problem, new pest like FAW, and environmental concerns. These are included as special topics in the weekly meeting schedule.

2.5 Facilitation, not Teaching

The role of a facilitator is crucial for successful learning and empowerment of farmers, because FFS does not focus on the teaching but guidance through the learning process. A facilitator is assigned to a FFS for the full duration and is present at the scheduled FFS meetings. Facilitators usually reside in the locality of the group and speak the local language but in some cases discussion in a language other than mother tongue of the farmers creates gap in the learning process and sometimes the purpose is defeated.

©Jeffrey Shoemaker/M.Ed.

During FFS sessions the facilitator remains in the background, listening attentively and reflectively, asking questions and encouraging participants to explore more in the field and present their ideas. Facilitator's presence is more as a mentor to guide the process. FFS facilitators are encouraged not to answer a technical question directly but try to probe and pose counter questions to stimulate reflection and learning (the Ws in FFS). In discussions on technical issues, the FFS facilitator should only moderate the discussion, where the bulk of information comes from the group members. To facilitate participation by all, small-group discussions are commonly conducted where the participants first discuss among themselves in groups of 3-4 persons before discussing the issue in plenary, which mostly takes place during the AESA presentation.

2.6 Group Trials and Experimentation

Innovation and experimentation are vital components of the FFS learning process. It offers opportunities for learning and building capacity among farmers to continuously adopt to change and improve the way they manage their resources. The experimentation in FFS is similar to the process of Participatory Technology Development (PTD) but has less emphasis on generation of formal research outcomes related to technologies rather it ensures more emphasis on the process of experimentation and analysis. Group manages trials of Participatory Action Research activities at the site, which usually becomes the meeting point and learning space for the group (Figure 74).

At the formation stage of an FFS, an experimental theme is defined followed by decisions on the various technologies or practices to study and compare for addressing a given constraint. These may be research generated technologies or simply farmers' innovations or local practices. Typical experiments in FFS may be tested for the crop management procedures or FAW biology or ecology and its management. In experimentation, a control treatment is usually included in the design, to provide a standard against which various alternative (new) options can be compared.

Figure 74. Group trials/activity by farmers

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2.7 Participatory Action Research (PAR)

Participatory action research involves practitioners as both subjects and co researchers. Its aim is to create an environment in which participants give and get valid information, make free and informed choices and generate internal commitment to the results of their enquiry.

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What is PAR?
PAR is the process of collective/collaborative enquiry with the purpose of initiating community action on solving problems.

Who can do PAR?
P stands for participation, which means the process of enquiry should be participated by all persons/ institutions that can make relevant contributions to develop solutions to local problems.

Where to do PAR?
PAR take place in a farmer's field in cooperation with the farmers' understating and participation to find out the solution of their problems.

When to do PAR?

PAR is being done during the weekly AESA, in insect zoo and in the field trials that are being set up during the training.

For whom to do PAR?

- PAR is by farmers
- PAR is for the farmers
- And of the farmers

So, PAR in the IPM is the people's voice.

Why to do PAR?
Farmers are dealing with many field problems, which cannot be solved by centrally developed advices or technologies. The diversity of local farm ecosystem is so enormous that farmers knowledge should be linked to that of outsiders (extension workers, researchers) to effectively address locally felt problems. PAR is done to

- explore the unknown facets of a system and their synchronization,
- know the problem, to analyse the problem and to solve the problem, and
- reach to concern with pragmatic and assured solution.

"Ws" of PAR
- What?
- Who?
- Why?
- Where?
- When?

The process of crop production and crop management are no more new concepts for farmers. But the idea of each slot of the activity has some reasons and those reasons sometimes catapult towards success and sometimes to failure. In the PAR the traditional practices are never neglected rather viewed with rationality. So IPM present and past are important to drive or to establish new theme, which is accepted as rational mode of pest management.

Participatory Action Research (PAR) through cyclic adoption brings about new technology i.e., Participatory Technology Development (PTD). PTD is strengthened by cumulative experiences of farmers in varied situation.

IPM past and towards future through PAR

- IPM was existing
- Change of dimension
- Authoritative dogma
- Vertical information system
- Horizontal information system

Activities in PTD

1. Getting started
2. Looking for things to try
3. Designing experiments
4. Trying things out
5. Sharing results
6. Keeping up the process

Transformation PAR to PTD

Innovative and qualitative research method of inquiry provides rich source of data collection leading to technology development, which is participatory in nature.

Strength of PAR in IPM approach

- PAR recognizes farmers' participation in the modus operandi to design package and practices of plant protection measures for solving their problems.
- It approves curriculam develeopment, execution and evaluation through cyclic process i.e. process enlightenment in all phases.
- Focuses on voice and every day experiences.

PAR as a learning process empowers in three ways

- It empowers because of the specific insights, new understandings and new possibilities that the participants discover in creating better explanations about their social world
- Participants learn how to learn a new process
- PAR liberates when participants learn how to create new possibilities for action.

2.8 Agro Ecosystem Analysis (AESA)

Agro-ecosystem analysis (AESA) is a tool to guide farmers to learn how to develop skills and knowledge about ecosystems and to make better informed decisions. Working in groups, farmers observe field situation and make note of their observations e.g., crop (biometrics), insects, diseases, weed, water, weather etc. quantifying the data is critical for analysis.

The purpose of AESA is to know the role of each and all factors in a population dynamics of the pest. Since ecological parameters are ever changing with the crop growth stages and prevalent abiotic factors so regular observation of a field is important. Regular field visit helps to analyze problems and opportunities encountered in the field and to improve decision-making skills independently regarding crop and pest management.

The analysis follows a cycle of observations, analysis of the factors available in the standing crop and interactions and by the required action. By carrying out AESA regularly in the FFS, farmers develop a checklist of indicators, which play important role at different times with same magnitude or at the same time with different magnitudes. The process is holistic and farmers work in sub-group and these groups work under a trained facilitator.

Usually this exercise takes about an hour and in most of the weeks to match learning cycle with the life cycle of a crop and pest so it never undermines the role of all ecological parameters. This learning cycle strengthens the capacity building of farmers to analyse pest risks. AESA is completely a field-based study, the designing of its activities to be undertaken in a particular week is relevant to the crop/pest dynamics and decision making.

The data to be collected and materials required during field observation are needed to be pre-scheduled. During the slot for Today's Activities the objectives of the AESA and materials and methods are to be discussed.

AESA encompasses major activities of FFS. Learning through field activity by participation is always considered as theme of the IPM-FFS curriculum. Joint participation of all farmers in the point of action (field) opens the avenues of learning. The ideas or inferences established in such type of informal education are no less renowned than research, and the discovery of new ideas of pest control through participation is popularly known as Participatory Action Research, which is predominantly workhorse of IPM-FFS programme of Dept of PPQ & S in different crops.

IPM past and towards future through PAR

1. Field observations
2. Drawing
3. Group discussion and Presentations
4. Decission making

AESA methodology

AESA includes the following methodology wherein participants in sub-group walk across the field, and record the following observations:

- Plant: observe the crop stage, plant height, number of cobs, and damage by pest/disease, deformity or deficiency symptoms, etc.
- Pests: observe and count pests at different places on the plant.
- Defenders (natural enemies): observe and count parasitoids and predators.
- Diseases: observe leaves and stems and identify any visible disease symptoms
- Rats: count numbers of plants affected by rats.
- Weeds: observe weeds in the field and the intensity.
- Water: observe the soil moisture of the field.
- Weather: observe the weather condition.
- While walking in the field, manually collect insects in plastic bags. Use a sweep net to collect additional insects. Collect plant parts with disease symptoms.
- The group talks about the crop situation. The facilitator will ask questions to initiate the discussion and to stimulate critical thinking.
- Each group will first identify the pests, defenders and diseases collected.
- Each group will analyze the field situation in detail and present their observations and analysis in a drawing (the AESA drawing).
- Each drawing will show a plant/hill representing the field situation, weather condition, soil moisture, disease symptoms, etc. Pest insects will be drawn on the left and defenders will be drawn on the right. Write the number next to each insect. Indicate the plant parts where the pests and defenders were found. Try to show the interaction between pests and defenders.
- Each group will discuss the situation and make a crop management recommendation.
- The small groups join each other and a member of each group will present their analysis in front of all participants. A different person will present each week.
- The facilitator will facilitate the discussion by asking guiding questions and makes sure that all participants (also shy or illiterate persons) are actively involved in this process.
- Formulate a common conclusion. The whole group should support the decision on what field management is required in the IPM plot.
- Make sure that the required activities (based on the decision) will be carried out.
- Keep the drawing for comparison in the following weeks.

The steps in AESA

STAGE 1: Field observations
In sub-group, farmers make observations in the field based on a range of monitoring indicators. Emphasis is on observing the interactions between various factors in the agro-ecosystem. The activity is participatory in nature (Figure 75).

STAGE 2: Record field observations
Each sub-group records and analyses its findings from the field, including making drawings of the field situation and elaborate decisions and recommendations. This extends from abiotic factors like sunshine, rainfall, RH percent , temperature, wind direction, edaphic factors etc. to biotic factors like crop growth stage, susceptibility of plant parts, pest and stages of life cycle, weeds etc. The activity is participatory in nature (Figure 76).

STAGE 3: Chart preparation and Drawings
Each sub-group depicts the findings in a broad sheet with the help of drawing by coloured pencil/ sketch pens, pasting of field collected materials, mounting of micro-specimens representing the actual eco-system etc (Figure 76). At the top the sun is drawn symbolically (cloudy, rising sun etc.) and wind, rainfall, soil moisture also drawn in the sheet. Defenders are drawn on the right side classifying predator, parasitoid, infected/dead specimens etc. On the left side depiction of pest complexes is made focussing life stages and potentiality. At the centre standing crop is drawn with associated biotic factors. At the last conclusion is made based on the AESA. The activity is performed in a participatory mode.

STAGE 4: Group presentations
Each sub-group (comprising members) present its results and conclusions. Feedback /supplementation and questions from the other groups implore the group at dais to defend their decisions with logical arguments. The activity is made through group dynamics.

STAGE 5: Decision making
Participants synthesize the presentations and agree on a collective action for implementation of the informed decisions arrived at. The activity is group dynamics in nature.

Figure 75. Field observations

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Figure 76. Chart preparation and Drawings

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Figure 77. Group presentations

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Special topics of the day

The focus of the special topics is decided by the FFS group and plays a central role in FFS. Special topics can cover a wide range of topics and can be multisectoral. It is a part of the FFS curriculum and learning experiments. This provides an opportunity for the facilitator, researcher or specialist to give technical inputs needed for a general understanding of the subject and to raise level of knowledge among the participants. The topic of the day is normally farming related but could be any subject of concern as the farmers desire for. If a facilitator lacks the specific expertise, external resource person can be invited.

2.9 Group Organization and Group Dynamic Exercises

A group is a social entity comprising two or more individuals who work together for common purpose. Group method is an effective extension method based on the principle that individuals who come together and work as a group can achieve more than their individual achievements combined (synergism). Further, working in a group fosters participation and democratization. It strengthens the capacities of communities to identify opportunities, set priorities and nurtures assets such as independent decision making in plant protection approach for the future. The group dynamics always go through process of filtration and at the end, if continue, it is sustainable and provides bondage on the issues for which it was formed. Group dynamics is supportive to the learning process and also sustainable to carry forward the message of IPM-FFS.

To ensure participation by all, an important component of FFS is the sub-grouping arrangements where smaller groups of 5-6 individuals are formed at the beginning of the FFS cycle. Each sub-group has its responsibilities, usually in rotation, such as welcoming the gatherings, materials management for AESA, programme management, Ice breakers etc. Thus the term host team is meant to the sub-group that manage in the week. By choosing name of natural enemies like spider, dragonfly, *chrysoperla*, *Trichoderma* etc. to each sub-group, makes it easier to identify group of people and above all familiarizes the name to remember for a long period of time about potentiality of farmers' friendly role in agricultural ecosystem.

In FFS group dynamic exercises different expressions and in different orientation the perception is depicted to create a pleasant and informal learning environment. These exercises facilitate learning and create space to reflect and share. They also enhance capacity building in communication skills, problem solving and leadership skills. Further, group dynamics (Figure 78) can be an effective way to deal within the process of group maturation (Forming >Storming >Norming > Performing > Adjourning). Each learning session is usually facilitated by that day's host team.

Figure 78. Farmers playing group dynamic

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2.10 Farmers as Experts

The FFS approach recognizes community members as the experts within their particular contexts and considers indigenous and local knowledge an important source of information to be used within the FFS learning process. Through the process, FFS members learn how to improve their own abilities to observe and analyse problems, and to develop practical and relevant solutions. The approach inspires members to learn continuously by exploring and educating themselves on issues and topics that affect their livelihoods (Figure 79).

Figure 79. Farmers as experts in their field

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Experiential learning: The basic assumption is that learning is always rooted in prior experience, which is unique to each person and that any attempt to promote new learning must in some way take account of experience. Therefore, sharing and discussion of own idea into common idea among FFS members is a core element of FFS (Figure 80).

Figure 80. Sharing and discussion are the core elements of FFS

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- The farmer's field provides the main learning materials and any exercise should have its roots in the farmer's field.
- Activities are based on what is happening in farmers' field at this time. One can not discover something if it happened in the past or will happen in the future but it must remind the activities performed through simulation-design of curriculum.
- Any activity is undertaken enhances farmers' experiences of the topic, i.e. include discussion and sharing among participants to gain insights from local practices, as well as identify technical gaps.
- The people who are discovering are primarily farmers. The purpose is to help participants to remember more of what they are learning. Therefore, exercises are designed for practical discovery rather than only by seeing or hearing like formal lecture something to convince an idea of gross value.

2.11 Systematic Learning Process

All FFSs follow the same systematic learning process where the cornerstone is to observe and analyse their field experimental activities. Farmers meet weekly on regular schedules defined by the group members. Farming-related topics are interwoven with group organisational aspects and group dynamics to form the learning sessions that usually are held on weekly basis and of half a day duration.

The activities such as taking care of the field plots towards experimentation like fixed plot survey, collection of larvae of pest or other fauna or weed flora, defoliation or detillering activities, weeding, and feeding are set up to convince farmers in the learning by doing mode. In-between FFS group formation and starting the regular learning cycles there is a period of group establishment usually referred to as ground working. This period entails forming and organising the group, problem identification, selection of learning enterprise and setting up the farm experiments, a process that usually takes about a month. So conduct of survey of that is very much important to select the FFS village for effective and successful implementation of the IPM-FFS programme. Besides, it is shaped to informal learning process so it can cater out the knowledge of IPM and participatory technology development to the farming community surrounding the target village. As a matter of fact, this type of programme is undertaken for horizontal dissemination of information.

The bench –mark survey format needs to be followed to analyse different parameters of FFS village.

Format of baseline survey on farm production of management in the village

1. Name of the farmer and his father:
2. Farm area (ha):
3. Type of soil:
4. Irrigation source:
5. Village:
6. Block:
7. District:
8. Crop/variety and season:
9. Major pests:
10. Minor pests:
11. Diseases:

12. Known natural enemies:
13. Control practices followed for pests (Give the name of pests):
14. Control practices followed for diseases (Give the name of diseases):
15. Pesticides used: Total quantity used/ha: Total volume of water

    Chemical used:

    Type of pesticide used: No. of tank loads used/ha No. of sprays done
16. Biopesticides used:

    Name: Qty/ha No. of times used
17. Do you use cocktail type of pesticides? If so name them:
18. Fertilizers/manures used: No. of cartloads or bags/ha

    FYM/Compost:

    Chemical fertilizer:

    Others
19. Common weeds noticed: Type of weeding: No. of weedings done
20. Common weeds noticed: Type of weeding: No. of weeding done
21. Water management Crop stage of irrigation: No. of irrigations/rainy

    Rainfed:

    Irrigated:

    Drainage facility:
22. Total No. of labourers used: Land preparation:……….

    Sowing/transplanting/gap filling:………………..

    Manures/fertilizer application…………… Irrigation:………..

    Weeding:…………. Watching:……………. Harvesting:…………….

    Threshing /bugging/transplanting:…………….
23. Total quantity of seeds used/ha
24. Loss due to natural calamity/ drought/flood/epidemic:
25. Interest paid on loan:
26. Average yield in last season
27. Ownership of land

Economic analysis of farm production

1. Gross yield :
2. Net yield:
3. Gross income:

   Fixed cost of production/ha:
   a) Cost of seeds:
   b) Cost of land preparation:
   c) Irrigation:
   Total:

4. Net profit after removing fixed costs:
   Non fixed costs of production/ha:
   a) Cost of manures:
   b) Cost of fertilizers:
   c) Const of pesticides:
   d) Cost of labour (includes all):
   Total:

5. Net profit:
6. Cost benefit ratio: Gross expenditure: Gross income:

2.12 Cyclic Information System

In the FFS learning the knowledge acquired is sustainable and implemented with revision for a longer period. It enhances the capability with the time and always transforms into a new dimension through modification. Modification is the outcome of evaluation and satisfactory result is the outcome of sustainability (Figure 81).

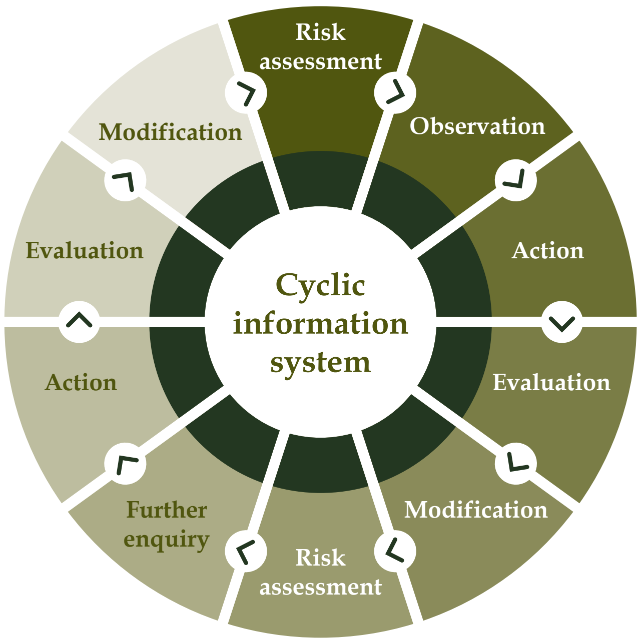

Figure 81. Cyclic information system

Competence not information is the goal: In FFS the focus is on developing skills and competence rather than assimilating information regarding new technology options. The focus is on understanding the basic science behind various aspects of the agro-ecosystem to enable farmers to carry out their own innovation process, i.e. understand the "why" behind the "how" or the "how" behind which …when … what etc. Technologies are not taught as blueprint solutions but as examples of how to support various agro-ecological processes linked with various problems.

2.13 Curriculum of a Typical FFS Learning Session

Time	Activity	Description	Assigned to
8.00 AM	Opening	Welcome address	Facilitator
8.10 AM	Briefing and group farming	Activities of today and recalling of previous activities	Group leader (Farmer)
8.20 AM	Field activity	AESA (Agro ecosystem Analysis)/field trial observations/special topics and data collection	All farmers (Participatory)
9.20 AM	Energizer	Ice-breaking	Farmer/Facilitator
9.30 AM	Drawing/ labelling/ AESA processing Rearing/ mounting etc.	Self-preparation for presentation	Farmers (Participatory)
10.00 AM	Group dynamics	AESA presentations and discussion	Farmers-active facilitator-moderator
10.50 AM	Energizer	Ice-breaking	Farmer/Facilitator
11.00 AM	Special topic	Ice-breaking	Farmer/Facilitator
11.30 AM	PTD	Technology for adoption	Farmers-deciphering
11.45 AM	Planning of next crop/pest/ simulation	Farmers threat week's activities to the concept perception	
12.00 PM	Closing	Vote of Thanks	Based on FFS reciprocation

Welcome Address

In the beginning of the session, it is required on the part of facilitator to welcome the participants for their involvement in the programme. It is seen that when the programme is two or three weeks old, farmers take the command and arrange to run the programme efficiently. Through this introductory slot the farmers are acquainted with the facilitators, and facilitators get an opportunity to know personally each participant about their experience, skill, eagerness to adopt new technology and different facets of farm practices are in vogue in that area.

Activities of today and recap of previous activities

In this slot brief sketch of activities that are to be undertaken on that day need to be focussed. This is actually a routine / engagement schedule of that day. The activities are concerned to AESA, so the extra articles required in the field are to be told besides the designing of AESA and data from those activities are also to be informed to the farmers. Further for authentic inference, more number of replications is important so each group activity may be considered as one replication; so activities to be briefed to the 6 to 8 sub-group. Besides this, activities undertaken in the previous week are to be recapitalized to link the process or system with today's activities.

FFS is a powerful tool for information dissemination and pest management. On this background it is intended to adopt management of pests in Maize through FFS, but with a focus on arresting the spread and containing the FAW. The detailed information on FAW is discussed elsewhere in this document. This section narrates the model curriculum for IPM-FFS in Maize.

Chapter 3

Steps and implementation of Maize IPM-FFS with special emphasis on FAW

3.1 Preliminary Steps in Conducting IPM-FFS in Maize

Survey

Surveys are to be done to select appropriate villages or areas to initiate Integrated Pest Management-Farmer Field Schools (IPM-FFS). Selection of a location/village is extremely important to ensure that the programme content is applicable to the farmer's problem and area where Maize production is being hampered by FAW. Selection of the target village may be supported by data of the benchmark survey.

Selection of a village

The village must be selected based on fulfilment of following conditions/factors

- The Maize is the major crop in that area
- Farmers depend more or less on Maize crop for their livelihood
- Pest responsive cultivation practices
- Regular occurrence of pest and disease and endemic areas
- Previous history/record of incidence of FAW and other major pests
- Awareness level among farmers about FAW and its damage potentiality
- Interest of farmers
- Other factors like social, economical and cultural conditions of that location

Coordination with stakeholders

Farmers are the major stakeholders of IPM-FFS programme. Hence, to identify the specific village and target groups are very much important. It is also important to involve locally available extension functionaries of the State Government at District, Block and Panchayat level.

The Central IPM Centres are being the nodal agency of the Directorate of Plant Protection Quarantine and Storage liaison with the Plant Protection wing of State Agriculture Department is very much essential to reach the target area where IPM-FFS programme can be implemented. The programme can be considered as successful if adoption of technology imparted during the training programme gets its access and practiced regularly by farmers in successive years. So, it is pertinent to remain in contact with the villages where IPM-FFSs were conducted in the past years. These villages may be considered as IPM model villages.

Steps for coordination with stake holders

A. Block level coordination

Steps

1. Block level Agriculture Officer or Agricultural Extension Officers may be contacted and explained the aim of the Maize IPM-FFS programme and requested to arrange preparatory meeting with Maize farmers for better understanding of the problem.
2. Discussion can be made on the following issues:
    - *Strategic locations for Maize IPM-FFS*
    - *Criteria for participants*
    - *Activities to be carried out*
    - *Supplements to be provided by the organisers.*
3. Assurance may be ensured to deal with season long field-based activities.

B. Village level coordination

Steps

1. Explanation is to be given about Maize IPM-FFS activities.
2. Invitations to be made to the lead farmers, village head/panchayat members/ state government functionaries

3. Discussion to be made on the following issues:
   - Strategic locations for Maize IPM-FFS
   - Criteria for participants
   - Activities to be carried out and other formalities
   - Benefits of the programme
   - Participation mode is to be free to all.
4. Request to be conveyed to the government officials to support IPM-FFS activities in that village.
5. Based on the benchmark survey, data to be prepared about agricultural map of the village indicating target crop and pests, other plant protection features and farmers list.
6. In addition, prominent community personality, enthusiastic farmers or scientific organisations and other individuals who may be able to support for supplementing Maize IPM-FFS to be involved. If possible other farmers may be invited to take part in this meeting.
7. Location of IPM-FFS field, training venue and training schedule should not be interfered with other programmes as it may cause conflict of interest.

Considerations in farmers' meeting

1. To gain an understanding of conditions, constraints, needs and opportunities in the local area, involvement of participants in PAR exercises to access ravages caused by FAW in Maize is very much pragmatic. Having completed the above, explanations are to be provided to participants regarding IPM methodologies, role of stakeholders, the learning process through FFS and the benefits of Maize IPM-FFS. An expert on Maize or person having in-depth knowledge about the topics may be invited to talk about his experiences about field schools and how farmers can be benefitted from it.
2. Next step is curriculum development based on the available agro climatic conditions, and community choice may be given advantages in it.
3. The activities pertaining to meeting–participants, time, place etc. are crucial issues and to be decided by the lead farmers during the initial couple of weeks.
4. Lead farmers are actually the programme manager at the FFS level.
5. At the end of each meeting, reiterate the topics discussed and make sure availability of farmers and the facilitator.

Meeting with farmers

After the coordination meetings at village level, hold a meeting (Figure 82) with the concerned farmers to select IPM-FFS farmers. After selection of farmers, hold subsequent meeting for registration of selected IPM-FFS farmers and enlist individual data like address, land holding, crops grown and some other identifying features.

Apart from this, identification of potential participants is useful for cross checking the data collected from the field about the farmers' problems due to the infestation of FAW. However, the most important objective of these meetings is that farmers understand what the program is about.

Figure 82. Farmers' meeting

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3.2 Maize IPM-FFS Implementation

Developing a curriculum for Maize IPM-FFS

Like any other learning process, a curriculum is an essential guide for IPM-FFS participants. Curriculum shows them what they will study throughout the season and to a facilitator, it enables him or her to make the necessary preparations before facilitating Maize IPM-FFS meetings.

The following factors need to be considered while preparation of a curriculum:

- *Critical factors affecting farmers' crops*
- *Agreeable duration of meeting time*
- *Opportunities to gain relevant knowledge and skills*
- *Field based learning*

Objectives of the curriculum

1. Farmers should be the decision makers in plant protection technologies
2. Farmers should know the agro-ecosystem of his own field and rely on other technologies available for plant protection measures instead of opting pesticide as a sole option to mitigate pest problem
3. Farmer must think for a cost-effective technology so he can reduce input cost and increase his income from farm practices.
4. There are advanced methods of plant protection techniques like use of entomopathogens, behavioural management, augmentation and conservation of biological control agents etc. So farmers must have idea, access and practice of new generation technologies.

Designing of the programme should be such that every visit to the field should bring some message and enthusiasm by which farmers never think to isolate themselves. Following are important features to be considered during the designing of a programme.

1. Crop
2. Pest
3. Agro-ecosystem
4. Farmers' profile
5. Training objective
6. FAMEWS

Table 6. A typical time-table for conducting effective FFS

Time	Activity	Description	Assigned To
8.00 AM	Prayer/FFS Pledge	Welcome address	Facilitator
8.10 AM	Briefing and group forming	Activities of today and recalling of previous activities	Group leader (Farmer)
8.20 AM	Field activity	AESA (Agro ecosystem Analysis)/Field trial observations/Special topics and data collection	All farmers (Participatory)
9.20 AM	Energizer	Ice-breaking	Farmer/Facilitator
9.30 AM	Drawing/ labelling/ AESA processing, Rearing/ mounting/ tabulation of data etc.	Group activities of field based study	Farmers (Participatory)
10.00 AM	Group dynamics	AESA/special activities presentations and discussion	Farmers-Active facilitator-Moderator
10.50 AM	Energizer	Ice-breaking	Farmer/Facilitator
11.00 AM	Special topic	Problems of the field/standing crop/new issues	Farmers– Observation-Perception-Discussion

11.30 AM	Participatory technology development (PTD)	Technology for adoption	Farmers-Deciphering
11.45 AM	Planning of next week programme	Farmers threat week's activities to the concept perception	Farmers, Facilitators compromise
12.00 PM	Closing	Vote of Thanks	Based on FFS reciprocation

3.3 Week Wise Activities (1-14 weeks)

1st week

A. Curriculum of the week:

Crop stage: Pre-sowing

Activities	Assigned to
1. Opening-Welcome address	Facilitator
2. Registration of FFS farmers	Facilitator
3. Ballot box test (Pre-evaluation)	Facilitator
4. Formation of sub-group through group dynamics	Facilitator
5. Land prepration-cleaning, levelling, bunding and application of basal dose of fertilizers	
6. Selection of seed /seed rate/ seed treatment/intercrop	Facilitator/Participatory farmers
7. Discussion on Effect of seed treatment/Seed germination test/ Different cultivation practices PAR: Effect of seed treatment on management of FAW and other insect pests and diseases	Energizer
8. Identification of FFS field	Facilitator/ Participatory
9. Field preparation and synchronous sowing/cultivation	Farmers
10. Closing	Facilitator/ Participatory farmers

B. Objectives of the week

- ***Registration of 30 farmers:*** Proper selection of the farmers assures good participation throughout the season. The composition of farmers consists of real growers who take decision on plant protection strategies. Some lead farmers to be identified who can voluntarily participate and lead the sub-group during various FFS activities.

- ***Ballot box exercise:*** A pre Ballot Box Exercise (BBE) should be conducted to assess farmer's knowledge about crop production, protection, and IPM related questionnaire are prepared. So, orientation of the curriculum development can be made accordingly. Further it also helps to assess the effectiveness of the training while post evaluation (Post BBE) test is made.

- ***Sub-group formation:*** Sub-group formation should be made comprising farmers of different age groups, qualification, land holding, pattern of crop management etc. Ensure gender balance in the sub-group formation should be made by accommodating experienced and active farmers in all groups. Every sub-group will have one lead farmer (Figure 83).

- ***Seed selection:*** It is essential to select the seeds as per the agro-climatic zone for better productivity, tolerant/resistant to specific pests and diseases of that area as recommended by the State Department of Agriculture.

- ***Seed rate:*** Seed rate should be optimum as per the recommendation, so that there should not be overlapping of canopy to avoid pest to harbour and multiply. There should be enough space to take plant protection measures in case of pest and disease attack. Sufficient light and air should reach the lower parts of a plant and soil.
- ***Seed treatment:*** Bio pesticides/chemical pesticides are to be used for prevention of seed/soil-borne diseases and soil pests. It helps in seed germination by preventing soil-borne pathogens.
- ***Synchronous cultivation:*** It is followed to prevent availability of susceptible growth stage and overlapping generation of pests
- ***Field preparation and sowing:*** Deep ploughing during field preparation will destroy the resting stages of pests.

Figure 83. Sub-group has experienced and active farmers

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C. IPM model Questionnaire as a tool for group dynamics

1. Whether any damage caused in the last season?
2. In which crop?
3. Where it caused damage?
4. How it caused damage?
5. When it was noticed?
6. What was the incidence?
7. Whether that causal organism is known to you earlier to this area?
8. What you did?
9. How that affected yield of Maize?
10. What was the yield of Maize previous season?
11. What are the management practices followed last year?
12. How different seed varieties responded to that pest?
13. Whether the field was deeply ploughed?
14. Whether seeds were treated?
15. Whether any other crop grown along with Maize in the same field?

D. Benefits from the activities:

Farmers (Figure 84) able to know-

- Selection of the seeds in view of tolerant/resistant
- Yield potentiality of the seed, duration of the crop
- Seed rate, spacing
- Seed treatment– seed-borne diseases
- Sowing activities
- Deep ploughing, clean cultivation
- Decision making

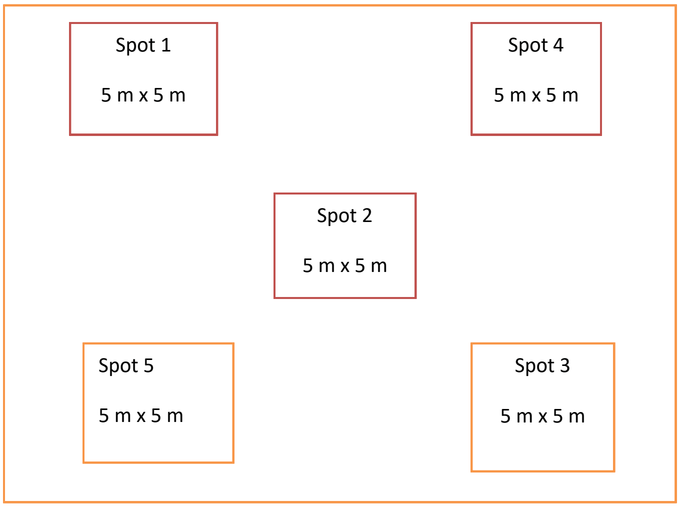

Figure 84. Sub-group has experienced and active farmers

2nd week

Crop stage: Germination Seedling (7 DAS)

A. Curriculum of the week

Activity	Description	Assigned to
Opening	Welcome address, recapitulation of previous activities and briefing about today's activities	Group leader (Farmer)
Agro Ecological System Analysis (AESA)	1. Field visit 2. Observation for germination and data collection-based on format 3. Scouting and observation for initial foliage feeders/seedling diseases and associated natural enemies 4. AESA field activities	Facilitator
Energizer	Ice-breaking	Farmer/Facilitator
AESA process	Drawing/labelling/ AESA processing Rearing/ mounting/tabulation of data etc	All farmers (Participatory)
AESA discussion	Germination, initial seedling diseases/ pests, associated NEs and relevant AESA inputs	Through group dynamics
Energizer	Ice-breaking	Farmer/Facilitator
Special Topic	Establishment of insect zoo	Farmers
PTD	Observation of seed treatment	Farmers
Planning of next week programme	---	Farmers/Facilitator
Closing	Vote of Thanks	Based on FFS reciprocation

B. Questionnaire for the week

1. Have all the seeds germinated?
2. Reason for ungermination?
3. Any seedling death observed?
4. Have you found any damage to the leaves?
5. What is the nature of damage?
6. Have you observed any animal/organism on leaves/at the base of the plant?
7. Whether one organism eating others?
8. Whether that organism is crawling or flying?
9. How many seedlings per square meter?
10. Any plant observed other than Maize plant?
11. What was the other plant stage and population?
12. Whether any other organisms feeding on the unwanted plants?
13. ………………….so on

C. Benefits of the week

Farmers able to know-

- Role of seed treatment
- Seed-borne diseases
- Role of seed rate and number of plants in unit area
- Appearance of organisms
- Concept of weed occurrence

Data sheet for observations					
Area of 5 m × 5 m	Description	Assigned to	Activity	Description	Assigned to
Spot 1					
Spot 2					
Spot 3					
Spot 4					
Spot 5					

3rd week

Crop stage: Early vegetative stage (14 DAS)

A. Curriculum of the week

Activity	Description	Assigned to
Opening	Welcome, recapitulation of previous activities and briefing about today's activities	Group leader (Farmer)
AESA	1. Field visit 2. Study of the plant 3. Scouting and observation of FAW and associated natural enemies (PAR) 4. Observation and recording of weed population 5. AESA field activities	All farmers (Participatory)
Energizer	Ice-breaking	Farmer/Facilitator
AESA process	Drawing/labelling/ AESA processing Rearing/ mounting/tabulation of data etc	All farmers (Participatory)
AESA discussion	Diseases/pests, associated NEs and relevant AESA inputs	Through group dynamics
Energizer	Ice-breaking	Farmer/Facilitator
Special topic	Insect zoo experiment continuation	Farmers
PTD	Scouting method of FAW Migration of pest and defenders based on AESA	Farmers
Planning of next week programme	---	Farmers/Facilitator
Closing	Vote of Thanks	Based on FFS reciprocation

B. Questionnaire for the week

About plant botany

1. What is the plant height?
2. How many number of leaves present per plant?
3. Is there any whorl formation in the plant?
4. What is the colour of the leaves?

About the pest

5. If any scraping/damage/spots on leaf?
6. How many such leaves affected per plant?
7. Whether any organism found during study?
8. Where they were found?
9. What they feed on?
10. Any small cluster of eggs found on the leaf?
11. …… so on

C. Benefits of the week

Farmers able to know-

- About the plant characteristics
- Susceptible plant parts
- Biology of FAW
- Migration of pest and defenders
- Concept of insect zoo

4th week

A. Curriculum of the week

Crop stage: Early vegetative stage (21 DAS)

Activity	Description	Assigned to
Opening	Welcome address, recapitulation of previous activities and briefing about today's activities	Group leader (Farmer)
AESA	1. Field visit 2. Scouting and recording of foliage feeders/ diseases and associated NEs on main crop as well as intercrops 3. Observation and recording of weeds population 4. AESA field activities 5. Habitat study of spider in different agro-ecosystem (PAR)	All farmers (Participatory)
Energizer	Ice-breaking	Farmer/Facilitator
AESA process	Drawing/labelling/ AESA processing Rearing/ mounting/tabulation of data etc.	All farmers (Participatory)
AESA discussion	Diseases/pests, associated NEs and relevant AESA inputs	Through group dynamics
Energizer	Ice-breaking	Farmer/Facilitator
Special topic	Food and habitat of natural enemies	Farmers
PTD	Spiders are polyphagous and migratory based on PAR	Farmers
Planning of next week programme	---	Farmers/Facilitator
Closing	Vote of Thanks	Based on FFS reciprocation

B. Questionnaire for the week

Plant pest association

1. What is the height of the plant?
2. Any new leaf development started?
3. How the whorls look like?
4. If any damage found in the whorl?
5. What kind of damage noticed?
6. What type of organism found in the whorl?

Spider identification and migration

7. Have you noticed any spiders (wingless creatures)?
8. How do they look like?
9. Do they have wings?
10. How many numbers of legs do they have?
11. How the eyes look like?
12. Is there any same creature in different ecosystems?
13. What they feed on?
14. Have you found any food with creatures?
15. If such spiders are found in the Maize field?
16. ………. So on

C. Benefits of the week

Farmers able to know-

- Plant pest association
- Pest feeding preferences on plant
- Migration of pest and defenders
- Migratory habitat of spiders and feeding dimension

5th week

A. Curriculum of the week

Crop stage: Early to mid vegetative stage (28 DAS)

Activity	Description	Assigned to
Opening	Welcome, recapitulation of previous activities and briefing about today's activities	Group leader (Farmer)
AESA	Field visit 1. Scouting and recording of foliage feeders/ diseases and associated NEs on main crop as well as intercrops 2. Observation and recording of weed population 3. AESA field activities 4. Installation of Pheromone trap for monitoring of FAW moths (PAR)	All farmers (Participatory)
Energizer	Ice-breaking	Farmer/Facilitator
AESA process	Drawing/labelling/ AESA processing Rearing/ mounting/tabulation of data etc	All farmers (Participatory)
AESA discussion	Diseases/pests, associated NEs and relevant AESA inputs	Through group dynamics
Energizer	Ice-breaking	Farmer/Facilitator
Special topic	FAW life stages, identification and damaging symptoms	Facilitator
PTD	Role of Pheromone traps in monitoring and management of FAW	Farmers
Planning of next week programme	---	Farmers/Facilitator
Closing	Vote of Thanks	Based on FFS reciprocation

B. Questionnaire for the week

1. How many leaves are present?
2. How the leaves look?
3. Is any organism found in the whorl?
4. Are any damaging symptoms or any other materials found in and around the whorl?
5. Any clusters of eggs found on leaf?

6. How do they look like?
7. How many eggs are there in clusters?
8. Have you noticed any round, coloured small insect?
9. Where they were found?
10. What they feed on ?
11. Whether they move from plant to plant?
12. ……… so on.

C. Benefits of the week

Farmers able to know-

- About Maize botany
- Life stages of FAW and identification larvae and eggs
- Insect composition in Maize agro-ecosystem
- Habitat study of some insects

6th week

A. Curriculum of the week

Crop stage: Mid vegetative stage (35 DAS)

Activity	Description	Assigned to
Opening	Welcome address, recapitulation of previous activities and briefing about today's activities	Group leader (Farmer)
AESA	Field visit 1. Scouting and recording of foliage feeders/ diseases and associated NEs in Maize as well as intercrops 2. Observation and recording of weed population 3. AESA field activities 4. Collection of FAW larvae and eggs 5. Plant compensation experiment (PAR)	All farmers (Participatory)
Energizer	Ice-breaking	Farmer/Facilitator
AESA process	Drawing/labelling/ AESA processing Rearing/ mounting/tabulation of data etc.	All farmers (Participatory)
AESA discussion	Diseases/pests, associated NEs and relevant AESA inputs	Through group dynamics
Energizer	Ice-breaking	Farmer/Facilitator
Special topic	Natural enemies of FAW and recycling of entomopathogens	Farmers
PTD	Discussion about habitat of FAW larvae, egg laying, pupation and trapping of moth in spider web Discussion on Pheromone traps based on PAR	Farmers
Planning of next week programme	---	Farmers/Facilitator
Closing	Vote of Thanks	Based on FFS reciprocation

B. Questionnaire for the week

Habitat of the larvae

1. How many larvae observed on a single plant?
2. On which plant part they were found?
3. How big are they?
4. Which portion of the plant they feed?

Entomopathogens

5. Any natural death of larvae?
6. Which colour they are?
7. Are the dead larvae soft?
8. How they were laying?
9. Whether some larvae are in sluggish movement?
10. How many larvae you found with such type of deaths?
11. Whether larvae or egg mass found with any wasps?
12. Any larvae/insects emerged from dead FAW larvae?
13. Any small cocoon formation on dead FAW larvae?
14. Have you found any moths in the traps?
15. How many moths are trapped?
16. Why moths are attracted to the trap?
17. What is the sex of moths?
18. How it can be used in IPM approaches?
19. ……… so on

C. Benefits of the week

Farmers able to know-

- Natural enemies in Maize agro-ecosystem
- Habitat of FAW larvae
- Egg laying of FAW on plant parts
- Mechanisms of Pheromone traps and attractant
- Entomopathogens
- Any outcome from group dynamics

7th week

A. Curriculum of the week

Crop stage: Late vegetative stage (42 DAS)

Activity	Description	Assigned to
Opening	Welcome address, recapitulation of previous activities and briefing about today's activities	Group leader (Farmer)
AESA	Field visit 1. Scouting and recording of foliage feeders/ diseases and associated NEs on Maize as well as intercrops 2. Study and observation of central shoot of plant and whorl 3. Observation for borer population apart from FAW 4. Observation for moths trapped in Pheromone trap 5. Recycling of entomopathogens (PAR)	All farmers (Participatory)

Activity	Description	Assigned to
Energizer	Ice-breaking	Farmer/Facilitator
AESA process	Drawing/labelling/ AESA processing Rearing/ mounting/tabulation of data etc.	All farmers (Participatory)
AESA discussion	Diseases/pests, associated NEs and relevant AESA inputs	Through group dynamics
Energizer	Ice-breaking	Farmer/Facilitator
Special topic	Prey predatory relations in field conditions with respect to Insect zoo	Farmers
PTD	Observation of eggs and larvae collected previous week to know field parasitisation/ infection based on data	Farmers
Planning of next week programme	---	Farmers/Facilitator
Closing	Vote of Thanks	Based on FFS reciprocation

B. Questionnaire for the week:

1. Whether any hole found in the central shoot? Shoot and stem borer
2. Whether the holes are located in the central shoot?
3. How many holes found in the internodes as well total shoot?
4. How the holes look like?
5. Whether any material found near the holes?
6. Is there any discoloration /dying of apical part?
7. Whether any whorl formation has started? About FAW
8. How many whorls are present?
9. Is there any protuberance or special plant growth in the whorl?
10. Is this structure fed by any organisms?
11. What are those organisms?
12. How they look like?
13. Whether any damage in the whorl?
14. How is the damage look like?
15. If any faecal matter is present in the infested part?
16. Is FAW life stages are safe in field condition?
17. Whether any emergence from the eggs of FAW collected last week?
18. What is the incidence of parasitisation of eggs and larvae?
19. ………….. so on

C. Benefits of the week

Farmers able to know-

- Prey predatory relations
- Recycling of FAW and store for future use
- other pests of Maize stem and shoot borer
- Habitat of FAW
- Parasitisation of egg and larvae

8th week

Crop stage: Reproductive stage (49 DAS)

A. Curriculum of the week

Activity	Description	Assigned to
Opening	Welcome address, recapitulation of previous activities and briefing about today's activities	Group leader (Farmer)
AESA	Field visit 1. Scouting and recording of foliage feeders/ diseases and associated NEs 2. Search for FAW larvae at apical bud containing tassel and axillary bud contain silk 3. AESA field activities	All farmers (Participatory)
Energizer	Ice-breaking	Farmer/Facilitator
AESA process	Drawing/labelling/ AESA processing Rearing/ mounting/tabulation of data etc	All farmers (Participatory)
AESA discussion	Diseases/pests, associated NEs and relevant AESA inputs	Through group dynamics
Energizer	Ice-breaking	Farmer/Facilitator
Special topic	Pest and diseases of Maize and their management	Farmers
PTD	Feeding preference and habitat of FAW and habitat management	Farmers
Planning of next week programme	---	Farmers/Facilitator
Closing	Vote of Thanks	Based on FFS reciprocation

B. Questionnaire for the week

Habitat of the larvae

1. Have you found any FAW larvae in apical part of the plant?
2. Is there any damage to apical part?
3. What are the feeding materials?
4. Whether any economical loss may happen due to this infestation?
5. Whether cob formation has started?
6. What are the structures?
7. Whether any loose plant parts found within the cob?
8. Whether any damage symptoms found?
9. What are causal organisms for the damage?
10. …………….so on

C. Benefits of the week

Farmers able to know-

- Feeding preference and habitat management of FAW
- Pest susceptibility to plant parts
- Diseases of Maize and management

9th week

Crop stage: Reproductive stage (56 DAS)

A. Curriculum of the week

Activity	Description	Assigned to
Opening	Welcome address, recapitulation of previous activities and briefing about today's activities	Group leader (Farmer)
AESA	Field visit 1. Scouting and recording of FAW on different parts of the Maize plant 2. Scouting and recording of foliage feeders/ diseases and associated NEs 3. Observations of experiment on plant compensation mechanism (7th week PAR) 4. Observation on intercrop with Maize 5. AESA field activities	All farmers (Participatory)
Energizer	Ice-breaking	Farmer/Facilitator
AESA process	Drawing/labelling/ AESA processing Rearing/ mounting/tabulation of data etc.	All farmers (Participatory)
AESA discussion	Diseases/pests, associated NEs and relevant AESA inputs	Through group dynamics
Energizer	Ice-breaking	Farmer/Facilitator
PAR based programme	Plant compensation ability of the plants based on PAR	Farmers
PTD	Mass production and recycling of Entomopathogens as farmers practice based on PAR Intercrop as diversity of agro-ecosystem and livelihood (Farmers' practice)	Farmers
Planning of next week programme	---	Farmers/Facilitator
Closing	Vote of Thanks	Based on FFS reciprocation

B. Questionnaire for the week

Entomopathogens

1. How the infected larvae look like?
2. Of what colour entomopathogens are?
3. Whether entomopathogens established in field conditions?
4. Whether entomopathogens can store for future use?
5. Whether entomopathogens useful in FAW management?
6. How they act as management tool in IPM approach?
7. Is the number of insects per plant increasing?
8. Have you noticed any new growth from the damaged plants?

9. Why these structures have come?
10. What is the role of these structures?
11. Whether any damage by pest may be compensated by plant itself?
12. Whether intercrop acts as a harbour of natural enemy?
13. What are the plant parts of the intercrop that harbour the natural enemies?
14. Is there any alternate crop that acts as host pests of Maize?
15. Was the intercrop found infested with FAW larvae?
16. …………………..so on

C. Benefits of the week

Farmers able to know-

- Plant has a potency of re-growth of infested parts
- Role of intercropping (farmers' practice)
- Nectar and pollens are the feeding materials for parasitoids
- In an Agro-ecosystem antagonistic agents against the pest are found and they need to be conserved.

10th week

Crop stage: Cob formation stage: (63 DAS)

A. Curriculum of the week

Activity	Description	Assigned to
Opening	Welcome, recapitulation of previous activities and briefing about today's activities	Group leader (Farmer)
AESA	Field visit 1. Scouting and recording of FAW on different parts of the Maize plant 2. Scouting and recording of foliage feeders/ diseases and associated NEs 3. Observation of different NE complex in the Maize agro-ecosystem (PAR) 4. Observation for moths caught in Pheromone trap 5. Observation of Insect zoo 6. AESA field activities	All farmers (Participatory)
Energizer	Ice-breaking	Farmer/Facilitator
AESA process	Drawing/labelling/ AESA processing Rearing/ mounting/tabulation of data etc.	All farmers (Participatory)
AESA discussion	Diseases/pests, associated NEs and relevant AESA inputs	Through group dynamics
Energizer	Ice-breaking	Farmer/Facilitator
Special topic	Role of irrigation and nutrient management	Farmers
PTD	Role of different natural enemies in the Maize agro-ecosystem (PAR based) Understanding about prey predatory relationship	Farmers

Activity	Description	Assigned to
Planning of next week programme	---	Farmers/Facilitator
Closing	Vote of Thanks	Based on FFS reciprocation

B. Questionnaire for the week

1. What are the types of natural enemies?
2. What are their foods?
3. Where are they found?
4. What is the relationship with pest?
5. what is the food chain in the Maize agro-ecosystem?
6. How they act in the Maize IPM module?
7. Why more water can cause dislodging?
8. What are the critical stages of crops for irrigation?
9. Why at this stage more food is required to the plant?
10. What are the important plant parts susceptible to pest?
11. How the nutrient application is to be made?
12. Why split-application of nitrogen is important?
13. ……………..so on

C. Benefits of the week

Farmers able to know-

- Importance of irrigation
- Importance of nutrient management
- Role of NEs in pest management

11th week

Crop stage: Cob formation & development stage (70 DAS)

A. Curriculum of the week

Activity	Description	Assigned to
Opening	Welcome address, recapitulation of previous activities and briefing about today's activities	Group leader (Farmer)
AESA	Field visit 1. Scouting and recording of FAW on different parts of the Maize plant 2. Scouting and recording of foliage feeders/ diseases and associated NEs 3. Pesticide spray on target pest and non-target organisms (PAR) 4. AESA field activities	All farmers (Participatory)
Energizer	Ice-breaking	Farmer/Facilitator
AESA process	Drawing/labelling/ AESA processing / tabulation of data etc.	All farmers (Participatory)
AESA discussion	Diseases/pests, associated NEs and relevant AESA inputs	Through group dynamics
Energizer	Ice-breaking	Farmer/Facilitator

Activity	Description	Assigned to
Special Topic	Farmer dissemination of information through informal education	Farmers
PTD	Understanding about judicious use of pesticides for pest management (PAR based)	Farmers
Planning of next week programme	---	Farmers/Facilitator
Closing	Vote of Thanks	Based on FFS reciprocation

B. Questionnaire for the week

1. What is a pesticide?
2. How do you identify the pesticide container?
3. What is the toxicity label of present sample?
4. Why pesticide is required?
5. Against which organism pesticide is to be used?
6. What are the life stages of pest?
7. What is the damaging stage of life cycle?
8. How pesticide is to be used?
9. When pesticide is to be used?
10. What is the label claim?
11. What is the recommended dosage?
12. What are side effects of pesticide?
13. Is there any death other than target pest?
14. How pesticide may affect the agro-ecosystem natural enemies, soil, produce etc.?
15. What is the residual toxicity of pesticide?
16. How pest can be managed?
17. What is the importance of pest biology in pest management?
18. Why management is targeted against the total control?
19. What is the role of habitat of any organism management?
20. What are the factors responsible for choosing pesticide as a pest control method?

C. Benefits of the week

Farmers able to know-

- Judicious use of pesticides
- Decision making, Informal Education and Habitat Study

12th week

A. Curriculum of the week

Crop stage: Cob maturation stage: (77 DAS)

Activity	Description	Assigned to
Opening	Welcome, recapitulation of previous activities and briefing about today's activities	Group leader (Farmer)
AESA	Field visit 1. AESA field activities 2. Spraying pesticides: pesticide hazards and pesticide risk reduction	All farmers (Participatory)

Activity	Description	Assigned to
Energizer	Ice-breaking	Farmer/Facilitator
AESA processing	Drawing/labelling/ AESA processing / tabulation of data etc.	All farmers (Participatory)
AESA discussion	Diseases/pests, associated NEs and relevant AESA inputs	Through group dynamics
Energizer	Ice-breaking	Farmer/Facilitator
Special topic	Safe use of pesticides (PAR based)	Farmers
PTD	Safe use of pesticides	Farmers
Planning of next week programme	---	Farmers/Facilitator
Closing	Vote of Thanks	Based on FFS reciprocation

B. Questionnaire for the week

1. Why self-protection is required during pesticide spraying?
2. What are the personnel protective equipment?
3. What are the sensitive parts of human body?
4. Why are specific time, wind velocity, rain etc. important for spraying/dusting of pesticide?
5. Why label claim is important for pesticide spray?
6. What is antidote?
7. What are features of safe storage of pesticides?
8. What is important for selection of a pesticide?
9. What are the points of attention while buying a pesticide?
10. What are the major pests during this crop stage?
11. Where more attention is to be given to the crop?
12. If FAW larvae found feeding on
    leaves,
    cob
    tassel
    any other parts of plant
    Decision making .... group dynamics

C. Benefits of the week

Farmers able to know-

- Safe use of pesticides
- Decision making ability

13th week

A. Curriculum of the week

Crop stage: Cob maturation stage : (84 DAS)

Activity	Description	Assigned to
Opening	Welcome address, recapitulation of previous activities and briefing about today's activities	Group leader (Farmer)
AESA	Field visit 1. AESA field activities 2. Record keeping for cost benefit analysis and decision making (PAR)	All farmers (Participatory)
Energizer	Ice-breaking	Farmer/Facilitator

Activity	Description	Assigned to
AESA processing	Drawing/labelling/ AESA processing/ tabulation of data etc.	All farmers (Participatory)
AESA discussion	Diseases/pests, associated NEs and relevant AESA inputs	Through group dynamics
Energizer	Ice-breaking	Farmer/Facilitator
Special topic	Rodent and bird management in Maize agro-ecosystem	Farmers
PTD	Economic cost benefit analysis	Farmers
Planning of next week programme	---	Farmers/Facilitator
Closing	Vote of Thanks	Based on FFS reciprocation

B. Questionnaire for the week

1. Are any birds observed in field?
2. What do they feed upon?
3. Is it a bird or a pest?
4. What are the damage symptoms of birds?
5. How can they be managed?
6. Are rodents live in burrows in the field?
7. Is rodent managed in the Maize?
8. What is the damage symptom of rodents?
9. How rodent mangement can be done?
10. What is record keeping?
11. What is CB ratio?
12. Why CB ratio is important?
13. What are the things to be recorded during crop growth stages?
14. ……….so on

C. Benefits of the week

Farmers able to know-

- Management of rodents and birds
- Role of green tissues for plant nutrition
- Economic analysis and decision making

14th week

Crop stage: Cob maturation stage: (91 DAS)

A. Curriculum of the week

Activity	Description	Assigned to
Opening	Welcome address, recapitulation of previous activities and briefing about today's activities	Group leader (Farmer)
AESA	Field visit 1. AESA field activities	All farmers (Participatory)
Energizer	Ice-breaking	Farmer/Facilitator

Activity	Description	Assigned to
AESA process	Display of AESA chart, drawings of all the weeks Group dynamics –summary of all activities • Development stages of the plant • Different pests recorded in different stages of the plant • Management strategy of the pest • Special topics • PAR activities • Participatory technology Development (PTD) • Farmers as decision maker in their own field	All farmers (Participatory)
Planning for field day	Preparation of field day with discussion about analysis of yield data from IPM vs non-IPM plot identifying some parameters	Farmers/Facilitator
Closing	Vote of Thanks	Based on FFS reciprocation

3.4 Field Day

After the intensive 14-week programme of Maize IPM-FFS, summation and assessment of the activities are required for self-evaluation and judicious involvement in the activity. Since the theme of the activities are multifarious channelized through AESA and group dynamics, their evaluation is required for dissemination of the success and the new lessons learnt. As per the FFS guidelines only 35 farmers can be accommodated in the programme in a FFS village, hence bulk of the farmers sometimes remains untrained. It is customary to appraise the rest of the farmers in the field day programme. As a matter of act one FFS is usually conducted in a village, later which is called as the FFS village.

In the field day, attention is to be attuned to train the non-IPM farmers through horizontal dissemination of the information i.e. by the IPM trained farmers. To make the programme a whole concept involving the entire village farmers in the following activities can be designed

i) Yield assessment of IPM vs non-IPM

ii) CB ratio of IPM vs non-IPM

iii) Input and sprays of IPM vs non-IPM

iv) Post evaluation (Ballot box test) of FFS farmers

Besides these activities, the group dynamics also conducted for effective dissemination of information on Maize IPM especially towards management of FAW. Two sets of farmers are usually available in the field day. One set comprising well trained farmers on IPM-FFS who can be designated as village level Master Trainer. Another set comprising non-IPM farmers are not aware of IPM activities. So it is right forum to kindle and motivate then non IPM farmers about the advantages of IPM and adopt in future crops. The following activities are to be conducted for non IPM-FFS farmers to enable them to be competent in decision-making on plant protection activities.

- Comparative group dynamics among FFS and non-FFS farmers on issues
    1. Bio-ecology of FAW
    2. Ecological engineering for management of FAW
    3. Decision making
- Opinion of non-FFS farmers about FAW awareness-cum-management campaigns
- Formation of a model village free from pesticide pollution or IPM model village
- Exploration of possibilities of FFS farmers assist.

3.5 Evaluation Matrix for Facilitators

Facilitation skills	Scope for improvement	Good	Best practices
1. Preparation	Poor	Good	Accurate preparation of all topics
2. Study site / field	Uncomfortable	Comfortable	Excellent preparation (signs, etc.)
3. Goal	Not defined	Well defined	Clearly identified, but illustrated with various tools / examples
4. Time frame	Not defined	Well defined	Discussed with Participants
5. Introduction	No	Provides	Rich in information, but not lengthy
6. Steps / Procedure	Unclear	Clear and complete	Repeat / provide Details for complex Tasks
7. Go from one group to another	No	Yes – as needed	General discussion
8. Answer to questions	Direct	Questions / explains the context, etc.	Varied and involve the group ("Who can answer?")
9. Time management	Poor	Keeps on track	Verifies, adjusts, stimulates, etc.
10. Ask questions	No	Yes	Stimulates input from participants, analysis
11. Discussion	No	Yes	Stimulates input from participants, analysis
12. Summary	No	Yes	Varied style with contribution from participants
13. Who speaks?	Facilitator	Facilitator and farmer	Mainly participants
14. Continuous evaluation	No	Yes	Varies style– Questions, diagrams, repeats
15. General evaluation	No	Yes	Varied: Informal, tables and Figures, etc.
16. Organization of next meeting	No	Announced	Contact for follow-up before next meeting
17. Enthusiasm / motivation	Scarce	Yes	Stimulates learning Process
18. Kindness	Can be better	Yes	Favours communication and learning process

Chapter 4

PAR experiments for Maize IPM-FFS programmes

4.1 Effect of Seed Treatment & Other Insect Pests and Diseases of Maize

Objective	• To compare the germination and establishment of healthy Maize seedlings • To compare incidence of seedling diseases and early pest attack
Material and Methods	Selected seeds, seed treatment chemicals, seed treatment drum, plastic sheet, hand gloves, water, bucket etc. Treatments: T 1: Recommended seed treatment T 2: Untreated seeds Layout size : 5 m × 5 m No. of replications : 3 Treat the Maize seed with approved seed treatment chemicals/bio-pesticides as per the recommended method. Allow the treated seeds to get dry under shade. After shade drying, sow the treated seeds in demarked area for treated plot. Sow the untreated seeds in demarked area as a untreated control.
Field activity and observations	Observe for germination, seedling diseases, foliage feeders and associated natural enemies in randomly selected 20 plants in each replication. (Data Format sheet enclosed)
Discussion	Impact of seed treatment for better germination and effect against early attack of foliage feeders and soil-/seed-borne diseases.
Group dynamics	
Conclusion (Decision making)	

Format of Data collection

Date…………………………

Crop…………………………

Location/village……………………

Group name………………

Treatment……………………

Spot/replication…………..

Plant no.	Germinated/ not germinated	No. of leaves	Plant height (cm)	Damaged leaves due to scraping/ pin holed/ discoloured spots etc.	No. of insects	No. of natural enemies if any
1						
2						
3						
4						
5						
6 . . . . **20**						
Total						
Mean						

4.2 Insect Zoo Experiment

Objective	To convince farmers about pest-predator relationship among different organisms in field
Material and Methods	Pots, mosquito nets, hand lenses/magnifiers, vials/ plastic bottles for field collection, small knife, sticks etc. • Target crop nurtured in seven pots. • The plants are in transparent protective covering with facility of transpiration at top and small protective opening to introduce insect. • Insects, arachnids and some other small arthropods having prey-predator relations and pest of target crops. Treatments can be arranged as follows based on the organisms available in that particular ecosystem: 1. Pot with only known number of pests 2. Pot with pests and associated natural enemies in definite proportion 3. Pot with only natural enemies 4. Pot with particular stage of pest (egg/larvae/adult) and associated NEs 5. so on.... 6. Control –pot without any of the pests/NEs.
Field activity and observations	Regular observations to be taken on • Feeding of phytophagous insects on target crops • Predation to phytophagous insects • Feeding to natural insects in absence of phytophagous insects • Mortality of phytophagous insects with change of growth stage of the target crop
Discussion	Interaction of different organisms in a representative agro-ecosystem simulating the standing crop (on field condition) Farmers are to be convinced that, there is always a dynamic equilibrium among different organisms when the agro-ecosystem is undisturbed
Group dynamics	
Conclusion (Decision making)	

4.3 Scouting and Observations of Fall Armyworm

Objective	To help the farmers for better understanding about different stages of FAW occurring in the field in association with plant stage. This observation is the basis for better understanding and knowledge, leading to better decision-making, in turn resulting in greater production, fewer wasted resources, and more sustainability.
Material and Methods	Polythene bags, tags, notebook, vials/plastic bottles/jars, aspirator, pencil, sketch pen, knives (pen and cutlass), cardboard, flipchart, markers, eraser, camel hair brush, disposable gloves, measuring scale, rubber bands, magnifying glass. Methods/procedures: In the field, walk in the shape of letter "W", covering the entire field: At the start and at every turn, inspect 10 plants in a row. These ten plants are called a "station". Look carefully in the whorl of each plant for signs of recent leaf damage or fresh frass in the whorl. These indicate a live larvae, probably FAW, in the whorl. Do NOT include plants with some damage to older leaves, but with no clear signs of current damage. Only currently infested plants need to be counted. Keep track of the number of plants currently infested in this way (in this example FAW-infested plants are marked with an "X").
Field activity and observations	Look for signs of FAW presence (i.e. fresh leaf damage or frass in whorl). So the sampling does not depend on finding the larvae, or how many you find. This way the sampling is fast, non-destructive and can be done any time of the day. While scouting for FAW-infested plants, it is also important to make an overall assessment of the fields, the crops, and especially for natural enemies. There are many naturally-occurring farmers' friends that help control FAW – predators (ants, earwigs, pirate bugs, birds, etc.), parasitoids (wasps that kill eggs and larvae), and pathogens (bacteria, fungi, and virus).
Discussion	Life cycle of FAW, Scouting methodologies, damage symptoms, FAW habitat, natural enemies and their role.
Group dynamics	
Conclusion (Decision making)	

In the field, walk a letter "W", covering the entire field (Figure 85).

Figure 85. In the field, walk in the shape of letter "W"

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Collection of information on FAW

Parameters for field observations	Seedling	Early whorl	Late whorl	Cobs	Where to find
Egg masses	X	X	X		Leaves – both sides, stems larvae
1-2 instar	X		X		On leaves – presence or absence
3-6 instar larvae					In whorls (funnel) – presence or absence
Adult moth					Number on plants
Larvae attacked by pathogens		X	X		Presence or absence
Windowpane damage					Presence or absence
Pinhole damage					frass X presence or absence
Rugged damage					

Collection of information on FAW

Spot-1		Spot-1		Spot-1		Spot-1		Spot-1	
Plant no.	**Infested?**	**Plant no.**	**Infested?**	**Plant no.**	**Infested?**	**Plant no.**	**Infested?**	**Plant no.**	**Infested?**
1	X	1		1	X	1		1	x
2		2	X	2		2	x	2	x
3	X	3		3	X	3	x	3	x
4		4		4	X	4		4	
5	x	5	X	5		5	x	5	x
6	x	6		6	X	6	x	6	
7		7	X	7		7		7	x
8	x	8		8		8	x	8	x
9		9	X	9		9		9	
10	x	10		10		10		10	x
Total	6		4		4		5		7

The total number of plants infested in the 50 plants counted is 6 + 4 + 4 + 5 + 7 = 26

So in 100 plants it would be double: 26 × 2 = 52, or 52 percent of the plants infested.

4.4 Spiders and Ants as a Potential Predators in Different Agro-ecosystem

Objective	To understand about role of spiders and ants as a potential predators in agro-ecosystem
Material and Methods	Measuring tape, umbrella (black), stick (for drumming), soil scoopers, spiders, spiderlings, spider egg masses and ants to be collected from 5-6 agro-ecosystem. 1. 1 m × 1 m ground space 2. Umbrella (black) 3. Within the cracks and cervices 4. In the standing crop (web forming and non-webbing spiders) 5. Ants on the standing crop
Field activity and observations	Observation of physical similarities
Discussion	The farmers are to be focused on movement of spiders and ants in different agro-ecosystems, which are mutually reciprocated with availability of food and habitat.
Group dynamics	
Conclusion (Decision making)	

4.5 Installation of Pheromone Traps for Monitoring of Fall Armyworm

Objective	• To familiarize the farmers with traps as a tool for monitoring of FAW • To know the presence of FAW in and around the field
Material and Methods	Traps, FAW specific lures, notebook, flipchart paper, markers, funnel or bucket is the preferred trap for FAW, green lid/yellow funnel/white bucket etc. Place traps in the field just after the emergence of crop. A suitable location should be selected for positioning a trap. The selected site should be inside or on the edge of a Maize field, or an open area nearby. The Pheromone lure usually needs to be replaced every 3–6 weeks to achieve optimum results, depending on temperature, Pheromone components and release characteristics.
Field activity and observations	The traps should be checked two times per week by counting the number of FAW moths inside.
Discussion (Group dynamics)	Discussions related to the study: • How many individuals did we find? • Is the population increasing or Decreasing? How does that compare with the number of infested plants we see in the field in AESA? • Should we check our fields more frequently? • How do FAW move about? How much can they fly? What factors can favour increased infestation? What factors can decrease it? • How can we use trap as part of a community or government monitoring system? What role can our FFS play?
Conclusion (Decision making)	

4.6 Maize Plant Compensation Experiment Attack by Fall Armyworm

Objective	• To allow farmers to understand that the Maize plant can compensate leaf damage caused by FAW at the early seedling or vegetative stage. This can support farmers to make better decisions on how to manage FAW or other pests that can cause leaf damage. • To help farmers discover that spraying of chemicals is not a must when early defoliation is observed in the field.
Material and Methods	Maize plants, scissors. This kind of study does not require a separate study plot, it can be set-up in the IPM plot by marking plants/areas where plants are cut. There are 6 treatments about 1 m × 1 m each (Figure 86), plus the control plot with no defoliation (this is the rest of the IPM plot): ***Treatment 1:*** 25 percent defoliation at seedling stage (4 to 6 leaves): 7–15 days after planting (DAP) ***Treatment 2:*** 50 percent defoliation at seedling stage (4 to 6 leaves): 7–15 DAP ***Treatment 3:*** 25 percent defoliation at seedling to vegetative stages (knee-height to 1 m height): approximately 30 DAP ***Treatment 4:*** 50 percent defoliation at seedling to vegetative stages (knee-height to 1 m height): approximately 30 DAP ***Treatment 5:*** 25 percent defoliation at late vegetative stage (more than 1 m height): approximately 45 DAP ***Treatment 6:*** 50 percent defoliation at late vegetative stage (more than 1 m height): approximately 45 DAP ***Control:*** No defoliation at all (this is the rest of the IPM plot) Select five plants per treatment at random; or mark 1 m2 to assess yield cuts later on. • Before proceeding with defoliation, observe the field and destroy all egg masses and FAW larvae present on the plants. • Divide leaf surface into ten parts. • Cut off the leaf part(s) in relation to the defined treatment percentage without damaging the main vein (rib).
Field activity and observations	• Observe weekly to evaluate plant growth rate in relation to the stages. • Set up small groups of FFS members to scout and crush egg masses every two days.
Discussion	Discussions related to the study: • growth (regeneration) rate • yield per treatment • comparison of the yield losses • gross margin
Group dynamics	
Conclusion (Decision making)	

Figure 86. Layout

Treatments will be randomly assigned to the 6 plots + the control plot.

4.7 Recycling of Entomopathogens to Manage FAW larvae

Objective	• To demonstrate the utilization of potential entomopathogens exists in that particular area for effective control of FAW.
Material and Methods	• Dead larvae killed by pathogens collected from the field, small blender or mortar and pestle, material to filter, pesticide sprayer, water, soap etc. • Naturally killed fungi/viruses are easily identified in the field. Fungal killed larvae turn rigid and appear frozen on the leaves eventually turning white or light green as the fungal spores matures. • Whitish fungal growth ***Beauveria bassiana***, ***Verticillium*** lecanii • Greenish sporulation-***Metarhizium*** anisopliae, Nomuraea rileyi • Virus-killed larvae become soft and many hang from the leaves, eventually oozing viroid particle and fluids. Collect infected/dead larvae from the field, crush them, filter, dilute with water as per requirement and spray directly into the whorls of those plants, which are currently infested with FAW larvae.
Field activity and observations	Spray onto the field where living FAW larvae present and collect observations.

Discussion	Discussions related to the study on the effect of recycling pathogen sprays on FAW larvae. Presence of newly dead larvae and percent of infestation. Role of weather parameters on the efficacy of entomopathogens spray. Estimate cost, benefits and constraints.
Group dynamics	
Conclusion (Decision making)	

4.8 Life Cycle of the Fall Armyworm

Objective	• To help farmers understand the biology and life cycle of the FAW and to recognize the various stages. • To enhance better decision-making for IPM.
Material and Methods	Field plots, hand lenses/magnifiers, vials or plastic bottles for field collection, mosquito nets, small knife, cut lash, sticks etc. **Method 1:** Open field Insect zoo Look for egg masses starting one or two weeks after planting. Look for FAW in nearby fields if not present. Select 1 or 2 Maize plants that will be covered by muslin veil cages. If the plants already have egg masses of FAW, note where to find them. Remove all other insects from the plant. If there are no egg masses, release adults of FAW to lay eggs, if possible. Observe regularly – different stages of development, where they live and feed on the plant, how long it takes to change from one stage to another. Continue this until the life cycle is complete. **Method 2:** Insect zoo in bottles, jars, or other containers Collect egg masses and preserve them in well aerated plastic bottles, observe them daily until they hatch (most likely, it will take 2-3 days maximum for eggs to hatch). Feed emerging larvae regularly with fresh Maize leaves. It might not be easy for the FAW to survive its entire development cycle in simple containers, therefore, collect FAW at different stages of development: egg masses, various instars (i.e. from smaller to larger larvae), pupae, adult moth, and try to observe as each one develops onto their next stage.
Field activity and observations	Observe feeding habit, moving, growth stages and duration, morphological characteristics.
Discussion	Life stages of FAW, behaviour of FAW, stage associated habitat, damage symptoms, susceptible stage of crop, potentiality of the FAW stage, FAW stage associated NEs etc.
Group dynamics	
Conclusion (Decision making)	

4.9 Effects of Pesticides on Non-target Pests (Natural Enemies and Beneficials)

Objective	• Evaluate the effect of pesticides on non-target pest (natural enemies and beneficial)
Material and Methods	Natural enemies of FAW, FAW larvae, petri-plates/ jars with lids, PPE, pieces of thin cloth and rubber bands, labels, fine-hair paintbrushes, aspirators, if available, tissue paper, scissors, forceps, long disposable stirrers for mixing pesticides, gloves, paper, pen, small hand sprayers (0.5 litre), small amounts of approved insecticides etc. Each group (5 sub-group) needs to collect 5-6 individuals of one kind of natural enemy as well as plant feeder (FAW larvae). Arrange it so that each group collects a different kind of natural enemy. Provide some food for the insects-sugar solution for parasite adults, prey for the predators and fresh leaves for the plant feeders. Keep the insects in a cool place whilst you prepare the other things for the experiment, or they will all be dying by the time you start the experiment. Each sub-group shall prepare and spray the recommended chemicals as per the label claim. **Treatment 1:** Pesticide spray on natural enemies and FAW larvae **Treatment 2:** No pesticide spray as it is control Note: For Do's and Don'ts, follow instructions as per label claim.
Field activity and observations	Observe the activities of natural enemies and plant feeders on hourly basis and record the mortality.
Discussion	Effect of pesticides on non-target pests in agro-ecosystem and chemical pesticide associated problems.
Group dynamics	

4.10 Record Keeping for Cost Benefit Analysis and Decision Making

Objective	• To allow farmers to know how much money they spend and gain, for better and informed decision making in a given enterprise • To facilitate comparisons between the different management practices and treatments in the field studies of the FFS
Material and Methods	Flip chart paper, markers, masking tape, notebook, pens (blue and red), ruler, calculator etc. This activity/experiment is from sowing to harvesting. Details on each intervention/activity and expenditure on the same need to be recorded accordingly. (For example cost of seed treatment chemical and labour charge for treatment). Group discussion practical (exercise) Prepare a notebook or format sheet for each treatment in the FFS.

Field activity and observations	Record-keeping should be done on a daily basis whenever an activity is done in a field school (or on the farmer's farm) starting from inputs sourcing to selling, except AESA.
Discussion	Evaluate and compare technologies, options under experimentation in the FFS, and to make an informed management decision at the end of the season on cost effectiveness of various methods for future planning.
Group dynamics	
Conclusion (Decision making)	

Notebook/calculation sheet

Crop: ________________ Location:________________

Year: _________________ Date:___________________

Expenditure head	Inputs/activity	Date	INR
Production cost	**Input cost** **Seeds** **Manures** **Fertilizer** **Sprays** **Others if any**		
	Labour cost		
Transport cost/ **Other cost**			
Total cost			
Income	**Gross income**		
Total	**Net income**		
Cost benefit ratio			

Chapter 5

FAO Fall Armyworm Early Monitoring Warning System (FAMEWS)

5.1 FAMEWS Mobile App

FAMEWS is an application for Android v6 or higher smart phones. The app should be used every time a field is scouted and Pheromone traps are checked for FAW. The app has these parts:

- Data entry: to collect, record and transmit
- Scouting data, including basic farm data, manual or scouting data and immediate advice
- Trap data
- IPM education
- Digital library
- Chat to share experiences expert resources.

Data are entered by making selections from drop-down lists. Each item provides a useful explanation that, in some cases, includes photos – for example, of different pests and natural enemies to help the user enter accurate data. The app is extremely intuitive, easy and fast to use.

5.2 FAMEWS Global Platform

FAMEWS global platform is an online resource for mapping data collected by the FAMEWS mobile app whenever fields are scouted, or Pheromone traps are checked for FAW. The platform provides a real-time situation overview with maps and analytics of FAW infestations. The data and maps provide valuable insights on how FAW populations change over time with ecology to better understand its behavior and guide best management practices.

5.3 Fall Armyworm Monitoring and Early Warning System (FAMEWS)

An integral part of FAO's sustainable management Programme for FAW is the FAW Monitoring and Early Warning System (FAMEWS). This consists of a mobile app available free of charge from the Google Play store for data collection and a global platform for mapping the current situation.

Farmer education and community action are critical elements in the strategy to sustainably manage FAW populations. That is why Farmer Field Schools (FFS) will be used to support implementation of an integrated ecological and sustainable FAW management strategy. FFS is an intensive farmer education approach promoted by FAO and many organizations worldwide, establishing platforms for farmers to learn, experiment and exchange, currently used in over 90 countries for a wide range of topics after nearly three decades since they first started.

As part of the FAW management strategy to reach rural communities affected by FAW, FFS will be combined with mass information campaigns, rural radio, participatory videos, community action plans for FAW management and short field courses for farmers and rural advisors based on experiential learning.

5.4 FAW Awareness and Video Link

ICAR-IIMR collaborated with the University of Michigan and SAWBO, to translate SAWBO animated video on FAW identification, scouting and management into different Indian languages (Hindi, Punjabi, Gujarati, Telugu, Kannada, Tamil, Odiya, Bengali, Marathi, Manipuri, Mizo, Nagamese, Malayalam). These are available online in the following links. Apart from this, Malayalam and Marathi translations of the same were co-ordinated by ICAR-KVK and 6 Grain corp. respectively.

- Hindi-https://youtu.be/LlNDUhFCBTs
- Bengali-https://youtu.be/FjIF43ViQEw
- Gujarati-https://youtu.be/s7CcvyaxX7g
- Punjabi-https://youtu.be/4twy79A0Tcc
- Tamil-https://youtu.be/6P2NvZBNDb0
- Telugu-https://youtu.be/DU2lDjnTDLY
- Kannada-https://youtu.be/FwNe4Q-BZT8
- Odia-https://youtu.be/jqE1esjE5_4
- Manipuri-https://youtu.be/_kkbOOxdQxI
- Mizo-https://youtu.be/w0r8j-- ZEzo
- Marathi-https://youtu.be/fprog39tUmM
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Observations

Observations

For More Information:

FAO Representation in India

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