An Illustrative Guide to Cotton Cultivation in the North Zone of India

ICAR - Central Institute for Cotton Research, Regional Station, Sirsa

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Dr V. N. Waghmare, Director
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Compiled and Edited by
Rishi Kumar, S.K.Sain, Amarpreet Singh, Subhash Chandra, Satpal Singh, S.K.Verma and V.N.Waghmare

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Dr D K Yadava,
Deputy Director General (Crop Science)
ICAR- New Delhi

Preface

Cotton occupies a prominent place in Indian agriculture in ensuring livelihood security, employment generation, and raw material supply to the textile industries. The North cotton-growing zone, though to be highly productive, faces multiple challenges such as climate variability, pest resurgence, resistance development, micronutrient deficiencies, and emerging disease threats. Addressing new issues every year requires not only strong research support but also effective dissemination of practical and location-specific recommendations to farmers in an easily understandable format.

The Indian Council of Agricultural Research (ICAR) has consistently emphasized the integration of research, extension, and capacity building to enhance crop productivity and sustainability for the betterment of farming fraternity. The preparation of the *"**An Illustrative Guide to Cotton Cultivation in the North Zone of India***" is a commendable initiative in this direction. Putting together concise scientific information with clear and high-quality action photographs, the document provides farmers friendly information in identifying field problems and adopting appropriate management practices in a timely manner. I appreciate the efforts of the ICAR-Central Institute for Cotton Research (ICAR-CICR) in developing this comprehensive guide covering all critical aspects and challenges of cotton cultivation from varietal selection, seed production, seed treatment, land preparation, sowing, nutrient and water management to integrated pest and disease management. The decision-making process through understanding economic threshold levels (ETLs), monitoring techniques, conservation of natural enemies, safe pesticide use, and off-season management reflects the Institute's commitment to promoting farmers friendly sustainable and environmentally responsible cotton production systems. The pictorial illustrations will significantly enhance farmers' diagnostic skills and strengthen decision making ability at the field level. Such practical tools are essential for reducing input misuse, delaying resistance development, and improving input-use efficiency to enhancing profitability.

I congratulate the Director, ICAR-CICR and his team of scientists involved in compiling this valuable guide. I sincerely hope that this ready reference for all stakeholders associated with cotton cultivation initiative will contribute to strengthen the cotton production system towards sustainable agricultural development.

(Dr. D. K. Yadava)
Deputy Director General (Crop Sciences)
Indian Council of Agricultural Research

Dr. Prashanta Dash,
Assistant Director General (Commercial Crops)
ICAR- New Delhi

Preface

Cotton being the commercial crops occupy a strategic position in Indian agriculture, contributing substantially to farmers' income, national exports, and industrial growth. Cotton plays a pivotal role in sustaining the textile value chain and supporting millions of farming families. The North Zone cotton ecosystem, pre-dominantly following cotton-wheat or cotton –mustard or rice-wheat intensive cultivation supported the dynamic of insect-pest and diseases require precise, science-based, and location-specific crop management strategies to maintain productivity and sustainability.

The Indian Council of Agricultural Research (ICAR) has always regularly prioritized the development and dissemination of improved technologies for commercial crops including cotton through network of research institutes and their regional stations. In this context, ***"An Illustrative Guide to Cotton Cultivation in the North Zone of India"*** developed by the ICAR-Central Institute for Cotton Research is a timely and appreciable initiative. The guide explains research findings into an easy-to-understand pictorial format, enabling farmers and extension personnel to quickly identify crop stage based interventions like nutrient requirements and deficiencies, insect pests, diseases, and appropriate management practices. The pictorial guide cover different aspects of cotton cultivation i.e. selection of suitable hybrids and varieties, seed treatment, land preparation, nutrient and irrigation management, to integrated pest and disease management resulting into holistic approach to cotton production. The importance and emphasis on economic threshold levels (ETLs), monitoring methods, conservation of natural enemies, and judicious use of agrochemicals aligns well with ICAR's commitment to sustainable and environmentally safe agricultural practices. The details of post-harvest management, stalk destruction, and off-season monitoring further strengthens the long-term pest and disease management framework in ensuing seasons.

I appreciate the team of scientists of ICAR-CICR for their continuous efforts in compiling this practical and zone specific document. I believe that this publication will serve as a valuable reference for farmers, field staffs and other stakeholders engaged in cotton production in the North Zone, and will contribute to the advancement and enhancement of commercial crop production in the country.

(Dr. Prashanta Dash)
Assistant Director General (Commercial Crops)
Indian Council of Agricultural Research

Dr. V. N. Waghmare,
Director, ICAR-Central Institute for Cotton Research
Nagpur (Maharashtra)-India

Preface

Cotton sustaining the livelihoods of millions of farmers is of national importance contributing significantly to the agricultural economy and also for textile sector of the country. The North Zone known for its assured irrigated cotton cultivation practices, in particular, plays a crucial role in cotton production, with diverse challenges including climatic variability, emerging pest dynamics, nutrient imbalances, and disease pressures. Under such scenario, timely dissemination of practical, science-based, and field-oriented information becomes essential to ensure sustainable productivity and profitability.

The ICAR-Central Institute for Cotton Research (ICAR-CICR) continuously works towards developing and refining improved production and protection technologies for different cotton zones of the country. Describing the research findings of ICAR-CICR & associated cotton researchers across the country into farmer-friendly formats remains one of our key priorities. This ***"An Illustrative Guide to Cotton Cultivation in the North Zone of India"*** is an important effort in this direction. By combining concise technical descriptions with clear, high-quality action photographs, the guide provides a practical visual tool for better understanding and adoption of recommended practices. The guide comprehensively covers all critical stages of cotton cultivation from selection of suitable genotypes either Desi or *Bt* Cotton, Hybrid seed production in desi cotton, seed treatment, crop establishment methods, nutrient and water management, to integrated pest and disease management. Special emphasis has been placed on understanding the importance of monitoring techniques, identification of major pests and diseases including Cotton Leaf Curl Disease (CLCuD), and safe and judicious use of agrochemicals. The emphasis on canopy management, defoliation practices, clean picking, stalk destruction, and off-season management further strengthens the sustainability perspective of this guide.

I appreciate the dedicated efforts of the team of scientists of different disciplines i.e. agronomy, plant breeding, entomology and plant pathology from our regional station for their contribution and expertise in preparing this comprehensive guide. The commitment to developing zone specific and farmer centric recommendations is commendable. I also acknowledge the valuable support of technical and field staff who continuously works to ensure development of this scientific advancements and for further dissemination to farming community effectively through extension efforts. I sincerely hope that adoption of the described practices will enhance productivity, improve input-use efficiency, reduce avoidable losses, and contribute towards sustainable cotton production systems.

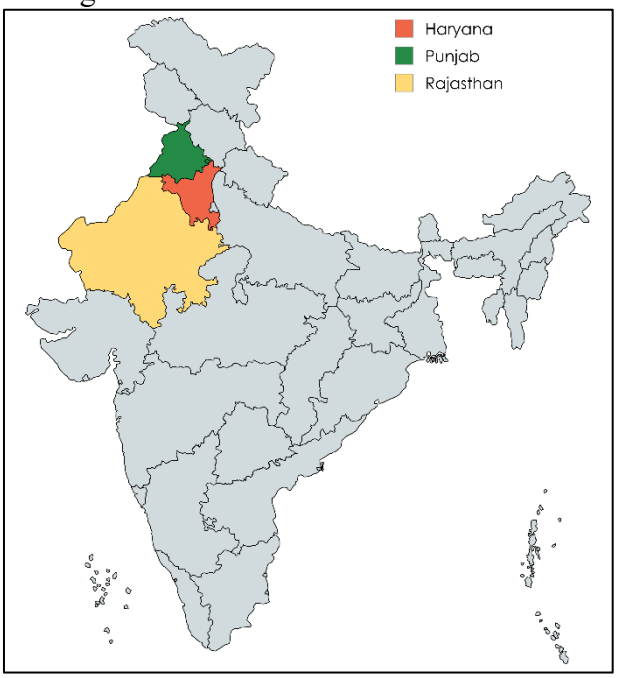
(Director)
ICAR-Central Institute for Cotton Research

Content

Introduction

Cotton is one of the most important commercial crops cultivated in all three major zones i.e. North, Central and South Zone of India. Cotton growing belts of North Zone of the country is playing an important role in supporting and sustaining the rural economy in irrigated medium soils. Source of livelihood to millions of farmers, farm laborers, traders, and industrial workers, cotton always remains in limelight without any ignorance. In field during the production process cotton needs care from the very first day until the last picking. Surprisingly crop also needs due care during off-season. Protected at the right time resulted in harvest of white gold but ignorance for a short time, either in intercultural operations including weeding, hoeing, irrigation scheduling, fertilizer applications or insect-pest and disease managements lead to considerable yield penalty. Cotton cultivation always remains highly knowledge intensive at the part of producers, input suppliers, industrialists, cotton researchers and extension officials but simultaneously sensitive to climatic variations, pest incidence, nutrient imbalances, and management practices. In North zone, recent years, farmers have faced challenges such as erratic rainfall, emerging pest & diseases problems, resistance to pesticides, micronutrient deficiencies, and pest's outbreaks. These challenges often result in reduced productivity and profitability. Therefore, there is a strong need for a comprehensive, practical, and field oriented guide that presents scientific recommendations in a simple, understandable, and visually demonstrative manner. **An Illustrative Guide to Cotton Cultivation in the North Zone of India** has been designed as a ready reference for farmers, extension personnel, input dealers, and field officers in simple and practical orientations. The uniqueness of this guide lies in its pictorial approach, where good quality action photographs are integrated with concise descriptions to facilitate easy identification, understanding and implementations for field operations, pests, diseases, nutrient deficiencies, and management practices. Visual learning enhances clarity, reduces confusion in diagnosis, and supports timely decision making at the farm level. By observing clear photographs of plant architecture, deficiency symptoms, pest damage symptoms, and management techniques, farmers can better relate recommendations to real field conditions. Pictorial guide begins with guidance on the selection criteria for appropriate cotton genotypes suited to the North Zone, soil specific suitable cultivars with suitable plant architectural traits for realizing maximum yield. In addition, the importances of desi cotton varieties and hybrids have also been highlighted, along with GMS based hybrid seed production protocol and quality seed productions. Proper seed preparation techniques such as acid delinting and recommended seed treatment methods are described to ensure healthy crop establishment and protection against seed and soil-borne diseases during the initial growth stages. Land preparation always forms the foundation of a successful crop, guide explains appropriate field preparation techniques, crop rotation systems, and the importance of pre-sowing irrigation for achieving optimal soil moisture conditions. Appropriate sowing methods as per soil types, ideal time of sowing, recommended spacing, plant geometry, and seed rate are elaborated to ensure uniform stand and proper aeration.

North Cotton Growing Zone of India



Year	Lint kg/ha	Area (lakh ha)	Factors contributing towards productivity in North Zone
2012	**704.66**	**15.44**	The incidence of sucking pests remained low during the season. Some hybrids released during the 2010-11 performed very well.
2013	**729.45**	**13.75**	The incidence of sucking pests remained low during the season. Some hybrids released during the 2012 performed well. Moderate to severe incidence of CLCuD were observed in Punjab.
2014	**579.42**	**15.55**	Whitefly and CLCuD incidence was very high and was above ETL all through the crop season in North Zone. Moderate to severe incidence of CLCuD was observed at farmer's fields.
2015	**433.49**	**14.02**	The white fly incidence remained high in zone; Hot, humid and partly cloudy weather with intermittent rains in season contributed to higher incidence. Moderate to severe incidence of CLCuD was observed at farmer's fields particularly in Punjab.
2016	**589.74**	**13.26**	Whitefly infestation was low to medium level. Crop was healthy and Low to moderate incidence of CLCuD was observed.
2017	**623.70**	**15.40**	Whitefly along with thrips above ETL & dominated for a much longer period i.e. 5-6 weeks. These sucking pests crossed ETL and hotspots were noted at several places in zone and Low to moderate incidence of CLCuD was observed at farmers' fields particularly in Punjab.
2018	**624.92**	**16.05**	The incidence of sucking pests remained low, The Pink bollworm infestation was first time reported at adjoining field to ginning mills in Uchana, Jind district of Haryana. Low to moderate incidence of CLCuD was observed at farmers fields particularly in Punjab.
2019	**638.36**	**17.31**	In general the rainfall in the zone was deficit by around 40.0% but this late September more rains created problems of water logging, lodging and boll rotting at farmers field. The incidence of sucking pests remained low during the season.
2020	**571.99**	**17.99**	The incidence of sucking pests remained low; Thrips incidence was slightly higher. The pink bollworm infestation reported in 32nd SMW (06-12 August) & ranged between 5-10 % based on Green boll damage.
2021	**459.71**	**16.43**	The incidence of sucking pests remained low; thrips populations were recorded above ETL for 3-4 weeks continuously. The pink bollworm infestation reported in 30th SMW (23-29 July) & ranged between 5-10 % based on Green boll damage. Low incidence of CLCuD was observed .
2022	**437.60**	**16.39**	The whitefly infestation recorded above ETL and populations very high in few blocks of Punjab and Haryana. The infestation of CLCuD was very severe. Parawilt and root rot has also been observed in serious proportions. The Pink Bollworm infestations reported above ETL in the 29th SMW (16-22 July) and moderate to severe incidence of CLCuD was observed.
2023	**450.56**	**17.96**	The sucking pest infestations recorded on an average but pink bollworm and boll rot infestation were very high. The Pink Bollworm infestations reported above ETL in the 25th SMW (18-24 June) and damage reported 10-70 % in entire zone. Boll rot incidence was high and very low incidence of CLCuD was observed.
2024	**484.46**	**11.85**	Whitefly above ETL from 24th SMW (11-17 June) onwards, thrips 27th SMW (02-08 July) onwards and PBW 28th SMW (09-15 July) onwards. CLCuD incidence was moderate to high particularly in Rajasthan.
2025	**466.71**	**11.78**	Leafhopper above ETL, excessive rainfall, PBW and boll rot were reported, moderate CLCuD incidence were reported.

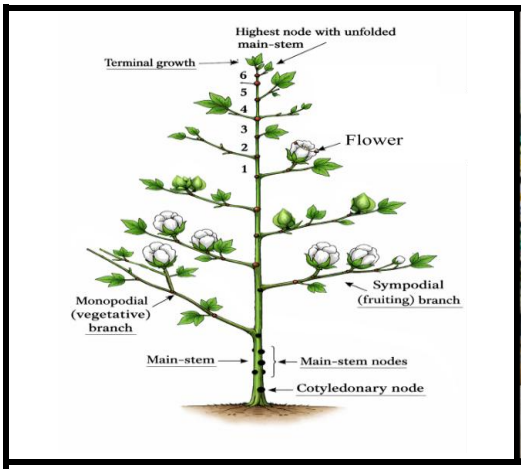
*Note: Factors identified based on local surveys, farmers feedbacks and research findings.

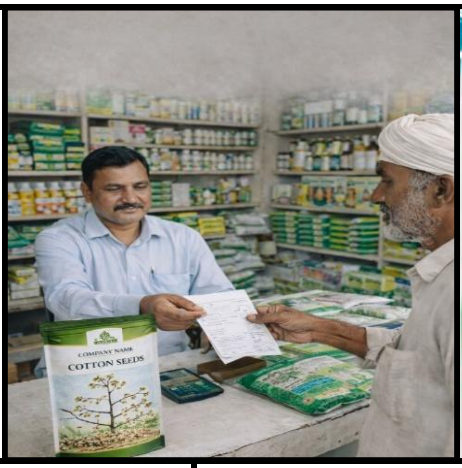
Yield and area source: The committee on cotton production and consumption (COCPC)

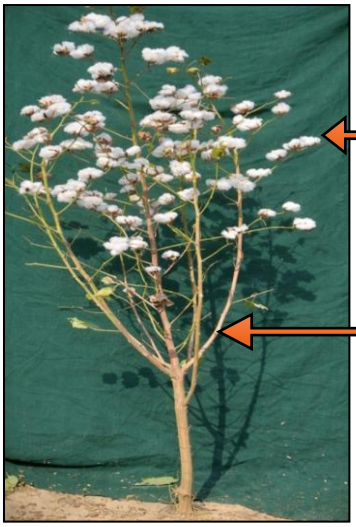
Seedling burning and low plant stand is a routine issue in zone, so instructions on gap filling using inherent soil moisture are also included in guide. Balanced nutrient management is another critical component covered in this guide. Detailed information on basal fertilizer application, recommended doses of macro-nutrients, and the importance of micronutrients along with visual symptoms of nutrient deficiencies will help farmers to identify problems. Integrated weed management practices, including identification of major seasonal and perennial weeds, along with appropriate pre and post-emergence control measures also been covered in the guide. This also outlines efficient irrigation scheduling, different irrigation methods, and proper drainage practices to prevent water logging stress. Canopy management techniques are described to regulate vegetative growth, improve light penetration to deter pest and disease infestations generally more pronounced in higher vegetative growth generally.

Emphasis has been placed on integrated pest management (IPM) strategies for major sucking pests and bollworms. The guide provides clear pictorial identification of pests as well as their life stages, damage symptoms, and economic threshold levels (ETL) based on both pest count and visible symptoms. Monitoring methods, including field scouting and use of traps, are described to promote need based pesticide application through proper decision making. Management strategies focus on a combination of cultural, biological, and chemical control measures to minimize resistance development and protect beneficial insects. Efforts have also been put to guide about major diseases affecting cotton, including Cotton Leaf Curl Disease (CLCuD), fungal infections, viral diseases, and nematode infestations. Guidelines for early detection, monitoring techniques, and integrated disease management practices are very crucial. The importance of natural enemies such as predators and parasitoids is highlighted to encourage conservation based approaches and reduce indiscriminate pesticide use. Precautions during spraying, avoidance of pesticide cocktails, and awareness about non recommended herbicides are also included to safeguard crop health, environmental safety, and farmer well-being. Harvest aids like defoliant application, clean picking, stalk shredding, and residue management have been explained to ensure better lint quality and reduce carryover of pests and diseases to the next season. Off-season monitoring and management strategies are emphasized to break the life cycle of insect pests and disease-causing organisms, thereby contributing to sustainable cotton production systems. The pictorial guide represents the collective efforts of group of scientists in compiling region specific; research based, and field validated recommendations. The Ready Reckoner with concise information supported with relevant photographs, aims to bridge the gap between technology development and disseminations at farmers' fields. Hopefully this pictorial guide will enhance farmers' knowledge, improve adoption of recommended practices, reduce input misuse, and ultimately increase cotton productivity and profitability in the North Zone.

Cultivar Selections for Better Cotton Productivity







Sympodial branch

Monopodial branch

Spreading genotype with more monopodias (Vegetative branch)

Semi-spreading genotype with less monopodias

Semi-compact genotype suitable for closure spacing

Compact genotype suitable for closure spacing

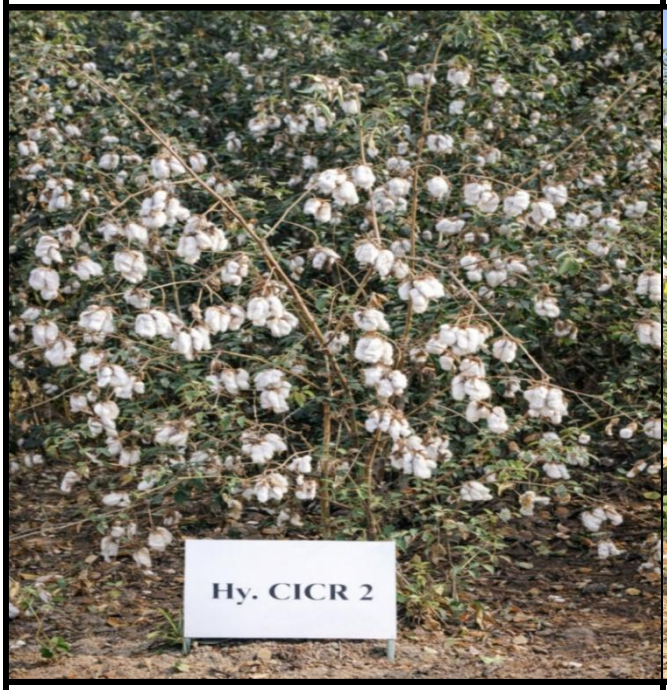
Cultivar Selections for Better Cotton Productivity

- Planning for cotton cultivation should be done in advance based on soil types, land availability for sowing and irrigation water availability.
- Grow only varieties/hybrids recommended by State Agricultural Universities/Department of Agriculture/ICAR-CICR.
- Always read the details mentioned on seed packets of Bt Cotton hybrids during purchase particularly for name of hybrid & seed company, batch or lot number, germination percentage (should be >80%), genetic purity (>98%), valid packaging and expiry dates and seed treatment information.
- Obtain bill printed originally from authorized dealers during purchase and retain the bills for record.
- All Cotton stakeholders should check color-coded certification tags while purchasing the seeds.
- Select cotton varieties/hybrids based on characteristics of the plants such as growth habit (Spreading/ Semi-Spreading /Compact), number of monopodial branches, plant height, boll pattern on sympodial branches, boll size, maturity duration etc.
- Higher yield may be realized by raising the compact varieties/hybrids in closer spacing with appropriate canopy management.
- Recommended varieties or hybrids of cotton should be selected based on the availability of irrigation water. If irrigation water availability is very less, preferred to grow desi cotton (*G arboreum*) varieties or American cotton varieties. In case of adequate availability of irrigation water, prefer to grow suitable Bt cotton hybrids.
- Recommended varieties/hybrids of cotton may be grown on soil types, early maturing genotypes may be preferred on medium/heavy soils.

Arboreum (Desi) Cotton Cultivar for Species Diversification

Desi Cotton Variety CICR 1

Desi Cotton Variety CICR 3



Desi Cotton Hybrid CICR 2

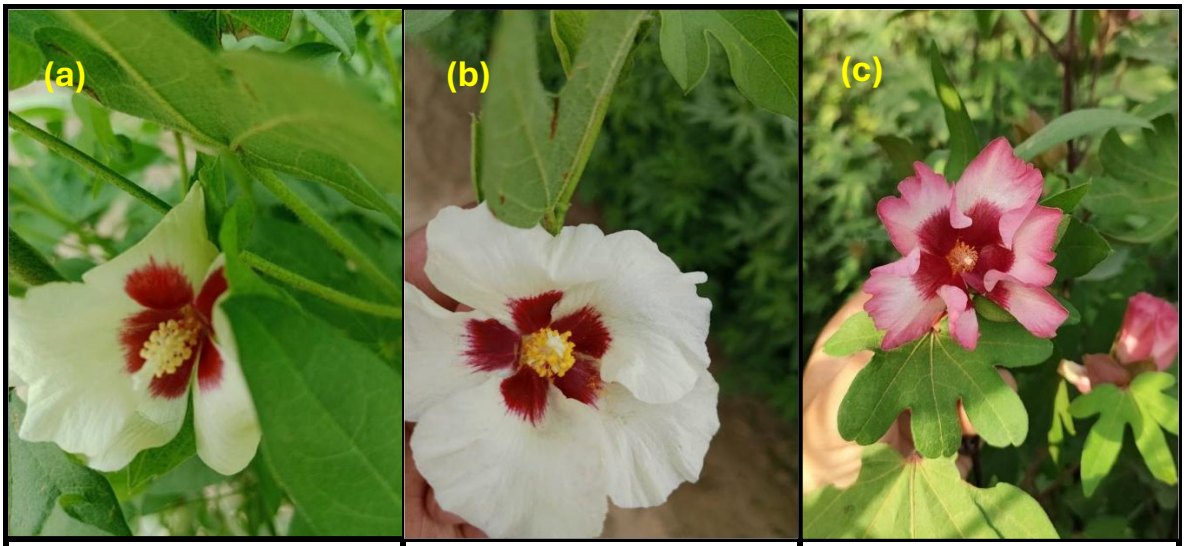
Desi Cotton Hybrid CICR 4

*CICR 4: recently identified hybrid in VIC -2025 on AICRP on Cotton

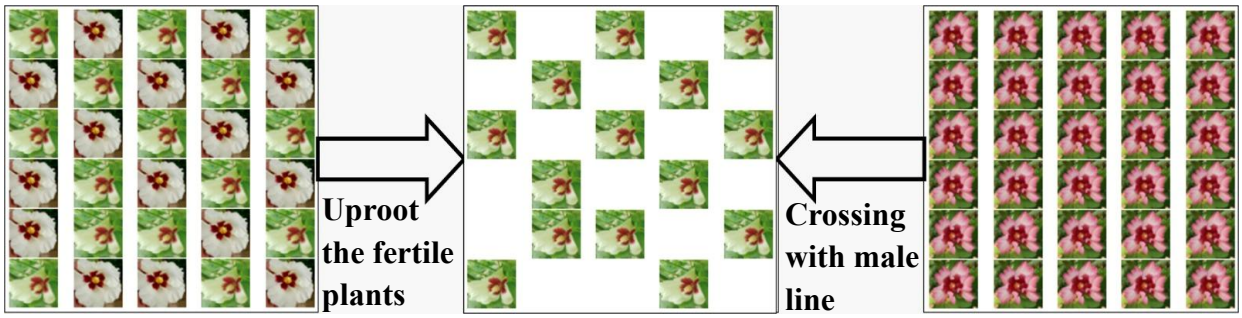
Arboreum (Desi) Cotton Cultivar for Species Diversification

- The unwavering faith of North Indian farmers in desi (*G. arboreum*) cotton for centuries reflects the extraordinary adaptability and climate resilience of this species.
- The natural surgical absorbent properties of its fibers benefit the public health services by reducing processing time and costs. Besides it, textile industries are also witnessing renewed interest in desi cotton in niche markets such as handloom, khadi and other indigenous cotton fabrics.
- Desi cotton is more adapted to marginal soils & low-input conditions and has inherent tolerance to many biotic stresses like leaf curl disease, sap-sucking insects and abiotic stresses like drought, high temperature, soil salinity etc.
- Desi cotton varieties like CICR 1, CICR 3, HD 423, HD 432, RG 18, RG 542, FDK 124, PBD 88 etc. can be grown in light soils with less water availability conditions.
- Desi cotton hybrids like CICR 2, AAH -1, FADH 9, RAJ.DH9 etc. can be grown in medium-heavy soils with adequate water availability situations.
- Prefer shattering tolerant genotypes to avoid multiple pickings and labor costs, desi cotton variety CICR 3 and hybrid CICR 2 developed by the station are known for their good shattering tolerance.
- Complete the sowing of desi cotton cultivars before 15 April to avoid seedling burning and maintaining the optimum population in fields.
- A blanket application of any recommended synthetic pyrethroids in first fortnight of July month to prevent spotted bollworms is advised and then use 2% KNO_3 (13:0:45) spray for proper flowers and bolls development in reproductive phase for higher yield of quality seeds.

Hybrid Seed Production in Desi Cotton



Male-sterile flower of the female line	Fertile flower of the female line	Flower of the male line
GMS based hybrid seeds CICR 2		

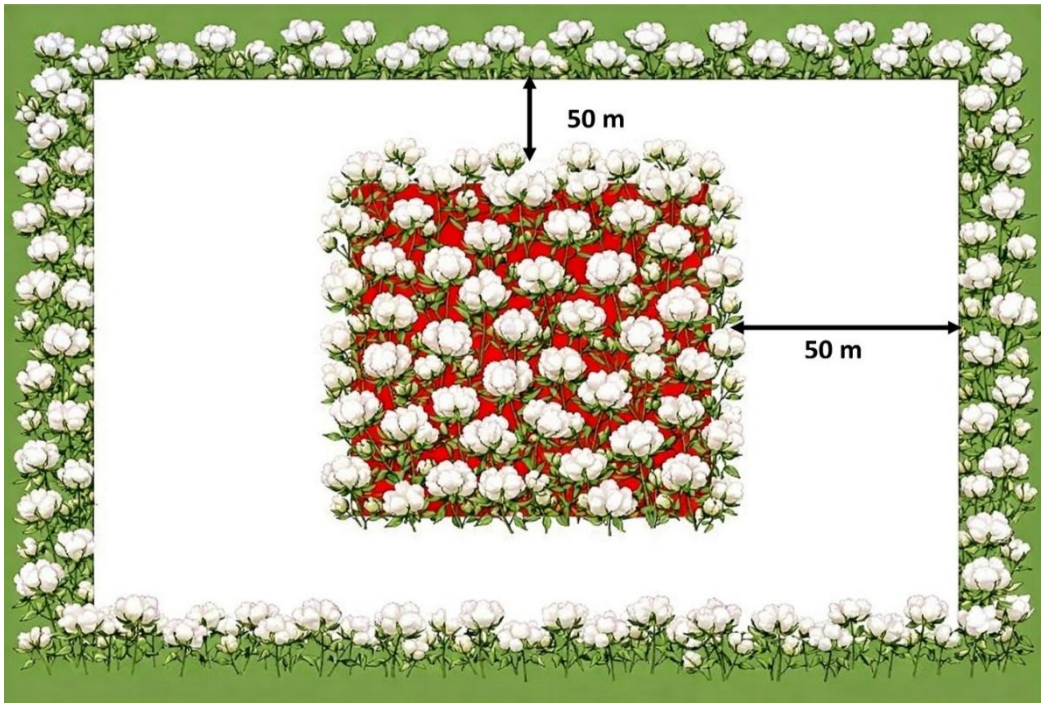


Crossing with male line should be performed after uprooting the plants with fertile flowers in female lines for producing the hybrid seeds

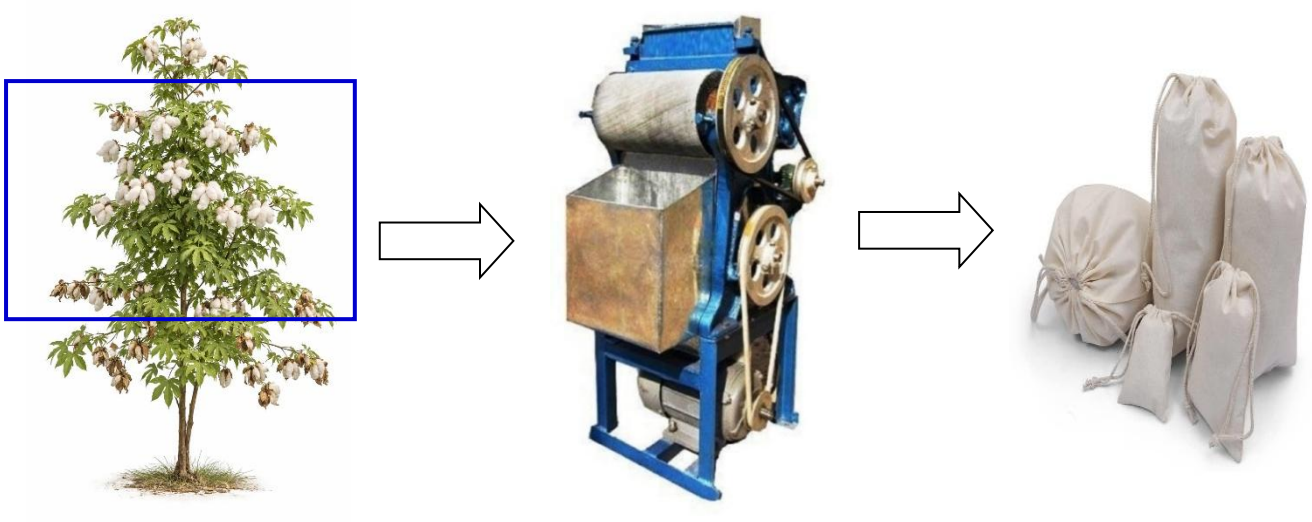
Hybrid Seed Production in Desi Cotton

- Cotton stakeholders can produce seed of GMS based desi hybrids like CICR 2 in their fields as it does not require emasculation in female lines and due to the distinct characteristics of the male and female lines, it requires comparatively less maintenance.
- Sow the female and male lines of the hybrid in 8:2 or 6:2 ratio in seed production plot and ensuring no other desi cotton field exists within a radius of 50-meter of the seed production plot.
- Apply heavy pre-sowing irrigation in deep ploughed soils and complete the sowing before 15th April and raise the crop as per recommended package of practices.
- Prior to initiation of crossing, identify and remove fertile plants (plants bearing male reproductive parts) from the female lines as soon as flowering begins.
- In the morning hours (8.00 -11.30 AM), perform crossing by touching one male flower (collected from the male line) to 4–5 female flowers.
- Spray 2% Potassium Nitrate (KNO_3) 13:0:45 at the time of 10% flowering and repeat the spray at 10 days intervals to ensure proper boll development. Additionally, 2% DAP or NAA 4.5 SL @ 21 ppm may also be applied as needed.
- At the appearance of the first flower on 10% of the plant, spray any synthetic pyrethroid insecticide for the management of spotted bollworm, such as Cypermethrin 10 EC @ 500 ml, Cypermethrin 25 EC @ 200 ml, Deltamethrin 2.8 EC @ 400 ml or Fenvalerate 20 EC @ 250 ml per hectare.
- For better seed quality, pick fully mature bolls between 140 to 150 days after sowing.
- First, pick the bolls from the male lines and store them separately. After that, carefully pick the crossed bolls and place in a dry area protected from direct sunlight and moisture.

Quality Seed Production in Cotton



Proper isolation must be maintained for particular seed production variety plot



Better opened bolls harvested from medium stratum of plants should be ginned and stored separately in low humidity conditions

Quality Seed Production in Cotton

- Farmers can undertake seed production program of Desi cotton (*G arboreum*) and American cotton (*G hirsutum*) varieties in their fields.
- Seed production for recommended varieties/hybrids should be done with state specific recommended package of practices.
- The Seed production plot should be isolated from other cotton fields by a distance of 50 meters on all sides for breeder seeds and 30 meters for certified seeds class.
- Proper plant spacing (row to row and plant to plant) should be maintained for appropriate genotype expression in field conditions.
- To maintain genetic purity, remove off-type plants at preferably flowering stage, based on differences in plant height, leaf shape, leaf color, stem color, flower color, petal spot, pollen color, boll shape and other distinguishing characteristics.
- Cotton picking for seed production should be carried out 140–150 days after sowing. Select large-sized and fully matured bolls from medium stratum of plant for better germination and vigor of seeds. Ensure that picked cotton is free from leaves, plant debris, and damaged plant parts.
- Keep seed of cotton of each variety separately and avoid mixing with other varieties. Clean the storage area properly before keeping the produce and seeds should be stored in a moisture-free and dust-free place.
- Each variety/hybrid should be ginned separately to avoid mixing seeds of other varieties. Always clean the ginning machine thoroughly after processing each variety. Proper tagging should be done after ginning.
- Seed may be stored in gunny bags, cloth bags and earthen plots. Seeds should be stored under low temperature and low humidity conditions for maintaining the seed viability.

Prominent Crop Rotations with Cotton

			
Cotton-Wheat		**Cotton-Mustard**	
			
Cotton-Chickpea		**Cotton-Barley**	
			
Cotton-Berseem		**Cotton-Sunflower**	

Prominent Crop Rotations with Cotton

Cotton can be successfully rotated with the Rabi crops under one year rotations as mentioned below:

- Cotton – Wheat
- Cotton – Barley
- Cotton – Sunflower
- Cotton – Barseem (fodder)
- Cotton – Mustard (Raya)
- Cotton – Chickpea (Bengal gram)

Climatic Requirements for successful cotton cultivation:

Cotton being a Kharif season crop for North Cotton Growing Zone of India has climatic requirements as mentioned below:

- Uniformly high temperature varying between 21°C and 32°C.
- Warm days and cool nights with large diurnal variations especially during the period of fruiting, boll & fibre development.
- Picking period must have bright sunny days to ensure good quality cotton.

Field Preparation

Implements	Functions
	
Chisel plough	Breaking of the hard pan with chisel plough
	
MB (Mould Board) plough	Inversion of soil with MB plough
	
Disk harrow	Field prepration with disk harrow
	
Cultivator	Pulverization of soil with cultivator
	
Planker	Clod crushing and leveling with planker

Field Preparation

(A) Soil types suitable for successful cotton cultivation: For North Zone of India, cotton can be successfully grown on all type of soils, except the very sandy soils, saline soils or waterlogged soils, and proper drainage of excess water during rains is essential in fields.

(B) Breaking the hard pan / Sub Soiling:

- Plough the field with mould board (MB) plough for deep ploughing before preparing the field for cotton sowing.

  OR

- Plough the field with sub-soiler / chisel plough cross at 1.0 m spacing.

Benefits of sub-soiling / deep ploughing: Help in breaking the hard pan, increasing water infiltration, better root development of cotton plants & prevents crop lodging and reduce parawilt in cotton.

(C) Secondary Tillage:

- Usually 2-3 rounds of cultivation are required to achieve the necessary soil texture for cotton. If the soil is particularly heavy or clay-rich, the disc harrow should be followed by cultivator to further refine the seedbed. This operation must be performed after the MB Plough. Planker (*Suhaga*) should be operated to ensure adequate clod crushing.

(D) Pre-sowing irrigation (*Rauni*):

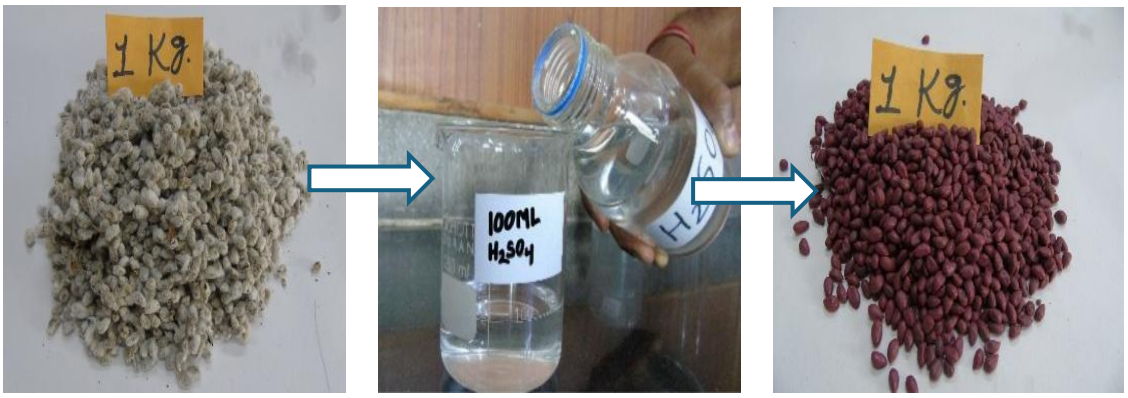
- For better germination and early establishment of plants apply heavy pre-sowing irrigation with canal or good quality tubewell irrigation waters.

(E) Final Seedbed Preparation:

- **The "*Wattar*" condition:** After pre-sowing irrigation (*Rauni*), wait for the soil to reach the *Wattar* (workable moisture) condition. This is the precise moment when the soil is dry enough for machinery to pass without causing compaction, yet moist enough to ensure seed germination.
- Once the field reaches *Wattar*, plough up the field with cross cultivation with tillers 2 times follow up with the Planker (*Suhaga*) to seal the surface and conserve that moisture for the sowing phase

Seed Treatment in Cotton Crop

Delinting



Seed with lint | **Treating with H_2SO_4** | **Delinted seeds**

Delinted seed washed with lime water and then clean water

Drying in shade

Different Treatments

Fungicide	Insecticide	Bio-agent

Seed treatment in Cotton crop

1. **Delinting of Seeds**
   Removal of lint using 100 ml concentrated sulphuric(H_2SO_4) per kg seed. Then wash, neutralize (lime water), and dry the seeds. The majority of certified seeds are already acid delinted.

2. **Selection of Healthy Seeds**
   Choose certified, clean, and well-filled seeds. Remove damaged, diseased, or shrivelled seeds to ensure good field emergence and uniform crop stand.

3. **Fungicide Treatment**

   Protects against damping-off, seedling blight, and root rot
   - Carbendazim @ 2 g/kg seed, or Thiram @ 3 g/kg seed, OR
   - Carbendazim + Thiram @ 2–3 g/kg seed, OR
   - Sedaxane 2.5%+ Fludioxonil 2.5% +Thiamethoxam 26.25% W/V @ 4ml/10 ml water for 1 kg seed.

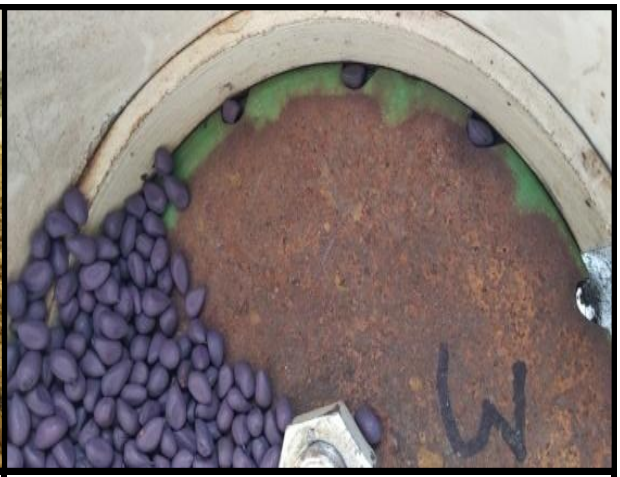
4. **Insecticide Treatment**
   Protects seedlings from sucking pests and termites
   - Imidacloprid 70 WS @ 5 g/kg seed, OR
   - Thiamethoxam 30 FS @ 7 g/kg seed

5. **Bio-agent / Biofertilizer Treatment**
   Coat seeds with beneficial microbes like *Trichoderma* or *Pseudomonas*. These suppress harmful pathogens, promote root growth, and improve nutrient uptake.
   - *Trichoderma viride / T. harzianum* @ **5-10 g/kg seed**
   - *Pseudomonas fluorescens* or biofertilizer @ **10-50 g/kg seed** (solid formulation)

6. **Shade Drying of Treated Seeds**
   Spread treated seeds in a thin layer on clean surface and dry in shade for 30-60 min. This helps chemicals adhere properly, uniformly and maintains the viability of both seed and bioagents.

Sowing of Cotton Crop

➢ Cotton Sowing Machinery

	
Cotton sowing with inclined plate planter	**Close-up view of inclined plate along with seed**
	
Cotton sowing with pneumatic planter	**Manual sowing by dibbling method**

➢ Cotton seed sowing

(A) Time of Sowing:

- Sow the crop from 1st April to 15th May.
- Sowing during this period ensures better yield and escapes the attack of insect pests and diseases.
- Sowing should be done in the morning and evening hours.

(B) Cotton Sowing Machinery:

i. Tractor operated Pneumatic Cotton Seed Planter-cum-Fertilizer Drill
ii. Tractor operated inclined plate planter-cum-Fertilizer Drill
iii. Tractor operated walk-behind cotton seed-cum-Fertilizer Drill (Seeds are manually dropped in the seed hoppers)
iv. Manually operated mechanical seed dibblers

Note:

i. If Bt cotton seed is to be sown, to avoid the development of resistance in bollworms against Bt cotton, non-Bt cotton seeds provided separately should also be planted as a structured refuge. Cultivate 20 percent area with non-Bt cotton seeds around Bt cotton area under bollworm protection conditions or 5% under unprotected conditions.

ii. Nowadays "Refugia-in-bag" technique having 5-10 percent mixture of Non-Bt seed with Bt seed available in the market, does not require any separate sowing.

➢ Seed Rate

The seed rate should be followed as per the table mentioned below:

States	Desi Cotton (Desi kapas) (per hectare)		American Cotton (Narma) (per hectare)		American Bt-Cotton (Narma) (per hectare)	
	Varieties	Hybrids	Varieties	Hybrids	Varieties	Hybrids
Haryana	7.5 kg	3.125 kg	8.75 - 10.0 kg	3.75 kg	10.0 kg Bt seed + (Recommended N-Bt as refuge)	2.375 - 2.970 kg
Punjab	7.5 kg	3.125 kg	8.75 - 10.0 kg	3.75 kg	10.0 kg + 2.5 kg refugia	2.375 - 2.970 kg
Rajasthan	11.25 - 15.0 kg	3.125 kg	8.75 - 10.0 kg	3.75 kg	--	2.375 - 2.970 kg

#Source: Package of Practices of respective State Agricultural Universities.

➢ Sowing and Spacing

To maintain optimum plant stand, spacing mentioned as below should be followed:

Crop	Haryana			Punjab			Rajasthan		
	R x R (cm)	P x P (cm)	~Total Plants per ha	R x R (cm)	P x P (cm)	~Total plants per ha	R x R (cm)	P x P (cm)	~Total Plants per ha
Desi Cotton (Desi kapas) Varities	67.5	30	49,382	67.5	45	32,921	67.5	30	49,382
Desi Cotton (Desi kapas) hybrids	67.5	60	24,691	67.5	60	24,691	67.5	60	24,691
American Cotton (Narma) varieties	67.5	30	49,382	67.5	60	24,691	67.5	30	49,382
American Bt & Non Bt Hybrids Narma	100 / 67.5	45 / 60	22,222 / 24,691	67.5	75	19,753	108 / 67.5	60 / 90	15,432 / 16,460
American Cotton HDPS (Narma)	67.5	15	98,765	67.5	15	98,765	67.5	15	98,765

#Source: Package of Practices of respective State Agricultural Universities.

Sowing Phase (April 1 – May 15): Successful establishment depends on precise depth (3-5 cm) and timing during this six week window.

➢ Sowing Methods

Flat sowing

Narrow raised bed sowing (Cotton sown on bed top)

Narrow raised bed sowing (Cotton sown in furrow)

Broad raised bed sowing (Cotton sown on one side of bed)

Broad raised bed sowing (Cotton sown on both sides of bed)

➢ Sowing Methods

Cotton sowing can be done with the following methods under North Cotton Growing Zone of India:

- Flat sowing method: Sowing on leveled flat lands.
- Ridge and furrow: Ridges and furrows can be made with tractor operated ridge-furrow maker.
- Narrow raised bed sowing: Narrow raised beds and furrows can be made with tractor operated narrow raised beds-furrow maker.
- Broad raised bed sowing: Broad raised beds and furrows can be made with tractor operated broad raised beds-furrow maker.

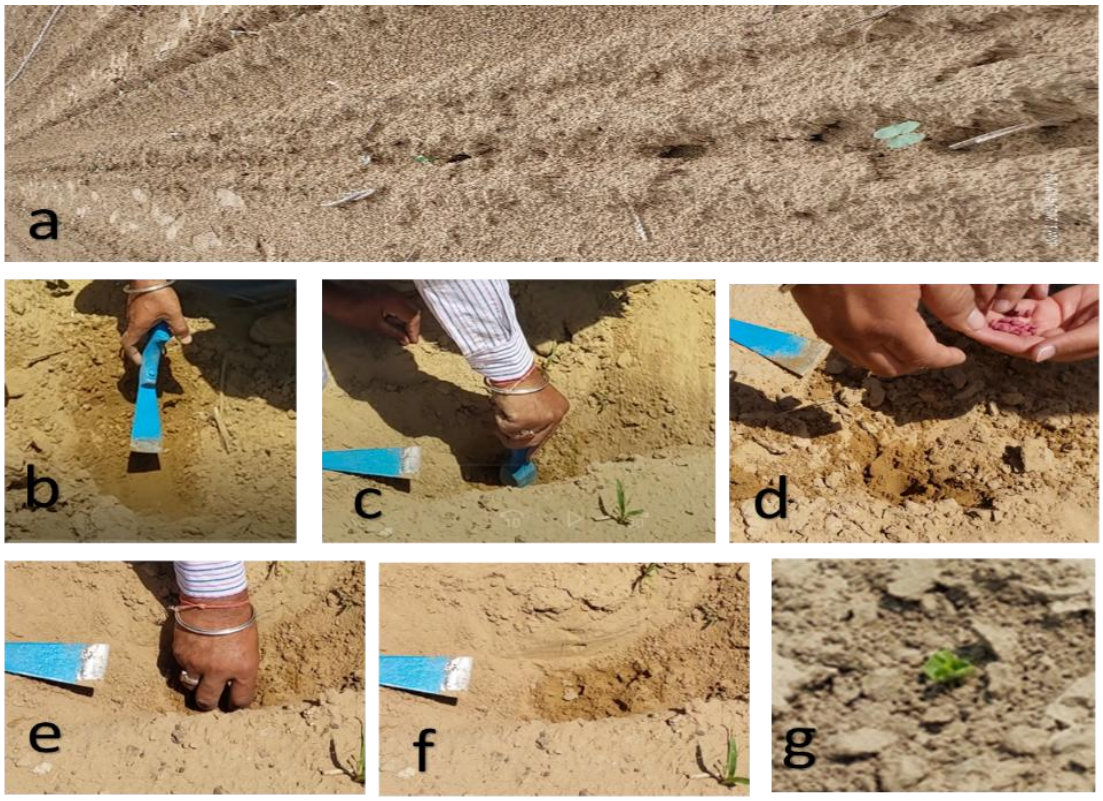
Note: Sowing can be done either on bed top or at the bottom of furrow or either on one side of broad bed or on both sides of broad bed with minor seeding mechanism adjustments depending upon cotton genotypes, soil types and irrigation water quality & availability.

Note:

i. Cotton seed sowing can be done either on flat surface lands or on ridges / beds or in furrows with minor seeding mechanism and bed shaper / bed maker adjustments in any type of cotton seed planters / drills.

ii. Cotton seed sowing can be done either on flat surface lands or on ridges / beds or in furrows manually be dibbling method after complete field preparation (after pre-sowing irrigation and at proper *Wattar* conditions). If sowing is to be done on ridges / beds or in furrows, then ridges-furrows or bed-furrows are made with tractor operated ridges-furrow or bed-furrow makers, after that sowing is done by dibbling method or by manually operated mechanical seed dibblers.

Gap Filling in Cotton Crops to Maintain the Optimum Plant Stand



Gap filling procedure: **(a)Field gaps in a row, (b) Removing the dry soil at the point of non-germinated seed spots, (c) Making hole with dibbler , (d –e -f) sowing the seeds and (g) seed germination after 4-5 days.**

Healthy crop with proper plant stand

Gap Filling in Cotton Crops to Maintain the Optimum Plant Stand

In cotton, a great scope is there to obtain good yield by maintaining proper plant stand. The technology "Gap filling technology for better crop establishment in inherent soil moisture" consists of gap-filling by manual operations using inherent field soil moisture. It is simple, less time, input and labour-consuming wherein 1-2 manpower can easily implement 10-20% gap-filling using inherent soil moisture in one hectare in a day depending upon the field gaps. Gap-filling using inherent moisture within 7-10 DAS has scope as a better alternative for maintaining proper plant stand and getting good cotton yield.

Technical guidelines and Methodology

I. Identify the field gaps/spots 5-8 days after sowing where seeds have not germinated
II. Soak the seed in water for about 2-4 hours
III. Remove the upper dry soil up to the soil moisture level on these spots
IV. Make the hole using seed dibber. If soil is harder for making holes, use trowel to make soil softer prior to seed sowing while maintaining soil moisture.
V. Sow 1-2 seeds in each hole and cove it gently with moist soil
Seeds will start germinating after 4-5 days, like the initial sowing.

Technical, agronomic advantages

This method outperforms traditional gap-filling practices by aligning with the plant's natural growth cycle. Unlike early irrigation (before 45 DAS), which can stunt root depth, this method utilizes existing moisture, encouraging robust taproot penetration. This gap-filling technology utilizes inherent soil moisture to ensure a robust, uniform cotton crop without the need for nurseries or supplemental irrigation.

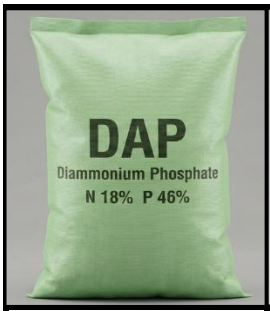
Nutrient Deficiency Symptoms in Cotton Plant

		
K-Deficiency	**Zn- Deficiency**	**S-Deficiency**
		
Mg-Deficiency	**B- Deficiency**	**N-Deficiency**
		
Fe-Deficiency	**P-Deficiency**	**Ca-Deficiency**

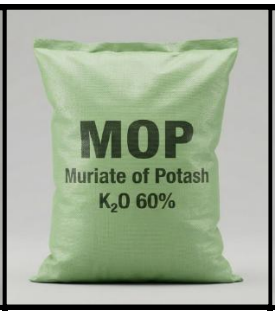
Nutrient Deficiency Symptoms in Cotton Plant

Nutrient	Deficiency symptoms
Nitrogen (N)	Symptoms of cotton N deficiency normally appear on older leaves first, and then rapidly move from older to younger parts of the plants. At the beginning, old leaves become uniformly pale green, pale yellow, then turn yellow, and develop brown necrosis areas.
Phosphorus (P)	Deficiency symptoms of this nutrient appear first on lower or older leaves and further upwards on a stalk. A purple pigmentation develops on the leaf margins and proceeds into interveinal tissues of leaves in severe cases, and then older leaves will be in chlorosis, necrosis, and abscission.
Potassium (K)	The deficiency symptoms of potassium often occur first at the bottom of the plant on the older, lower, or mature leaves. The leaves become brown reddish, the tips of leaves curl and break down. Normally, K deficiency symptoms may develop on mature leaves of the upper canopy after flowering commences K deficiency symptoms can also be found on young cotton leaves at the top of the plant and spread from the top to the bottom during flowering and boll development.
Magnesium (Mg)	Leaves become reddish and the veins remain green. The typical symptoms first present on older and mature leaves.
Calcium (Ca)	During this deficiency the cotton crops affected during the maturity stage. The leaf of cotton becomes crinkled. The upper leaves first become yellowish green with purplish ting and squares & young bolls become dry.
Sulfur (S)	The deficiency symptoms are first evident and more pronounced on younger leaves, while older leaves remain green. Young leaves become light green to yellow in colour.
Iron (Fe)	The deficiency symptoms show yellowing of top cotton leaves. Chlorosis first appears in the young leaves in the form of light yellowish spots between the veins, and then the younger leaves turn pale green to pale yellow, while the older leaves remain green and normal.
Zinc (Zn)	The plant also shows a shorter appearance. A typical Zn deficiency symptom of “little leaf” and inward curling of top leaves is evident in cotton. The main symptoms in cotton are chlorosis and malformation of young leaves and a general bronzing in the first true leaves.
Boron (B)	B- deficiency symptoms appear at the apex of the plant and on the fast-growing leaves; dieback of terminal growth, excessive drying and shedding of squares and young bolls.

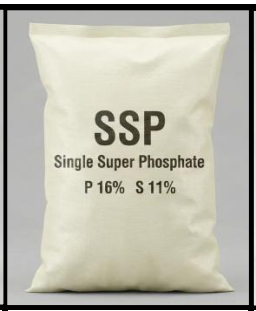
Nutrient Management in Cotton



DAP fertilizer



MOP fertilizer



SSP fertilizer

Urea fertilizer

Zinc sulphate fertilizer

Potassium nitrate fertilizer for foliar spray application

Magnesium sulphate fertilizer

➢ Methods of fertilizer application in cotton

Manual top dressing (broadcasting)

Manual top dressing (spot application)

Drilling of fertilizers in soil near root zone with tractor operated intercultivator-cum-fertilizer drill

Surface broadcasting with tractor operated broadcaster as basal fertilizer application

Foliar spray application of nutrient solutions by tractor operated power sprayer

Nutrient Management in Cotton

Fertilizer doses recommended by State Agricultural Universities of Haryana, Punjab and Rajasthan are as follows:-

Crop	Fertilizers	Fertilizer (kg per acre)		
		Punjab	Haryana	Rajasthan
Hybrids of American and *Desi* cotton	Urea	90	150	130
	*D. A. P.	27	50	35
	*S. S. P	75	150	100
	M. O. P.	--	40	14
Bt and Non-Bt varieties of American cotton and *Desi* cotton varieties	Urea	65 (Non-Bt varieties of American cotton)	45 (*Desi* cotton)	78 (*Desi* cotton)
		80 (Bt varieties of American cotton)	75 (Non-Bt varieties of American cotton)	87 (Non-Bt varieties of American cotton)
	*D. A. P.	27	(*Desi* cotton)	18 (*Desi* cotton)
			27 (Non-Bt varieties of American cotton)	35 (Non-Bt varieties of American cotton)
	*S. S. P.	75	(*Desi* cotton)	50 (*Desi* cotton)
			75 (Non-Bt varieties of American cotton)	100 (Non-Bt varieties of American cotton)

*Apply either DAP or SSP as Phosphorus source.
#Source: State Agricultural Universities of Haryana, Punjab and Rajasthan.

- Apply balanced and recommended doses of fertilizers in the crop based on soil test report.
- Avoid excessive use of nitrogenous fertilizers.
- Apply 10 kg zinc sulphate heptahydrate (21%) or 6.5 kg zinc sulphate monohydrate (33%) per acre to cotton at sowing.
- Apply 20 kg muriate of potash per acre in light soils of Punjab.
- Drill all phosphorus at sowing. Apply half nitrogen at thinning and remaining half at the appearance of flowers.
- If the soil is low in fertility, the first half dose of nitrogen may be applied at sowing instead of at thinning.
- Apply 400 g boron (4 kg borax) per acre at sowing in boron-deficient soils.
- To get higher yields, give 3-5 sprays of 2% potassium nitrate (13:0:45) at weekly intervals starting at flower initiation.
- For high yield and management of leaf reddening in Bt cotton, give 2 sprays of 1% magnesium sulphate (2.5 kg magnesium sulphate in 250 litres of water per hectare) at 15 days interval during full bloom and boll development stages. Apply 25 kg magnesium sulphate as basal dose at the time of sowing.
- Do not allow the crops to come under nutrient deficiency stress during its peak squaring, flowering and boll formation stages during July-August.

Weeds Identification and Management

➢ Major weed flora in cotton

		
Cyperus rotundus **(Motha)**	*Trianthema portulacastrum* **(Itsit)**	*Cynodon dactylon* **(Doob ghas / Khabbal ghas)**
		
Dactyloctenium aegyptium **(Gurta ghas)**	*Echinochloa crusgalli* **(Swank/Deela)**	*Cucumis trigonus* **(Chibber bel)**
		
Digeria arvense **(Tandla)**	*Tribulus terrestris* **(Bhakhkhra)**	*Ipomoea* spp. **(Lapeta bel)**
		
Cleome viscosa **(Hulhul)**	*Euphorbia microphylla* **(Chhoti dhoodhi)**	**Regrowth of** *Cyperus rotundus* **(Motha) after manual weeding**

➢ Weed Management

(A). Mechanical Weed Control:

- Manual weeding and hoeing should be done in the crop two or three times depending upon weed infestation as per requirements.
- The first hoeing should be done before first irrigation.
- Tractor operated cultivator / tractor operated rotary weeder / *triphali* or wheel hand hoe / *Kasaula* for weeding.
- Animal (bullock / camel) operated *triphali* can also be used.
- Use of tractor / animal operated weeder / *triphali* after fruiting should be avoided.

(B). Chemical Weed Control:

(i). Pre-emergence herbicide application:

- For control of weeds apply Pendimethalin 30 EC @ 2.5 litre per hectare as pre-emergence within 24 hours of sowing.
- Use 500 litre of water per hectare for its spray application with flat fan nozzle either in the morning or evening hours.
- Ensure a fine seedbed with adequate moisture in the field at the time of spray of herbicide.

(ii). Post emergence herbicide application:

- Spray Pendimethalin 30 EC @ 2.5 litre per hectare as post-emergence after first irrigation in 500 litre of water per hectare, if weeds emerge after first irrigation or with the rain. Remove the emerged weeds by hoeing & weeding / intercultural operations before spraying Pendimethalin.
- Or spray Pyrithiobac sodium 6% + Quizalofop ethyl 4% 10 MEC @ 1,250 ml per hectare by dissolving in 375 litres of water after first irrigation, in moist soil, to control annual grass and broadleaf weeds.
- Or spray Paraquat 24 SL @ 1,250 ml per hectare or Glufosinate ammonium 13.5 SL @ 2,250 ml per hectare in 250 litres of water as a directed spray to control weeds in between the crop rows. The directed spray can be done by using a protective hood.
- Paraquat and glufosinate are non-selective herbicides and cause injury to the crop if these fall on the crop leaves.

➢ Intercultural operations for mechanical weed control in cotton

		
Intercultural operation with camel operated *Triphali*	**Intercultural operation with engine operated power weeder**	**Intercultural operation with tractor operated inter-row rotary weeder**
		
Intercultural operation with tractor operated inter-row *Triphali*	**Field view after intercultural operation with tractor operated inter-row *Triphali***	**Manual hoeing and weeding with long-handled hoes (*Kasola*).**

➢ Intercultural operations for mechanical weed control in cotton

- Manual weeding and hoeing can be done in the crop two or three times depending upon weed infestation as per requirements with wheel hand hoe / *Kasaula*.
- Animal (bullock / camel) operated *triphali* can also be used.
- Tractor operated cultivator (*triphali)* can be used for intercultural operations.
- Tractor operated rotary weeder can be used for intercultural operations during early stages of crop growth.
- Engine operated power weeders can be a good option for weeding and intercultural operations during early stages of crop growth.
- Use of tractor / animal operated weeder / *triphali* after fruiting should be avoided.

Irrigation and Drainage

➢ Methods of irrigation in cotton

	
Pre-sowing irrigation	**Field after the *Wattar* condition (after ploughing and planking)**
	
Sprinkler irrigation	**Drip irrigation**
	
Flood irrigation	**Furrow irrigation**

➢ Irrigation

The artificial application of water to the soil or agricultural land which fulfills the demand for water is known as irrigation. Cotton requires 4-6 irrigations depending upon the seasonal rainfall.

- **Pre-sowing Irrigation (*Rauni*):**
  - A heavy irrigation must be applied before sowing to ensure the soil profile is fully charged with moisture, which is essential for uniform germination.
  - **The "*Wattar*" condition:** After irrigation, wait for the soil to reach the *Wattar* (workable moisture) condition. This is the precise moment when the soil is dry enough for machinery to pass without causing compaction, yet moist enough to ensure seed germination.
- ***Post Sowing Irrigations:**
  - **First Irrigation:** For optimal root development, the first irrigation should typically be delayed until 6–7 weeks after sowing. This encourages the roots to penetrate deeper into the soil. On light textured / sandy soils or in crops sown on ridges, the first irrigation may be advanced, if necessary.
  - **Subsequent Irrigations:** Further water applications should be based on the crop's physiological needs and local weather & soil conditions at an interval of two or three weeks. For better understanding of irrigation requirement observe the crop in morning hours avoiding peak mid day hours.
  - **Critical Stages:** Ensure the crop does not face moisture stress during the flowering and boll development stages, as this can lead to square and boll shedding.
  - **Termination:** All irrigation activities must be stopped by the end of September to allow the crop to mature naturally (to hasten the boll opening) and prevent a delay in harvest.

Note: The above mentioned irrigation schedule is for flood and furrow irrigation systems. For drip and sprinkler irrigation separate schedule is to be followed.

Methods of irrigation: The irrigation water can be applied with the following methods: (i) Flood irrigation (ii) Furrow irrigation (iii) Sprinkler irrigation (iv) Drip irrigation

➢ Water logging damage in cotton

Damage of cotton crop due to water logging

Damage of cotton seedling due to water logging

Yellowing of cotton crop after heavy rainfall and water drainage

➢ Water logging damage in cotton and field drainage

- Cotton crops are very sensitive to water stagnation especially during its early growth stages.
- Draining out of the stagnant water as early as possible is very essential, especially in the heavy textured soils and low lying areas.
- Water stagnation for more than 24 hours can cause root suffocation and trigger physiological disorders.
- Fields must be levelled (ideally with a Laser Land Leveller) and have an efficient drainage system to quickly remove excess rainwater.

After drainage:

- Give foliar sprays of 2% potassium nitrate (13:0:45) / 2% urea solution at weekly interval for quick recovery of the crop.
- Give light hoeing to open up and loosen the soil surface whenever the field soil reaches the workable condition (only if the crop is at early growth stages and intercultural operations are feasible).

Canopy Management

		
Excessive growth of cotton	**Detopping of cotton plant**	**Monopods Removed**
		
Cotton crop with mepiquat chloride application (background without mepiquat chloride)	**Internodal distance after mepiquat chloride application**	**Internodal distance without mepiquat chloride application**

Crop lodging-

	
Crop lodging due to heavy rain and strong winds	

Canopy Management

➢ Excessive vegetative growth in cotton:

- In heavy soils and canal irrigated areas, cotton attains excessive vegetative growth during rainy season.
- Excessive vegetative growth in cotton may cause crop lodging due to heavy rainfall and windstorms.

1. **Growth Regulators (Plant Growth Retardants):** Growth regulators are used to restrict excessive plant height and promote the translocation of nutrients to the bolls.
    - **Mepiquat Chloride:** Apply @ 300 ml per acre when the crop is 60 & 75 days old if the plants show excessive vegetative growth in high fertility soils, under canal irrigation or high rainfall.
    - **Purpose:** It reduces internodal length, making the plant more compact and reduces excessive vegetative growth.

2. **Detopping:** Detopping is the removal of the terminal growing point (terminal bud) to stop further vertical growth.
    - **Timing:** Perform this when the plant reaches a height of 100–120 cm or approximately 90–100 days after sowing.
    - **Method:** Manually nip off the top 2–3 cm of the main stem.
    - **Benefit:** This diverts the plant's energy from excess vegetative growth promoting the development of more sympodial (fruiting) branches and ensuring better boll filling.

3. **Monopodia Removal:** Monopodial branches are vegetative branches that do not directly bear flowers but consume significant nutrients.
    - **Practice:** Removal of early-stage monopodial branches (usually the first 2–3 branches from the base) allows the plant to focus on sympodial (fruiting) branches.
    - **Benefit:** This improves aeration within the field, reduces the micro-climate favorable for pests like whitefly and makes manual picking easier.

Caution: In North Indian conditions, if the plant population is already low (gap-filled areas), keep the monopodia to ensure the canopy covers the ground.

➢ Square shedding in cotton

Square (fruiting bodies) shedding in cotton

➢ Square shedding in cotton

As cotton is very sensitive to abiotic stresses especially during the reproductive stages (i.e. squaring, flowering and boll formation) and has the most drastic effect on the yield due to shedding of fruiting structure. Square shedding in cotton is a significant concern for farmers, as it can lead to r educed yields. Square shedding occurs when the hydrolytic enzymes cellulase and pectinase weaken cell walls and middle lamellae of cells in the abscission zone at the base of the pedicel. Any condition that increases shedding must increase the activity of these enzymes. The hormonal regulated shedding rate can be slow down by the application of their inhibitors. The exogenous application of plant growth regulators and osmo-regulators has been considered as a shotgun approach to withstand the ill-effects of abiotic stresses. To minimize the square shedding in cotton the following measures can be taken:

- Spray Naphthalene Acetic Acid (NAA) – Planofix 20 ppm (7ml / 15 litre water) twice at 15 days interval during peak squaring and flowering stages.
- Give 4 sprays of 2% potassium nitrate (13:0:45) at weekly interval starting at flower initiation.
- Give 2 sprays of 1% magnesium sulphate (1 kg magnesium sulphate in 100 litres of water per acre) at 15 days interval during full bloom and boll development stages.

Physiological Disorders and Injuries in Cotton

➢ Salinity damage in cotton

		
Cotton damaged in salt affected soils	**Symptoms of salt injury in cotton**	**Cotton damaged in salt affected soils**
		
Symptoms of salt injury in cotton	**Furrow sown cotton plant survived in salinity affected field**	**Salt deposition alongside the corners of beds / ridges**

➢ Salinity damage in cotton

Soil salinity refers to the accumulation of soluble salts in the soil, which can significantly impact the plant growth and soil health. It occurs when salt content reaches levels that are detrimental to the crops. High soil salinity can lead to osmotic stress in plants, making it difficult for them to absorb water and nutrients.

Cotton is highly sensitive to saline / salt affected soils. The following precautions should be taken into consideration for cotton cultivation in saline / salt affected soils and with poor quality tube-well irrigation waters:

- Apply heavy pre-sowing irrigation (*Rauni*) with good quality canal irrigation water. Do not use poor quality tube-well irrigation waters for pre-sowing irrigation (*Rauni*).
- Sowing of cotton should be done on flat beds. Do not sow the crop on ridges or raised beds.
- If sowing has to be done in ridge-furrow or raised bed-furrow method, so the crop inside the furrows.
- Apply first irrigation with good quality canal irrigation water.
- Do not sow in dry fields and irrigation afterwards. Apply pre-sowing irrigation (*Rauni*) before sowing.

➢ Parawilt or sudden wilt in cotton

Parawilt symptoms on cotton plants and field due to soil factors

Parawilt or sudden wilt symptoms on cotton plants and field due to water stagnation

Soil hard-pan, angular roots, poor root and shoot ration

➢ Parawilt or sudden wilt complex in cotton

Key Factors responsible:

- **Poor soil/continuous cropping, root damage/poor development**: Continuous cotton-wheat cropping system, shallow root development due to poor soil fertility (low OC) or damaged roots cannot support the high water/ nutritional demand of a fully developed plant canopy/ heavy boll load.
- **Soil conditions:** High electrical conductivity (EC) and, in some cases, high pH can exacerbate the stress.
- **Soil waterlogging/saturation:** Excessive soil moisture (due to heavy, late-season rains or over-irrigation) restricts root respiration, leading to poor root function and eventual collapse.
- **Environmental stress:** High transpiration rates driven by bright, sunny days and high temperatures cause the plant to lose water faster than it can be absorbed.
- **Physiological collapse:** The fundamental physiological cause of parawilt is a breakdown of the soil-plant-atmosphere continuum (SPAC), where the root system fails to meet the extreme transpiration demand (poor water & nutrition supply).
- **High-vigour/hybrids:** The condition is more frequent in high-yielding, rapid-growth Bt hybrids with heavy boll loads, which have higher water and nutrient demands

Symptoms: Sudden wilt, or parawilt, in cotton is a physiological disorder occurring when soils are suddenly saturated by heavy rain, and other physiological regions followed by bright, hot sunshine, causing a severe imbalance in water/nutrient uptake and transpiration. This condition can also be pretend by poor root development, low soil fertility, heavy boll load, coupled with heavy irrigation followed by high temperature. Affected plants show rapid wilting, leaf drooping, chlorosis (yellowing), and bronzing/reddening, often recovering but resulting in low yield.

Management:

- Adopt crop rotation and soil health management practices and deep ploughing before sowing using mould board (MB) plough, with sub-soiler / chisel plough cross at 1.0 m spacing.
- Use microbial biofertilizers for seed and soil treatment.
- Do not irrigate crops early and maintain proper field drainage
- Apply 3-5 sprays of 2% potassium nitrate (13:0:45)
- Apply recommended treatment (cobalt chloride@10 ppm or sodium benzoate@ 50ppm and/or drenching of copper oxychloride 25g+200g Urea / 10 L) within 24-hour time limit.

➢ Poor root development in cotton

Poor tap root development in cotton

Bending of tap root at right angle due to hard pan in soil

Curling up of tap root due to hard pan in soil

Poor tap root development in cotton and bending of tap root at right angle

➢ Poor root development in cotton

Poor root development takes place in the soils having hard pan. Breaking of hard pan is very essential for successful cultivation of cotton. The following precautions should be taken into consideration for cotton cultivation in soils with hard pan:

- Plough the field with mould board (MB) plough for deep ploughing before preparing the field for cotton sowing.

  OR

- Plough the field with sub-soiler / chisel plough cross at 1.0 m spacing before preparing the field for cotton sowing for deeper root development.
- Deep ploughing is very essential before cotton sowing in the fields where paddy has been cultivated after puddling during previous years.

➢ Seedling burning in cotton

Seedling burning in cotton due to high temperature

Seedling burning in cotton due to high temperature

➢ Seedling burning in cotton

Highly vulnerable and extreme climatic conditions of North India, *i.e.* high temperature and hot winds during sowing and seeding stage in May and June often results in the poor/negligible plant stand in some fields which require re-sowing. The following precautions should be taken into consideration to prevent seedling burning in cotton:

- Follow conservation agricultural practices by retaining previous crop residues as mulch on soil surface to prevent seedling burning.
- Give light irrigation especially with sprinkler irrigation (if available) during high temperature days especially in very light sandy soils. First irrigation can also be advanced in very light sandy soils depending upon local climatic conditions.
- Plough the field with mould board (MB) plough for deep ploughing before preparing the field for cotton sowing OR plough the field with sub-soiler / chisel plough cross at 1.0 m spacing before preparing the field for cotton sowing for deeper root development.

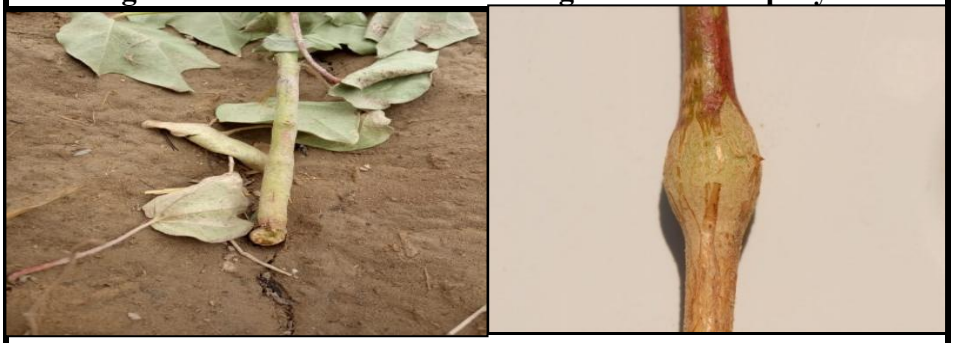
➢ Fertilizer injury in cotton

Cotton leaves burning due to stagnation of the fertilizer granules on wet leaves

Cotton leave burning due to high nutrient concentration spray fluids

➢ Herbicide injury in cotton

Damage to cotton leaves due to drifting of herbicide spray fluids



Damage to cotton plants due to overdose of pendimethalin herbicide

➢ Fertilizer injury in cotton

Spray application of high concentration of nutrient solutions and broadcast application of fertilizers on wet foliar surfaces may leads to leaf burning situations thus causing foliar damage to the crops. The following precautions should be taken into consideration to prevent the fertilizer injury in cotton:

- Foliar spray of plant nutrients should be done by dissolving recommended amount of fertilizer material in recommended quantity of water.
- Do not repeat the spray application with left over spray fluids on already sprayed crops.
- Do not broadcast the fertilizers (e.g. urea etc.) on wet foliar surfaces.

➢ Herbicide injury in cotton

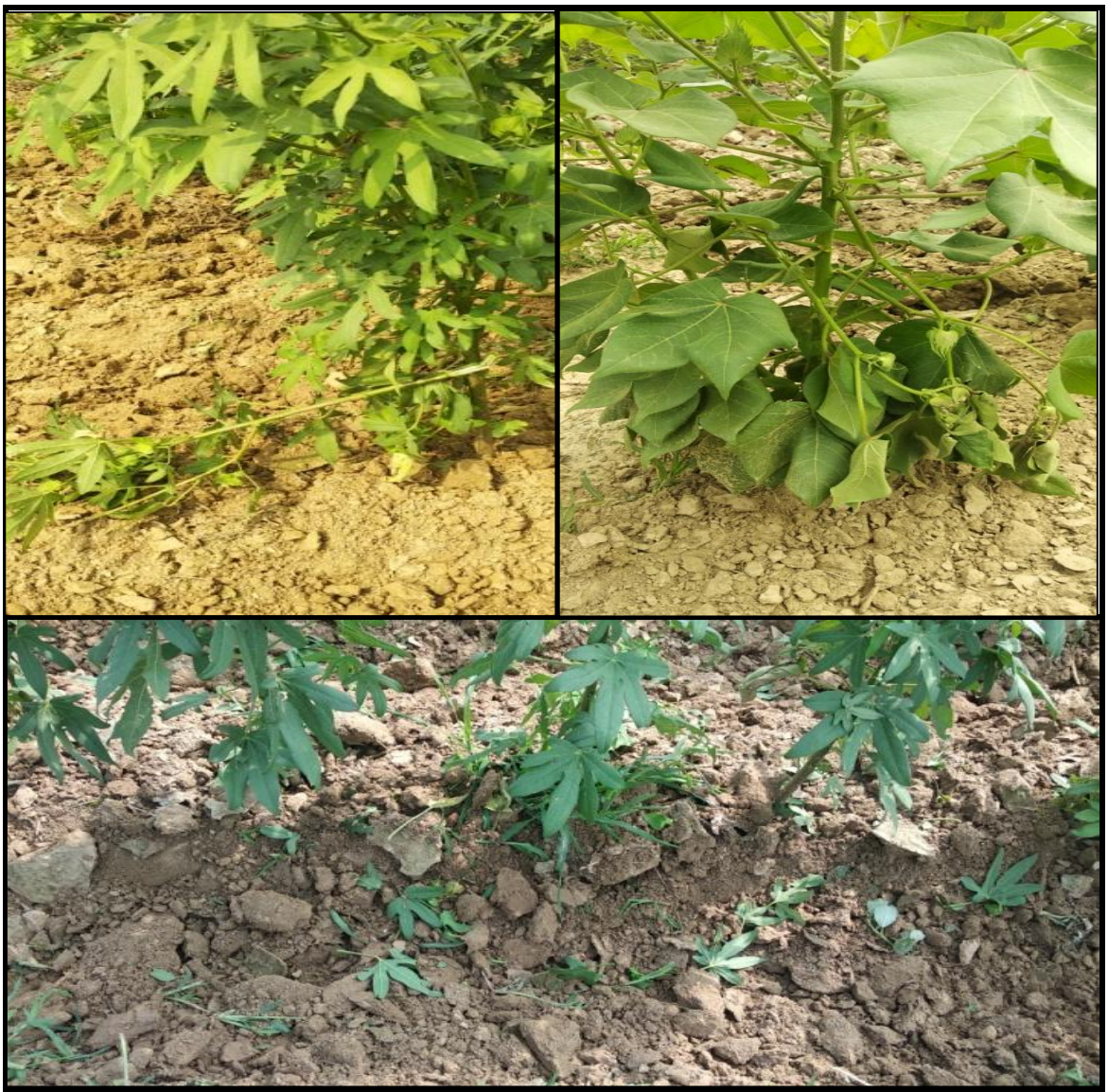
Herbicide injury to cotton occurs when wrong herbicides or wrong doses of herbicides are applied or when the non-selective herbicides fall on the crop leaves due to drifting with high velocity winds.

The following precautions should be taken into consideration to prevent the herbicide injury in cotton:

- Foliar spray of herbicides should be done by dissolving recommended amount of herbicide material in recommended quantity of water.
- Do not repeat the spray application with left over spray fluids on already sprayed crops / area.
- Do not use over doses of herbicides to control weeds
- Do not spray herbicides on windy days.
- Use protective hood for spray of non-selective herbicides.

➢ Mechanical injury in cotton

- **Use of tractor operated intercultural implements at wrong crop stage:**



Mechanical injuries (limb breakage and shedding of leaves and fruiting bodies) due to intercultural operations by tractor drawn implements at wrong crop stages

➢ Mechanical injury in cotton

Mechanical injury in plants refers to physical damage caused by external forces, which can disrupt plant's structure and can lead to various abnormalities / plant health issues. Mechanical injury occurs when plant parts are physically disrupted, often due to human activities, equipment use or by environmental factors.

- **Use of tractor operated intercultural implements at wrong crop stage:**

Mechanical injury [limb (branch) breakage, shedding of leaves and fruiting bodies (squares, flowers and bolls etc.)] takes place when the tractor operated intercultural implements are operated at wrong crop stages. The following precautions should be taken into consideration to prevent the mechanical injury in cotton:

- Do not perform intercultural operations with tractor operated intercultural implements when the crop is at branching stage and attains good height of 2.5 -3 feet or above.
- Use of tractor / animal operated weeder / *triphali* after fruiting should be avoided.

- **Sand aberration:**

Sand aberration in cotton due to sand storm

Sand aberration in cotton due to sand storm

- **Hail damage:**

Mechanical injury to cotton crop due to hail storm

- **Sand aberration:**

Mechanical injury due to sand aberration can cause considerable damage in cotton especially at seedling stage in sandy soils and results in to seedling burning and gappy fields. Sometimes complete crop failure also occurs, which needs re-sowing of crop. The following precautions should be taken into consideration to prevent the mechanical injury in cotton:

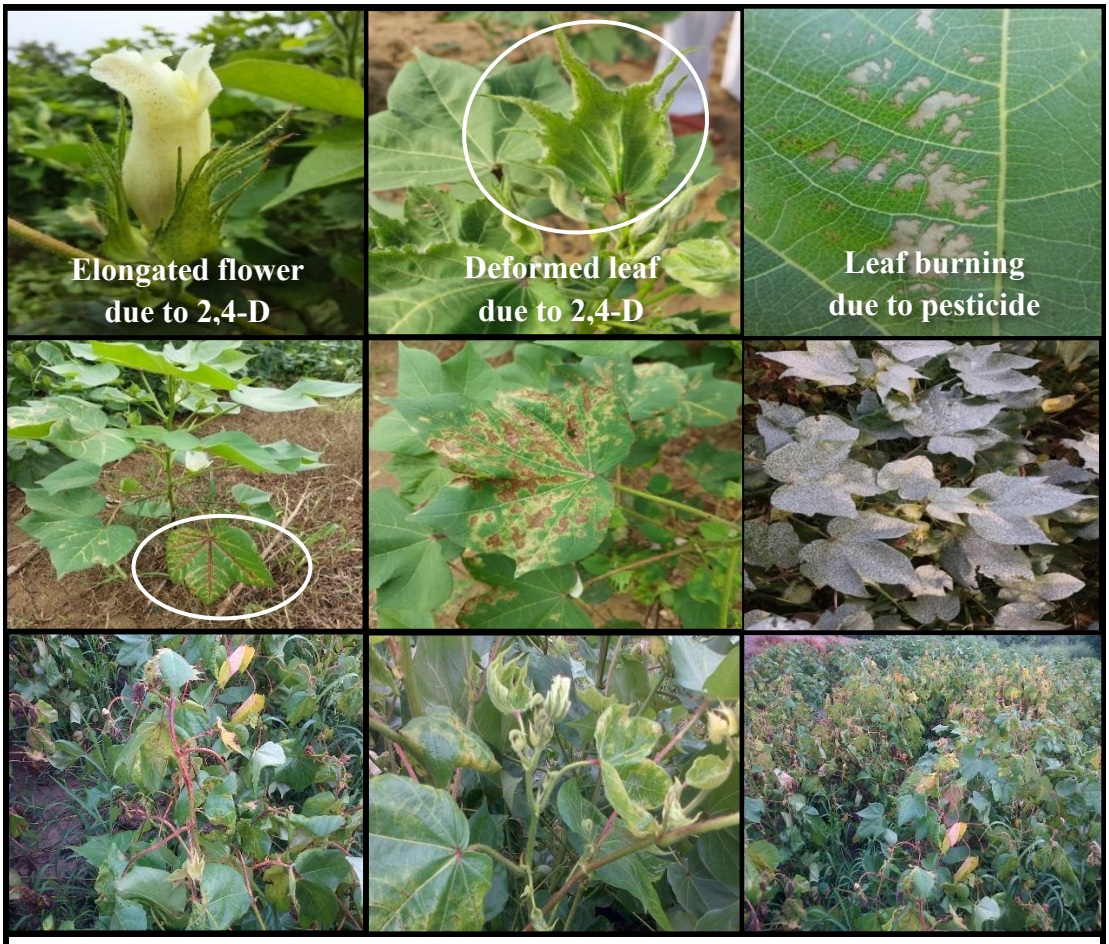
- Follow conservation agricultural practices in highly sandy soils by retaining previous crop residues as mulch on soil surface to prevent sand aberration.
- Avoid unnecessary intercultural operation in the crop, which loosen the soil surface and increase the chances of sand aberration during wind storms.
- Grow 2-3 rows thick crop of Bajra or Jowar etc. at borders and in between the crop, after dividing the entire field into equal areas of half an acre or so (depending upon the requirement and nature of soil).
- Give light irrigation especially with sprinkler (if available) during wind storm seasons in very light sandy soils. First irrigation can also be advanced in very light sandy soils depending upon local climatic conditions.
- Grow thick row of *Saccharum spontaneum* (*Sarkanda grass*) on the periphery of the fields.

- **Hailstorms damage:**

Mechanical injury due to hailstorms can cause considerable damage in cotton especially at seedling stage. Sometimes complete crop failure also occurs, which needs re-sowing of crop. The following precautions should be taken into consideration to minimize the losses due to mechanical injury during hail storms in cotton:

- Give foliar sprays of 2% potassium nitrate (13:0:45) / 2% urea solution at weekly interval for quick recovery of the crop.
- Give one split application of nitrogenous fertilizers for quick recovery and re growth of the crop
- Give light hoeing to open up and loosen the soil surface whenever the field soil reaches the workable condition (only if the crop is at early growth stages and intercultural operations are feasible).
- If complete crop damage occurs (due to hail damage at seedling stage), re-sow the crop as early as possible.

Precautions Required During Handling and Spraying of Pesticide



Damage symptoms due to mishandling and using cocktail of insecticide, fungicide, plant growth regulator & micronutrients.

Do not spray mixture of insecticide, fungicide, micronutrients and plant growth regulators

Pesticide cockatails to be avoided

Precautions Required During Handling and Spraying of Pesticide

Proper usage of pesticides is essential to ensure effective control of insect pests and diseases while protecting human health, beneficial organisms, crops, and the environment. The following precautions should be strictly followed before, during, and after spraying.

Pre spray:

1. Always purchase recommended pesticide from authorized dealers and retain the original copy of bills.
2. Always read all instructions carefully mentioned on pesticide label and follow all guidelines.
3. Spray pump should be cleaned or washed with detergent powder before and after each spray. If possible then use different spray pumps for insecticide and herbicide to avoid any phytotoxicity on crops.
4. Use only window based recommended insecticide by SAU's/Research Institute/ KVK's or State Agriculture Department.
5. Avoid tank mixing of insecticide, fungicide, micronutrients and plant growth regulators.
6. Always use insecticide safer to natural enemies as well as less toxic to the environment.
7. Don't use synthetic pyrethroids on cotton for the control of bollworm complex till the end of September to avoid the resurgence of the whitefly population.

During spray:

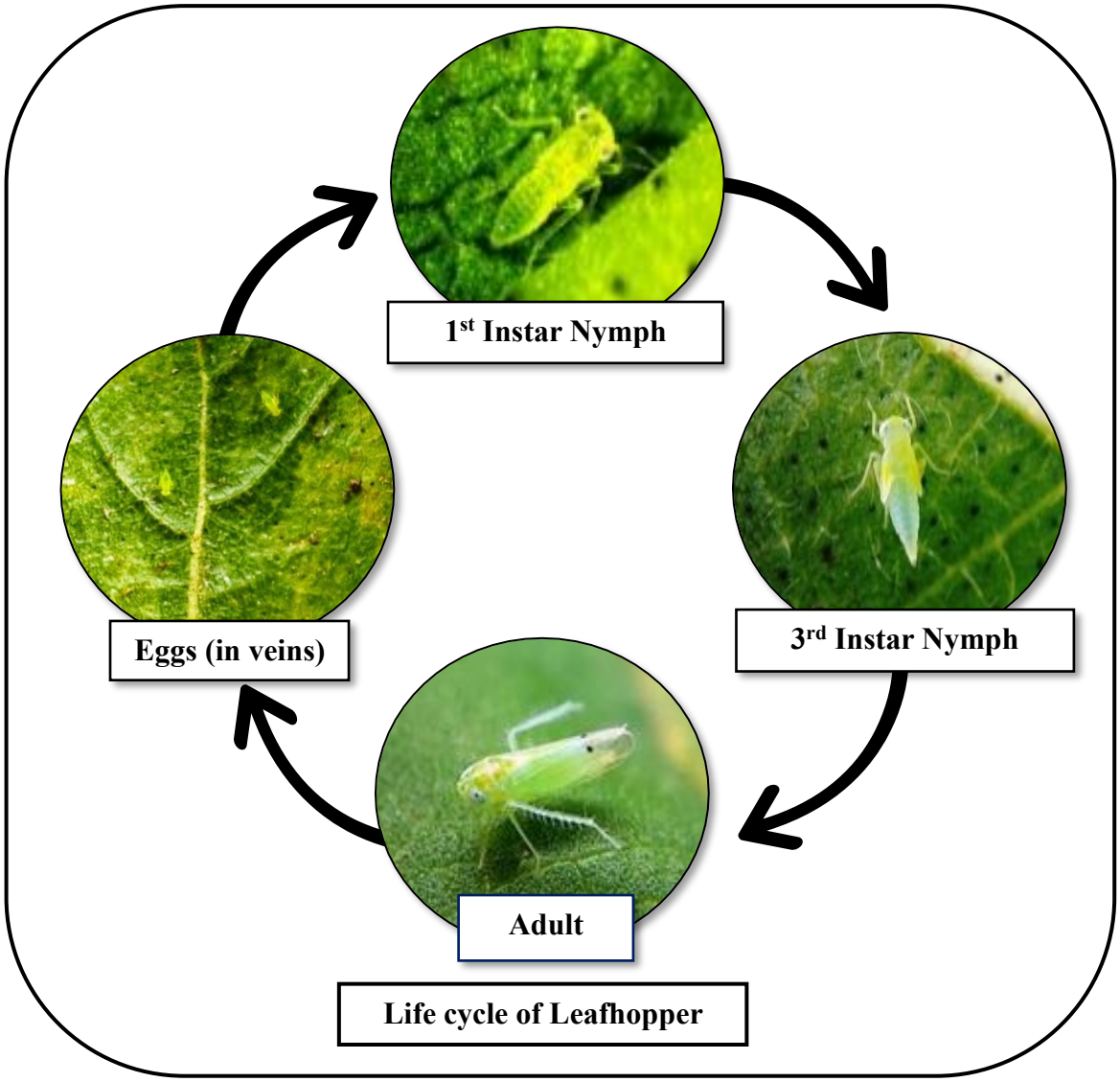
1. During spray wear all protective aids such as full sleeve clothes, shoes, mask, goggles and hand gloves.
2. Do not drink, eat or smoke with contaminated hands without washing with soap.
3. Spray insecticide before 12 noon or in the evening.
4. Use fix type solid hollow cone nozzle for spray of insecticide.
5. Proper coverage of plants with insecticides is essential.
6. Use 150-200 litres/acre of water for the spray of pesticide

Post spray:

1. Do not repeat the insecticides of the same group in subsequent sprays.
2. Repeat the spray immediately if it rains within 24 hours after the spray.
3. Keep pesticide in labeled containers and store in safe and locked place or almirah.
4. Keep Agro-inputs away from children and farm animals.
5. Dispose the pesticide container properly and don't discard it in an open area or field.

Identification of Sucking Pest and Their Economic Threshold Levels

➢ Leafhoppers



Grade-I	Grade-II	Grade-III	Grade-IV
Damage symptoms			

➢ Leafhoppers

1. Leafhoppers: *Amrasca biguttula biguttula* (Ishida)(Cicadellidae: Hemiptera), is a polyphagous pest with piercing and sucking type of mouth parts.

Life Cycle: The nymphal period varies from 5-16 days, while the adult longevity is 13.37±5.17 days. Compared to males (21.38±5.39 days), females live slightly longer (23.19±4.86 days). Around 11 to 15 generations are completed in one year in India, largely due to the continuous availability of host plants and a favorable climatic condition in various zones.

Host range: Polyphagous pest attacking cotton, okra, castor, groundnut, pigeon pea, soybean, sorghum, maize, cowpea, etc.

Prominent off -season host: Castor, potato, tomato, radish, marigold, etc.

Activity Period: Incidence in North initiates from 26th SMW, with its peak during 30-32nd SMW in North zone.

Damage Symptoms& ETL:

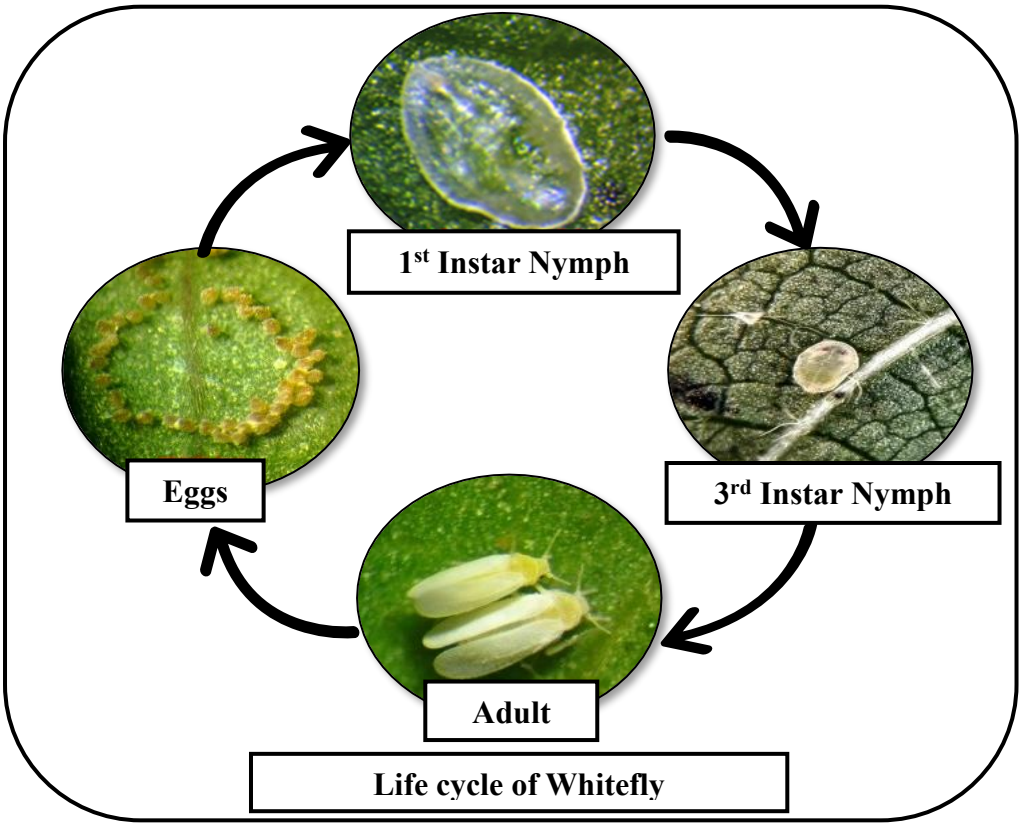
- Sap sucking by nymphs and adults result in various levels of injury grades (Grade I-IV).
- The initial symptom of leafhopper damage is marginal yellowing of leaves, followed by crinkling and curling of leaves across the plant.
- Under severe infestation, nymphs and adults suck cell sap and inject toxic saliva, leading to leaf drying, reduced photosynthetic activity, and the characteristic "hopper burn" symptom.

Different Grades of Leafhopper Infestations:

Grade-I	Entire foliage is free from crinkling or curling with no yellowing with scattered presence of leafhopper in plant foliage
Grade-II	Crinkling and curling of a few leaves in the lower portion of plant + marginal yellowing of leaves.
Grade-III	Crinkling and curling of leaves almost all over the plant. Plant growth hampered
Grade-IV	Extreme curling, crinkling, yellowing, bronzing and drying of leaves (Hopper Burn)

Economic threshold level (ETL): 6 nymphs/3leaves or Grade-II injury as crinkling, curling and marginal yellowing.

➢ Cotton Whitefly



Direct Damage Symptoms			
			
Initial symptoms as yellow Island	Symptoms with moderate incidence	Severe Symptoms (Numerous eggs/nymphs)	Severe Symptoms (sooty mould and honey dew)
Indirect Damage Symptoms			
			
Cotton Leaf curl Virus Disease (CLCuD)	Appearance of Honey dew	Development of Sooty Mould	Blackening of lint
Damage symptoms			

➢ Cotton Whitefly

2. Cotton Whitefly: *Bemisia tabaci* (Gennadius) **(**Aleyrodidae: Hemiptera), is a polyphagous pest with piercing and sucking type mouth parts.

Life cycle: Eggs hatch in 3–5 days in summer and over 30 days in winter. Nymphs (crawlers) settle underside the leaves, feed on phloem, and become immobile. They pass through three molts; nymphal period is 9–14 days in summer and 17–19 days in winter. Pupal stage lasts 2–8 days. The total life cycle is 14–107 days. Whiteflies complete 12 generations in a year.

Host range: Whitefly survives on a wide range of alternate hosts such as malvaceous crop plants, cucurbits, crucifers and weed hosts prominently cotton, moong bean, okra, mustard, brinjal, chili, potato, cabbage, cauliflower, bathu and milk thistle, etc.

Prominent off-season host: Chilli, brinjal, tomato, sunflower, milk thistle, jangli palak, summer moong, etc.

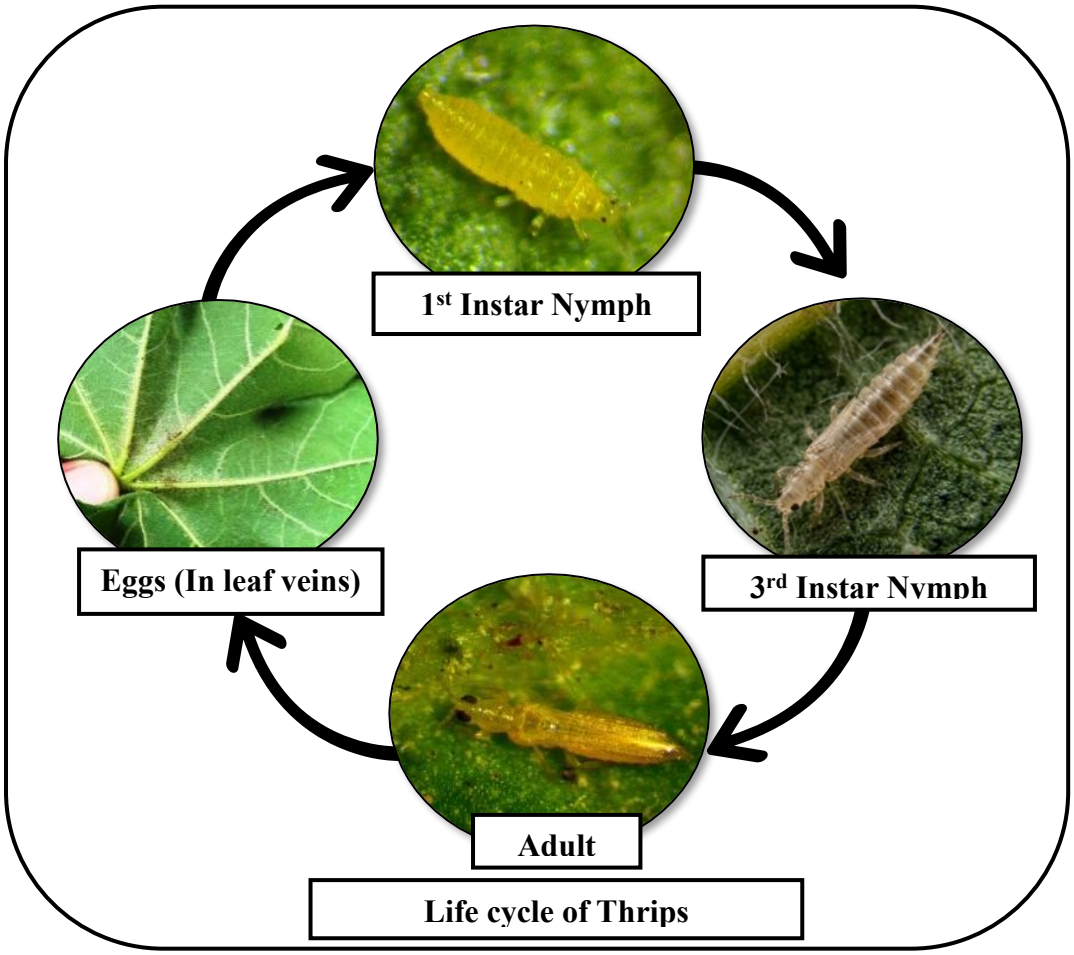
Activity Period: Whitefly infestation on cotton is observed from sowing to harvest. Activity periods ranged between 27-40th SMW with two peaks in North zone of India , first in 31-32nd SMW and second in 37-38th SMW.

Damage Symptoms& ETL:

- Nymphs and adults suck sap from leaves → leaf yellowing (chlorosis)
- Leaf curling and wilting, plants become weak
- Excretion of honeydew →oily and shiny leaves, black sooty mould on leaves and bolls.
- Shedding of squares and bolls, poor boll development.
- Acts as a vector for Cotton Leaf Curl Virus (CLCuV), causing severe yield loss

Economic threshold level(ETL): 18 adults/3leaves />50% of observed plants(10 out of 20) infested with honey dew.

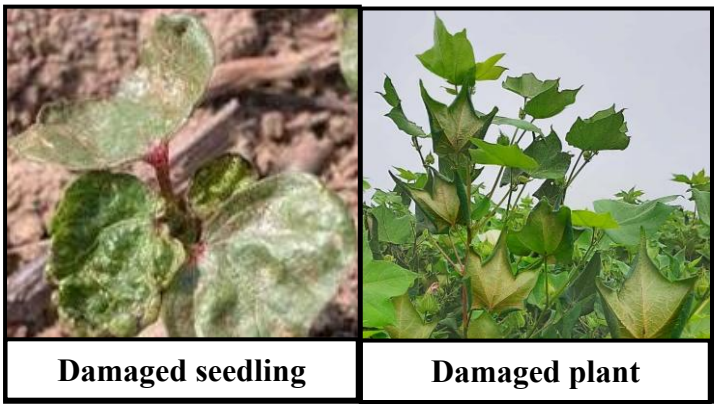
➢ Thrips



Life cycle of Thrips

Grade-I	Grade-II	Grade-III	Grade-IV

Damage symptoms



Damaged seedling	Damaged plant

➢ Thrips

3. Thrips: *Thrips palmi, Thrips tabaci*, and *Scirtothrips dorsalis*, (Thysanoptera: Thripidae), among which *T. palmi* is the most prominent. Thrips are a polyphagous pest with rasping and sucking types of mouth parts.

Life Cycle: Female thrips lay, kidney-shaped eggs inside tender cotton leaf tissues, buds, or flowers and the eggs hatch in five days. The nymphs live for five days, pupation occurs inside the soil, pupal period lasts for four to six days. Adults have a lifespan of 14–28 days. In a single year, thrips can produce up to 15 overlapping generations.

Host range: Major off-season alternate hosts include cauliflower, onion, garlic, and cabbage, whereas the *Kharif* season host plants are eggplant, chilli, and okra. Additionally, various weeds and ornamental plants such as congress grass, rose, carnation, marigold, orchids, and chrysanthemum.

Prominent off-season hosts: Eggplant (Brinjal), pepper (Capsicum), onion and garlic, cabbage and cauliflower, beans, papaya chilli and congress grass.

Activity Period: Damage invariably commences from the cotyledon stage and progresses to mature leaves and other plant parts.

Damage Symptoms& ETL:

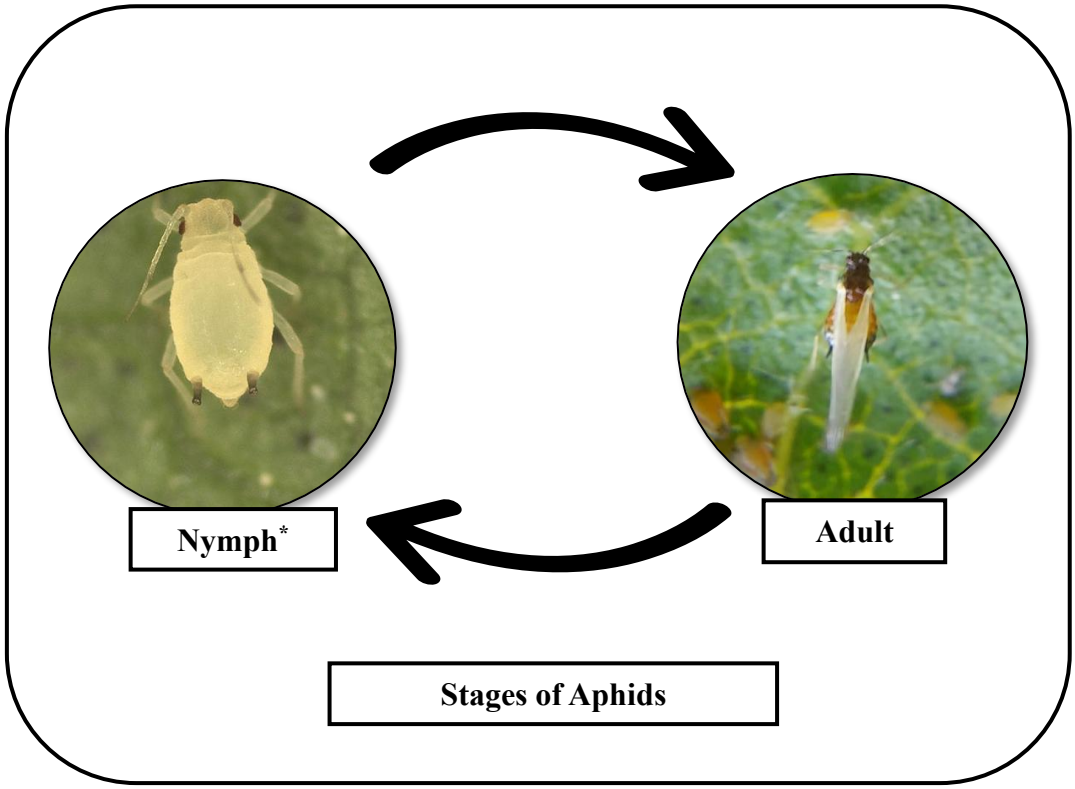
- Nymph and adult scrape leaf surface and suck sap. The damage occurs during crop's early vegetative phase.
- Wrinkled or depressed leaves due to draining out of cellular content, affected leaves turn silvery and curled upward with shiny white spots. With the increase in size of leaves, the cracking of leaf lamina is visible.
- Late bud formation is the result of higher infestation during the vegetative stage. Damage from thrips causes early square dropping, delayed crop maturity, and decreased yield.
- Affected plants lose the apical dominance, leading to an unusual growth pattern referred to as 'crazy cotton'.

Different Grades based on Symptoms:

Grade-I	Scattered presence of thrips in plant foliage without any symptoms
Grade-II	Silvery patches along the sides of veins on underside of leaves above mid canopy
Grade-III	Silvery patches extending all over the leaf lamina, turning later into brown patches. Leaf stiffness causing its erectness or movement of the leaf in an upward direction, expo sing the leaf's lower surface
Grade-IV	Downward curling around the leaf margins, extreme browning, leaf stiffness, and cracking of the leaf lamina

Economic Threshold level (ETL): 30 nymphs or adults/3leaves or IInd grade - Silvery patches along the sides of veins.

➢ Aphid



Nymph* Photo source- https://www.vegetables.bayer.com/ca/en-ca/resources/cultivation-insights/cucurbit-aphid-borne-yellows-virus-on-cucumber/_jcr_content/root/responsivegrid/responsivegrid_copy_/image_copy_443507979.coreimg.png/1648662002237/cucurbit-aphid-borne-yellows-virus--cabyv--on-cucumber3.png

Damage symptoms

➢ Aphid

4. Aphid: *Aphis gossypii***,** (Aphididae: Hemiptera) is a polyphagous pest with piercing and sucking type of mouth parts.

Life Cycle: Aphids live in colonies, and the females multiply parthenogenetically and viviparously. In a day female may give birth to 8-22 nymphs. The nymphal period lasts for 7-9 days, and the adults live for 12-20 days. The pest has 12-14 generations per year, leading to quick population explosions**.** Nymphs are small, yellowish green to brownish, wingless insects that feed on plant sap and pass through four nymphal stages. Adults are yellow to dark green/black and can be winged or wingless**.**

Host range: The cotton aphid has a very wide host range, including watermelon, cucumber, squash and pumpkin. Other vegetable crops they attack include eggplant and okra.

Prominent off-season hosts: Eggplant (Brinjal),various cucurbits (cucumber, pumpkin, bitter gourd).

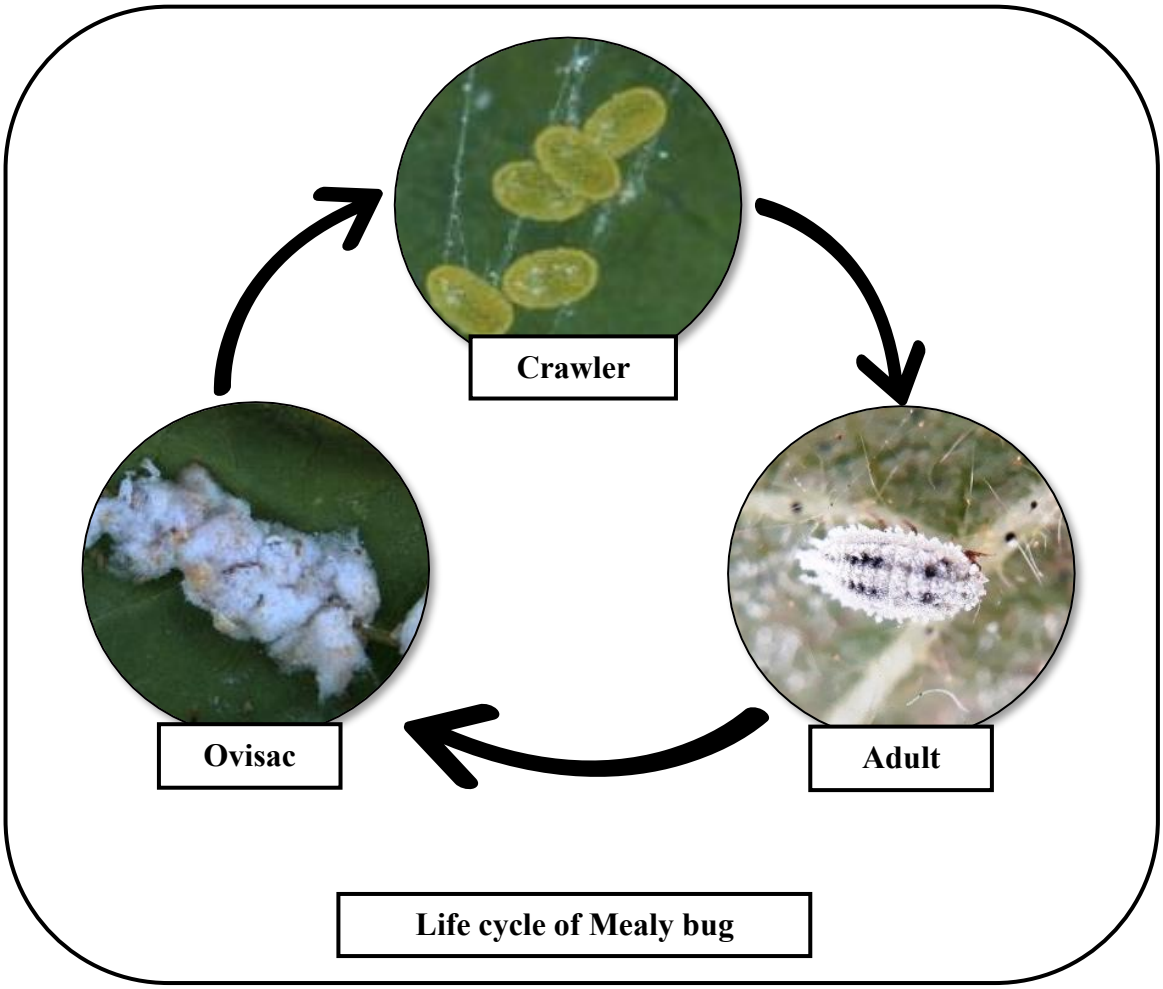
Activity Period: The infestation begins early in the season, often appearing in the last week of June and peak is generally recorded between September-October in North zone.

Damage Symptoms & ETL:

- Leaves are shiny with honeydew or darkened by sooty mould growing on the honeydew.
- Crumpling and downward curling observed under severe attack.
- Activity of ants on aphid-infested plants is common.
- Contamination of lint with honeydew and associated fungi leads to poor quality cotton.

Economic Threshold level (ETL): If>2 out of 20 plants observed showing cupping/ crumping (10% plants) or 50% plants infested with honey dew or 5-10 adults/leaf or 20 nymphs/leaf.

➢ Cotton Mealy Bug



Life cycle of Mealy bug

Damage symptoms

➢ Cotton Mealy Bug

5. Cotton Mealy Bug: Among mealy bugs *Phenacoccus solenopsis* Tinsley **(**Pseudococcideae: Hemiptera) dominant in North zone, is a polyphagous pest with piercing and sucking type of mouth parts.

Life cycle: Female lays 100-600 eggs in ovisacs. The developmental period of nymphal stages for females was recorded as 13.2 ± 1.8 (09-16) days , as compared to males, 18.7 ± 0.9 (17-20)days. The reproductive period lasted 30.2 ± 8.2 (10-47) days. Adult females longevity is 42.4 ± 5.7 (36-51) days, while males lived 1.5 ± 0.1 (1-2) days.

Host range: Cotton mealybug is highly polyphagous, infesting many field crops, vegetables, fruit crops, and weeds. Major hosts include cotton, pigeon pea, tomato, okra, papaya, brinjal, potato, grapes, marigold, hibiscus, and weeds like congress grass,mallow,wild sunflower, peepal and poplar etc.

Prominent off-season hosts: Tomato, brinjal, potato, grapes, marigold, hibiscus, congress grass and wild sunflower etc.

Activity Period: Peak activity observed during July- September months. The population generally observed at the boundaries adjoining to roadside, water channels, etc.

Damage symptoms & ETL:

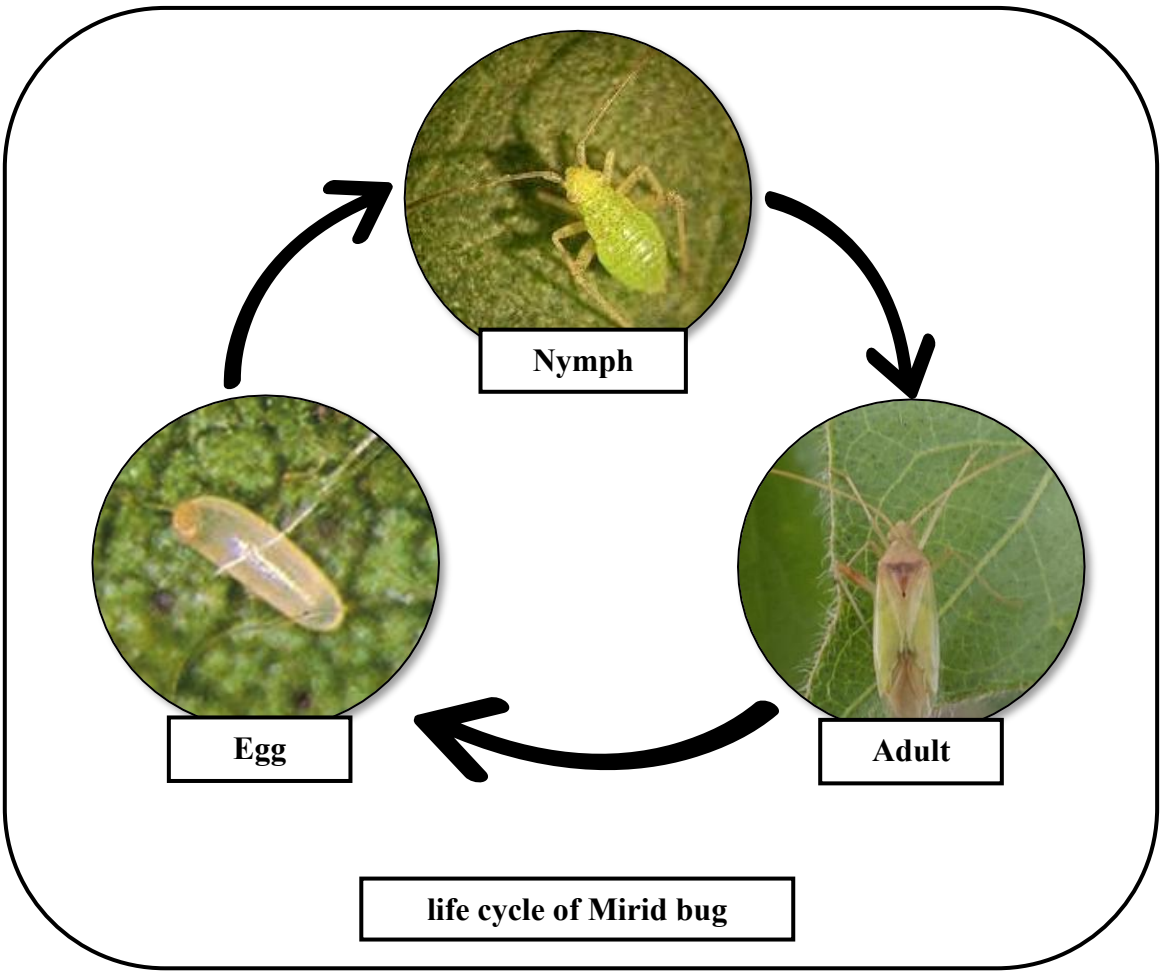
- Both nymphs and adults suck sap from leaves, stems, squares, and bolls.
- Infestation at vegetative stage causes stem distortion, twisting, and bushy growth.
- Honeydew secretion leads to sooty mould development**.**
- Sooty mould infestation resulted in blackening of the cotton lint.
- Infested plants show leaf curling, crinkling, and yellowing**.**

- **Injury Grade for monitoring and management of mealybug:**

Grade-0	Healthy plants with no mealybug infestation
Grade-I	About 1-10 mealy bugs scattered over the plant
Grade-II	One branch infested heavily with mealy bugs
Grade-III	Two or more branches infested heavily with mealy bugs, up to 50% plant affected
Grade-IV	Complete plant affected hampered and distorted growth.

Economic threshold level (ETL):>20 plants/acre showing damage grade-IIndor 2.0–2.6 mealybugs per 2.5 cm of apical shoot length.

➢ Mirid Bug



life cycle of Mirid bug

Damage symptoms

➢ Mirid Bug

6. Mirid Bug: *Campylomma livida* (Reuter) (Miridae: Hemiptera) is a polyphagous pest with piercing and sucking type of mouth parts.

Life cycle: Short life cycle (30–40 days) enabling rapid population buildup. Eggs are inserted inside tender plant tissues, making early detection difficult. Eggs are cylindrical, slightly curved and laterally compressed, shining white in colour, turning yellow as they mature. Eggs hatch within 4–5 days. There are five nymphal instars, each of about 2–3 days' duration. The wing pads start to develop at the third instar. Adults are elongated, about 7–9 mm long, with long legs and antennae. Development from egg to adult takes about 15–18 days. The adults can live for 3–5 weeks, and a female can lay up to 80 eggs in the lifetime.

Host range: Lucerne, pigeon pea, sunflower, safflower, sorghum, maize, pearl millet, dhaincha, castor, kangibooti , pig weed, turnip weed, soybean, moong bean, groundnut, etc.

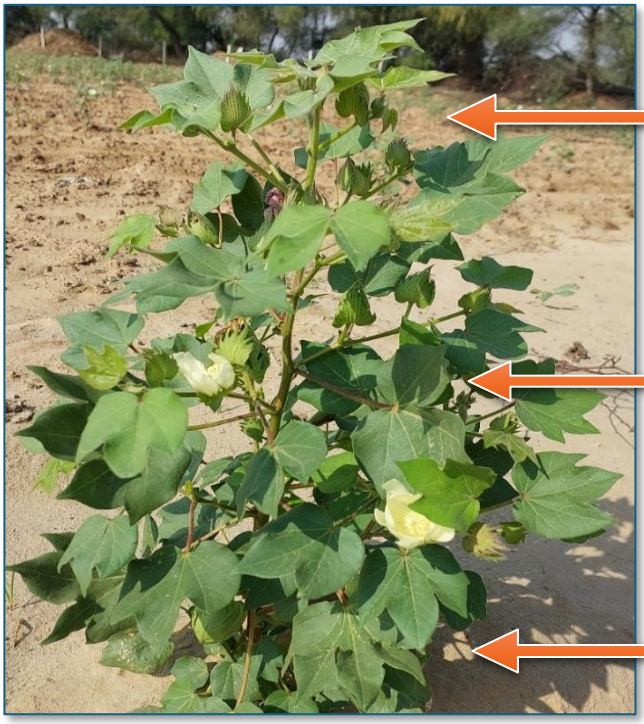
Prominent off-season hosts: Lucerne, sunflower, Amaranth etc.

Damage symptoms:

- Both nymph and adult cause damage.
- Feeding on the terminal growth, squares, flowers and bolls of cotton plants with the piercing/sucking mouthparts lead to excessive shedding of flowers, small squares and immature bolls.
- The feeding results in small, dark, sunken lesions on the surface of the boll, and in severe cases, deformed bolls (parrot-beaked) symptoms are seen.
- The fruiting bodies turn yellow and are dropped off. The lint quality of parrot-beaked bolls is found to be poor.

Economic threshold level (ETL):From top canopy squares, 25% plants affected or 5 Nymph or adults/plant.

Monitoring Methods for Sucking Insect-pests in Cotton



Observe three leaves (one each from upper, middle, and lower strata/canopy) plant

Monitoring of sucking pest from three canopy of plants with particular attention to the underside (abaxial) of the leaves.

Monitoring Methods for Sucking Insect-pests in Cotton

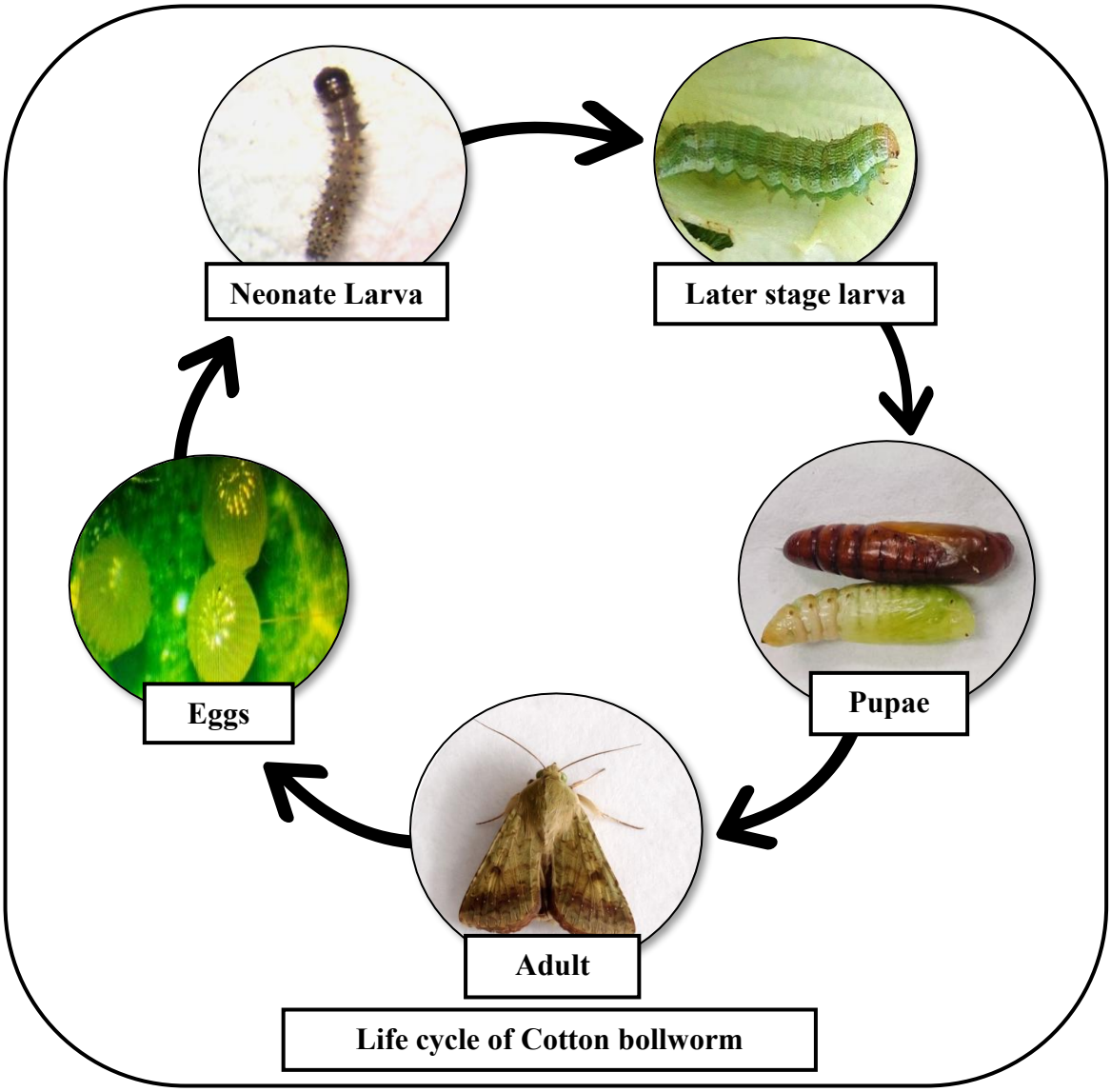
Monitoring of sucking pests in cotton involves regular field survey & surveillance to assess population build-up and damage.

- About 20–25 randomly select plants of uniform size avoiding boundary plants or plants in shade per acre should be examined in a zig-zag pattern, observing three leaves (upper, middle, and lower canopy) from each plant. In surveillance observations should be recorded from tagged plants from fixed locations.
- Since the sucking pests prefer to feed on abaxial side, attention should be given to the underside of leaves with gentle handling where these pests congregate.
- The number of nymphs and adults per leaf is recorded along with symptoms such as yellowing, curling, silvering, honeydew secretion, and sooty mould on entire plant.
- Compare the data to calculate Economic Threshold Levels for further guidance and timely management decisions

Pest Name Scientific Name	**Stage to Monitor**	**Monitoring Method**	**ETL (Economic Threshold Level)**	**Time of Monitoring**
Cotton Jassid, *A. biguttula biguttula*	Nymph & Adult	Observe 3 leaf one each from top, middle and lower strata of 20 plants	6 nymphs/3leaves or IInd grade leaf curling symptoms	Vegetative stage
Whitefly, *Bemisia tabaci*			18 adults/3leaves	Vegetative to boll formation
Thrips, *Thrips tabaci*			30 nymphs and adults/3leaves	Early crop stage to mid-season stage
Aphid, *Aphis gossypii*			10–15% plants infested	Early vegetative stage
Mealybug, *Phenacoccus solenopsis*		Sample 25–50 plants per acre (more along border rows).	≥20 plants showing damage grade IInd	Vegetative to boll formation
Mirid Bug, *Campylomma livida*		Count mirid bugs on 20 plants	From top canopy squares, 25% plants affected or 5 Nymph or adults/plant	Vegetative to boll formation

Identification of Bollworms and Their Economic Threshold Levels

➢ Cotton bollworm



Life cycle of Cotton bollworm

Damage symptoms

➢ Cotton bollworm

1. Cotton bollworm: *Helicoverpa armigera* (Hubner) (Noctuidae**:** Lepidoptera) is a polyphagous, cosmopolitan pest with biting and chewing type of mouth parts.

Life cycle: This bollworm completes its life cycle in 25–60 days**.** The female lays eggs singly on leaves and buds. The eggs are tiny, dome-shaped (nearly spherical) with fine ridges, creamy white to pale yellow when freshly laid, turning brown just before hatching. Larvae pass through 5–6 instars. Cannibalism is common in larvae; older larvae often attack and eat smaller or weaker larvae, which usually results in only one larva surviving per fruiting body (square or boll). Pupation occurs in soil, and adults live about a week, with several generations in a year.

Host range: *H. armigera* is a polyphagous pest feeding on about 300 plant species, including cotton, tomato, pigeon pea, cowpea, groundnut, chickpea, moong bean, bajra, okra, and sorghum etc.

Prominent off-season hosts: Chickpea, tomato, pea, summer moong, castor, sunflower, lucerne, berseem, oat and wheat etc.

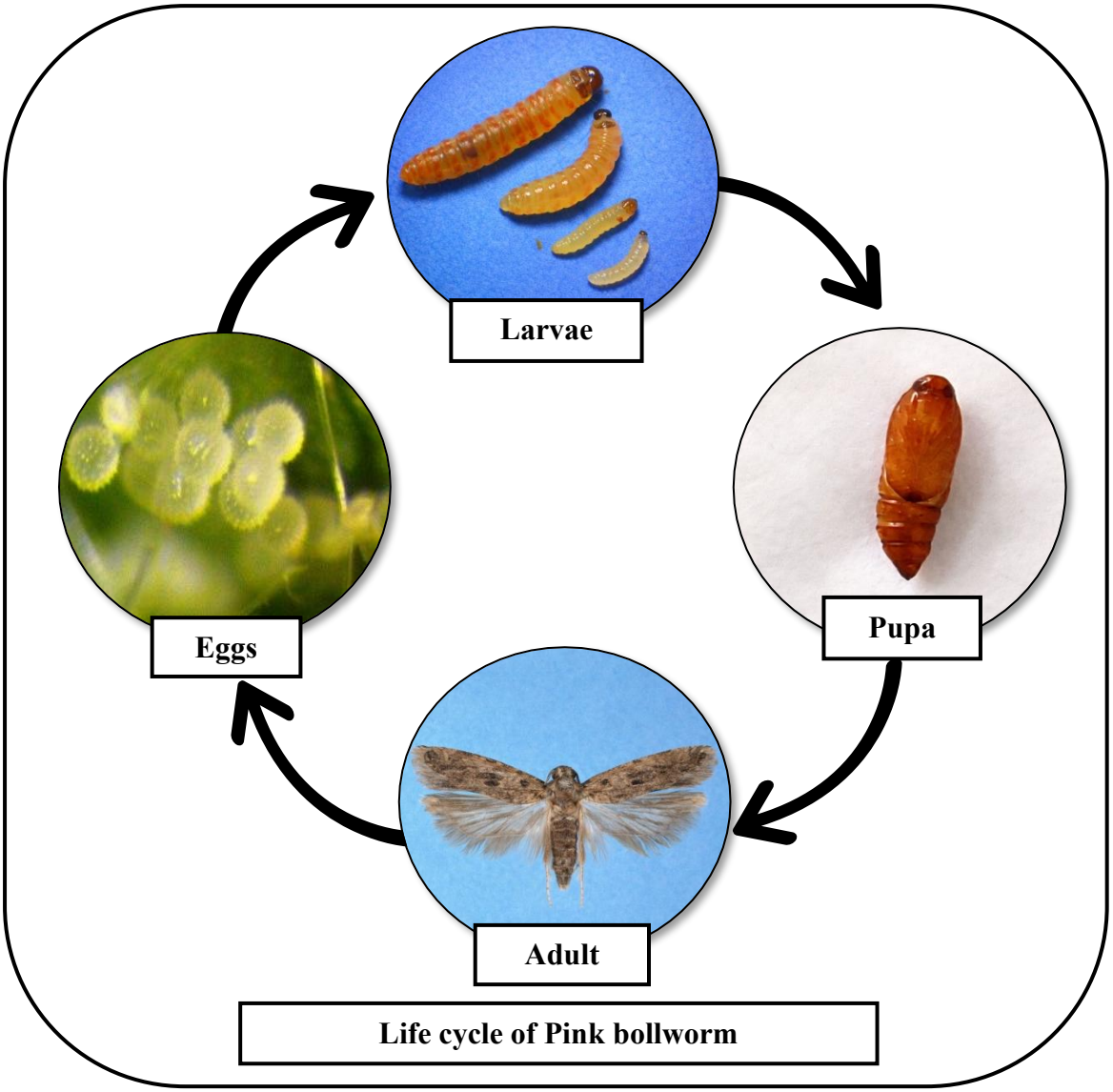
Activity Period: The cotton bollworm is active round the year depending on the host availability. In cotton crop, its primary incidence is seen at squaring stage i.e. July month onwards and reached at peak between September to October months.

Damage symptoms:

- The larvae feed on the leaves first, then bore into squares/bolls and seed, thrusting their heads into the boll while leaving the rest of their body outside.
- Feeding or damaged holes appear on damaged squares as they flare up.
- On squares and bolls, either with or without larvae, there are obvious round feeding holes without any excreta.
- When flowers and squares are available, larvae prefer to eat them, but they also consume young bolls. At the base of the boll, there are big, round entry holes.
- During its development, a single larva can harm 30–40 fruiting forms.

Economic Threshold Level (ETL): 20% plants with one or more flared squares or 1 egg/plant or 1 larva/ 2 plants.

➢ Pink bollworm



Life cycle of Pink bollworm

Rosette flower	Exit hole	Damaged greenboll	Bad opened bolls

Damage symptoms

➢ Pink bollworm

2. Pink bollworm: *Pectinophora gossypiella* Saunders (Gelechiidae : Lepidoptera) in India is functionally monophagous with biting and chewing type mouth parts.

Life cycle: The pink bollworm completes its life cycle in about 25–30 days under favorable conditions. Female lays eggs singly or in small groups of 4-5 on tender plant parts. Eggs are pearly white, flattened, oval, and very small**,** and hatch in 3–5 days. Larvae pass through several instars over 10–20 days and are white in the early instars, turn pink in the later instars. Sex differentiation is possible in mature larvae, as males possess a pair of dark, elliptical gonads visible dorsally on fifth abdominal segment, whereas females lack these spots. Pupation occurs inside the boll or in plant debris or soil and lasts about 7–10 days. Adults live for a short period, with several generations in a year under suitable conditions.

North zone typical life cycle: In north zone, the last generation of the year has a long cycle period due to winter wherein fully developed last generation larvae enter diapause. Diapause larvae survive in un-opened bolls, and cotton seed after joining two single seeds. Diapause duration ranged between 31-157 days based on existing climatic conditions and availability of food source.

Host range: In India, pink bollworm mainly infests all four cultivated cotton species (*G. hirsutum, G. barbadense, G. herbaceum, G. arboreum*), occasionally okra, with secondary hosts like hollyhock, kangibooti, and hibiscus.

Prominent off-season hosts/sources of carryover: Unopened bolls available in cotton stalks, seed cotton, cotton seed, kangibooti, and hibiscus etc.

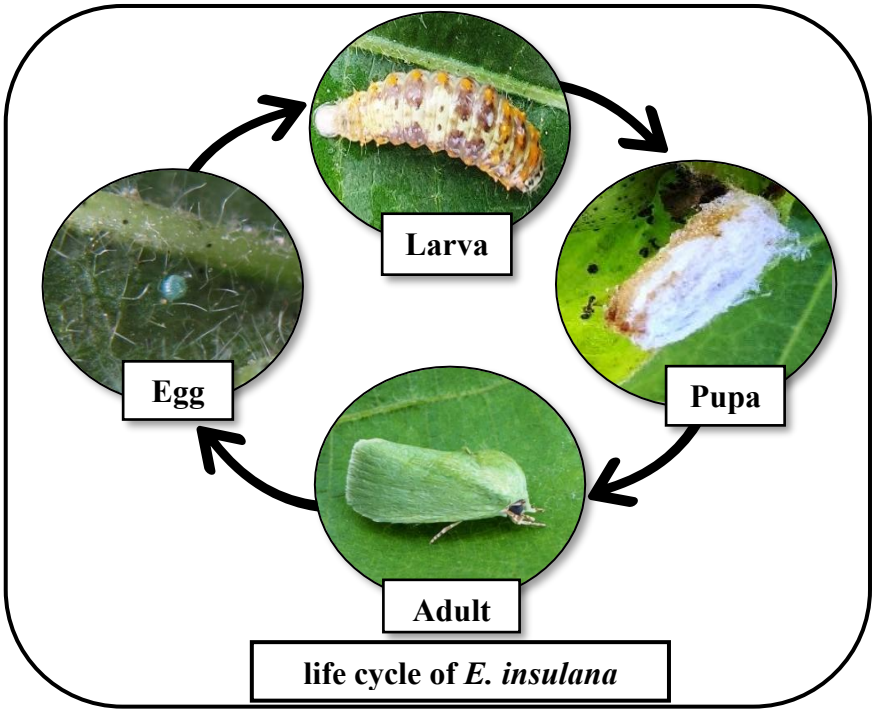
Activity period: The pink bollworm remains active during cotton season. The activity starts in May onward with favorable climatic conditions and availability of fruiting body and peaks during September-October.

Damage symptoms:

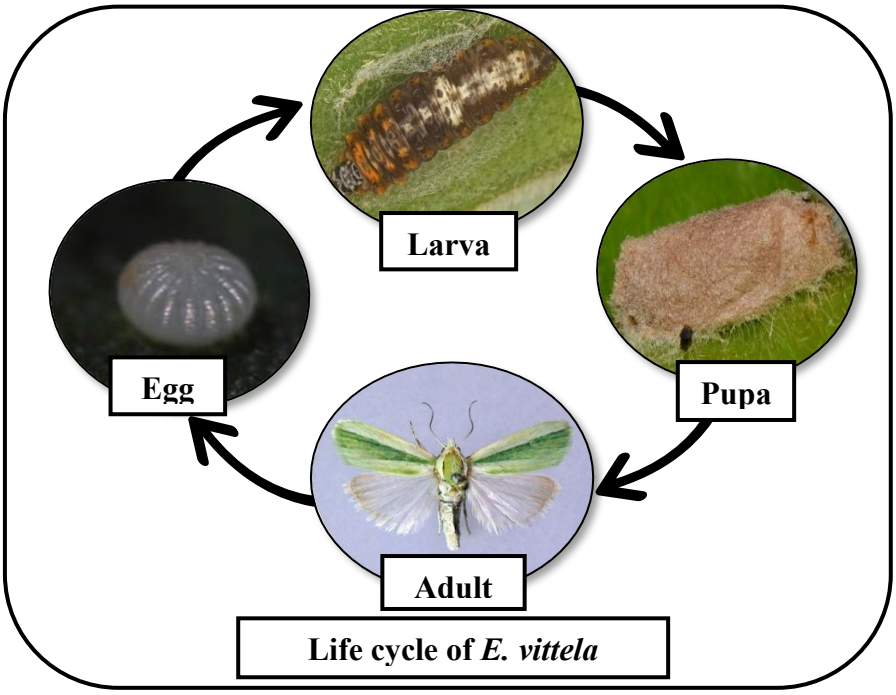
- Larvae bore into squares, flowers, and bolls soon after hatching. Infested flowers show resetting due to webbing inside petals.
- Entry hole on bolls is very small, often closed and invisible from outside. Bolls open prematurely with locule damage symptoms.
- In case of severe infestation, whole bolls is damaged and destroyed by larvae. The lint is also damaged and stained by excreta of larvae.

Economic threshold level(ETL): >10% rosette flowers (10 out of 100 flowers are damaged), or 10% green bolls damage or 5-8 moths catch per pheromone trap for consecutive 3 days.

➢ Spiny/Spotted Bollworm



life cycle of *E. insulana*



Life cycle of *E. vittela*

Damage symptoms

➢ Spiny/Spotted Bollworm

3. Spiny/Spotted Bollworm: *Earias insulana* (Boisduval) / *E. vittella* (Fabricius) (Noctuidae: Lepidoptera) is **oligophagous** in feeding behavior with limited range of host plants, mainly within the family Malvaceae with biting and chewing types of mouth parts.

Life Cycle: The spotted and spiny complete their life cycle in about 25–35 days, though it may be as short as 20–22 days under favorable conditions. The female lays eggs singly or in small groups of 2–3 on bracts, leaf axils, and veins on the underside of leaves. The eggs are small, nearly spherical, bluish-green when freshly laid, turning yellowish before hatching, and hatch within 2–3 days; A female may lay up to about 300-400 eggs. Larvae pass through several instars over 10–12 days and bore into shoots, squares, and bolls, feeding internally. Larvae of *E. vittella* are brownish without spines with white streaks, whereas larvae of *E. insulana* are greenish with distinct finger-like spines. Pupa is of boat shape and pupation occurs in a silken cocoon on the plant or among plant debris and lasts about 7–10 days. Adults live for about a week, with several generations in a year; adult moths can be distinguished by wing colour, *E. insulana* being silvery green to straw yellow and *E. vittella* creamy white or peach with a central green wedge on the forewing (wingspan about 20–22 mm).

Host range: In the North zone, Spiny bollworm (*E. insulana*) dominates and heavily damages *G. arboreum* & *G. hirsutum* cotton and occurs on okra, hollyhock, and other malvaceous plants.

Prominent off-season hosts: China rose, hollyhock, country mallow, kangibooti, tall mallow ,broom weed, sahadeva etc.

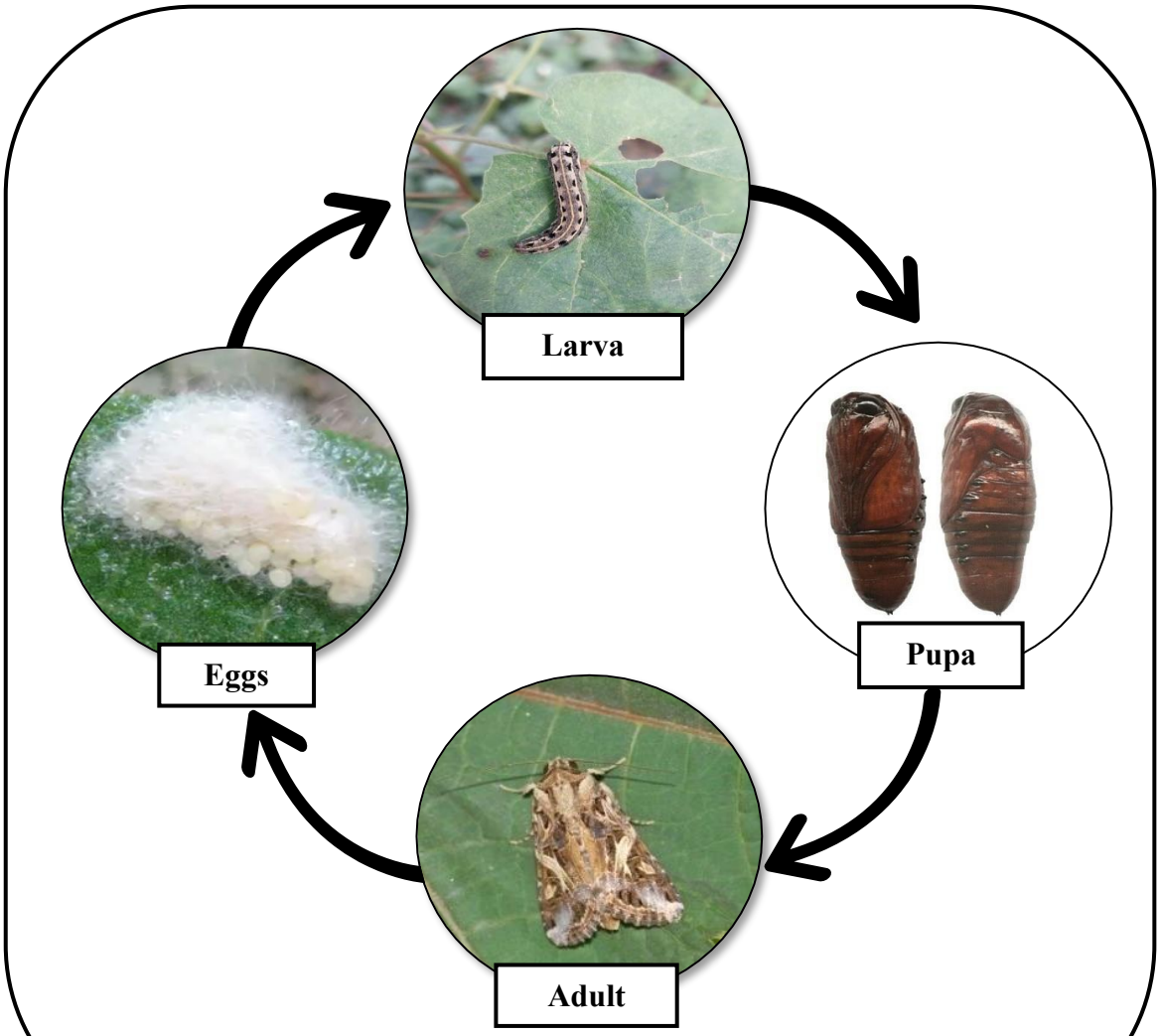
Activity period: *Earias* spp. bollworm incidence commences as early as on 3 weeks old crop**.** Generally, in early stage spotted bollworm attacks on shoot of cotton plants. The damage due to *Earias* spp. is high during fruiting stage during July to September**.**

Damage symptoms:

- Larvae bore into tender shoots causing dead hearts**.**
- Terminal shoots dry and main stem collapsed.
- Holes with excreta seen on shoots, squares, flowers, and bolls.
- Flare up of squares and their shedding, premature dropping also noticed.
- Shedding of squares and flowers is major indication of pest attacks**.**

Economic threshold level (ETL): 20% plants with one or more flared squares or 5-10% infestations in fruiting bodies.

➢ Tobacco Caterpillar



Life cycle of Tobacco caterpillar

DAMAGE SYMPTOMS

➢ Tobacco Caterpillar

4. Tobacco Caterpillar: *Spodoptera litura* (Fabricius)(Noctuidae: Lepidoptera) is a polyphagous pest with biting and chewing type of mouth parts and preferential feeding of foliage and fruiting parts.

Life cycle: The tobacco caterpillar completes its life cycle in about 25–40 days and may produce 8–12 generations in a year. The female lays eggs in clusters of about 250–300 on the underside of leaves. The eggs are creamy white to yellowish, spherical (about 0.6 mm in diameter), and covered with golden-brown hair scales from the female's abdomen, and hatch in 4–5 days. Larvae develop over 15–20 days, initially pale green, turning dark green with a black dorsal spot in the third instar, and finally dark brown with three dorsal lines. Pupation occurs in the soil and lasts about 7–10 days; the pupa changes from yellowish to reddish brown. Adults live about 8–11 days, with hind wings silvery unmarked and forewings brown with crisscross markings; females are dull in colour than males.

Host range: The *Spodoptera* larvae is a polyphagous insect and feed on over 112 crop species from more than 40 mainly dicot families. It attacks tobacco cotton, tomato, castor, groundnut, sorghum, maize, sunflower & cole crops etc. Favored weed hosts include *Alternanthera*, *Euphorbia*, *Eichhornia*, *Ipomoea*, *Parthenium* spp., and *Rumex spp.*.

Prominent off season hosts: Tobacco, castor, tomato, cole crops, congress grass, jangli palak & blue dawn flower etc.

Activity Period: *Spodoptera litura* remains active throughout the year and larvae prefer to feed on foliage. In cotton the peak incidence activity observed during vegetative to fruiting stage in August-September months.

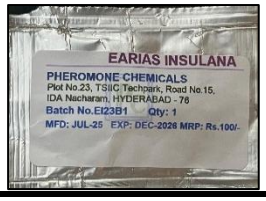
Damage symptoms& ETLs:

- The larvae feed gregariously on the underside of the leaves and scrape epidermal layer as well as skeletonize them leaving only the midrib and veins in severe cases.
- During severe attack, only the stem and side shoots will be standing in the field without any leaf or bolls.
- Cotton leaves in severe attacks appear sieve like.
- In absence of suitable leaves, larvae feed on the square, flowers or bolls by making small holes and causing significant losses.

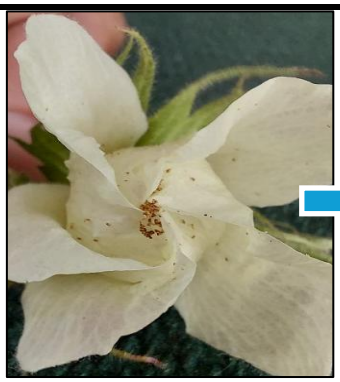
Economic threshold level (ETL):1 Damaged or skeletonized leaf/plant on 10 plants or 1 egg mass per 20 plants or 5 larvae per 10 plants.

Monitoring Methods for Bollworm

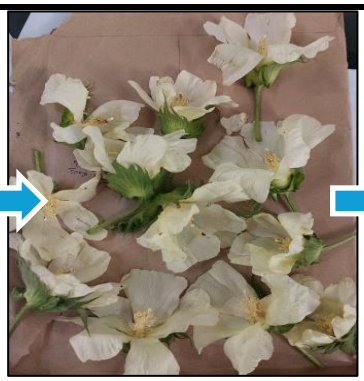
Monitoring through pheromone traps with specific lures



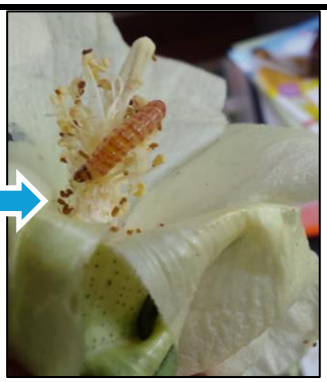
Rosette flower monitoring



Rosette flower collection



Opening of rosette flowers for PBW larval presence



Larvae found in rosette flowers

Destructive sampling

Green boll collection

Larva in dissected green boll

Dissected green bolls

Shed fruiting body sampling

Freshly dropped squares

Inspect collected squares for damage

Damaged squares

Monitoring Methods for Bollworms in Cotton

- The monitoring of bollworms with sex pheromone should be done with the initiation of flowering stage of cotton crop.
- Install pheromone traps 5/ha for pink bollworm, cotton bollworm, tobacco caterpillar and 2/ha for spotted bollworm.
- Observations on moth catch should be recorded on every alternate day.
- Observe mainly fruiting bodies of minimum 20 plants per acre for cotton bollworm, spotted bollworm and tobacco caterpillar. In case of pink bollworm collect 20 green bolls (10-15days old) and dissect the bolls for damage or larval presence. Compare the data for ETL and further guidance towards timely management decisions.

Pest Detail	Stage to Monitor	Monitoring Method	ETL (Economic Threshold Level)	Time of Monitoring
Cotton bollworm *H. armigera* & Spotted bollworm *E.insulana, E.vittella*	Egg & Larvae	Observe squares, flowers & bolls on 20 plants	5% fruiting bodies damaged or one larva/plant	Squaring & boll formation
Pink bollworm *P. gossypiella*		Inspect 100 flowers for rosette shape or larval presence&20 green bolls through destructive sampling or through installation of pheromone traps	5–10% rosette flowers or bolls with PBW larvae or 8 moths/trap for 3 consecutive nights*	With the initiation of flowering stage onwards
Tobacco caterpillar *S. litura*		Look for egg masses & leaf damage	7 egg masses/100 plants or 10% damage	Vegetative stage
All bollworms	Larvae	Divide the field into four quarters and collect 25 freshly shed fruiting bodies at random in each quarter (total- 100 fruiting bodies).	>5% fruiting bodies damaged	Squaring onwards

Fruiting bodies- square, flower, bolls.

* In case of Pink Bollworm, 5-8 moths/trap for 3 consecutive nights is ETL if offseason sources of survival exist nearby.

Management of Insect-pests of cotton

➢ General management practices for insect-pests of cotton

Subsoiler for breaking compact soil

Moldboard plough can be used for deep ploughing

Maintain proper spacing

Regular monitoring

Timely intercultural operations

Bunds and space between rows and crops should be weed free

Avoid cultivating non-recommended and undescriptive hybrids/varieties

Avoid intercropping moong in cotton in whitefly prone area

➢ General management practices for insect-pests of cotton

1. Cultural and Mechanical Management

- Avoid cultivating non-recommended and undescriptive hybrids/varieties as they may be highly susceptible to insect-pests and disease specially CLCuD and sucking insect-pests. Prefer to grow desi cotton in area wherever infestation of whitefly and leaf curl was severe in previous seasons.

- Get field soil samples tested from approved laboratories for genuine crop fertilizer application requirements and need-based micronutrients should also be applied like Zinc, Magnesium, Manganese and Boron.

- Avoid early and late sowing: Untimely sown crops attract insect-pests; especially late sown crops are prone to CLCuD and other diseases and insect-pests. Complete the sowing up to 15th May.

- Maintain the field, field bunds, irrigation channel clean and weed-free, as the weeds compete the cotton crop for nutrition and harbor sucking pests, especially whiteflyand act as the source of CLCuD inoculum.

- Destroy volunteer/ratoon/infected cotton plants and weed hosts on or near irrigation channel/ canal/ bunds/roadside and in fallow lands.

- Adopt crop rotation to break the life cycle of pests, reduce soil borne diseases inoculum and enhance soil fertility and health.

- Avoid growing whitefly and CLCuD alternate host crops near cotton crop. Do not cultivate crops like cucurbits, okra, moong, arhar, castor, dhaincha, and kinnow orchard etc. in and around cotton or vice versa to minimize build up and spread of pests and diseases in cotton.

- For better root development cultivate field with mould board plough or subsoiler, apply first irrigation after 6-7 weeks of sowing and last irrigation should be given at the end of September based on crop requirement and timely termination of the crop.

Yellow sticky trap (YST)

Yellow sticky trap (YST) with volatiles

Blue sticky trap (BST)

Jowar as border/ physical barrier

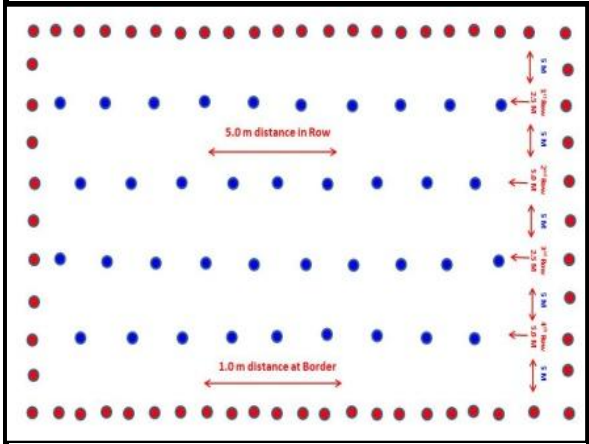
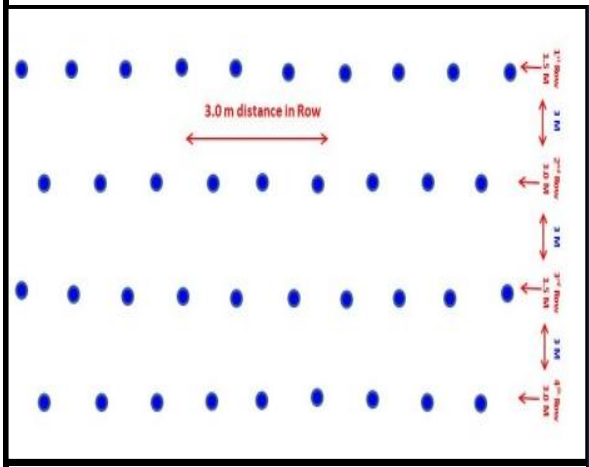
Pheromone traps

- Regular monitoring of weeds and other alternate hosts from February onwards to avoid the incidence of diseases, pests and CLCuD in ensuing season.
- Use low cost 30-40 yellow sticky traps (YST) per acre for whitefly as well as leafhoppers and blue sticky traps (BST) for thrips per acre.
- For Mealy bug, detachinfested twig gently from the plant, collect in plastic bags and take far away from fields and should be destroyed by burning. Avoid disposal of uprooted infested plant/ weeds in water channel/ common places.
- Install 8-10 bird perches per ha after 90 days of crop growth for the benefit of predatory birds.
- Egg masses and young larvae of tobacco caterpillar, feeding gregariously should be collected along with leaves and destroyed
- Remove and destroy infested rosette flowers and bolls.
- Timely termination of crop and collection and destruction of bad opened bolls, grazing of cattle, sheep, goat after last picking reduces the carry-over of Pink bollworm. After the final picking, cotton field should be shredded with the help of shredder to kill the surviving larvae.
- Destruction of cotton stalk and weeds during off-season and in-season
- Avoid ratoon cropping.

2. Botanicals/Biological control

- Conserve natural enemies and parasitoids such as green lacewing, ladybird beetles, spider, Zanchius bug, *Encarsia* spp., *Eretmocerus* spp., etc.
- Use botanical and initially apply NSKE 5% (50ml) or Neem oil 5 ml or neem oil-based formulation 5 ml /litrefor sucking pests and bollworms during 0-60 days after Sowing if ETL approaches
- Releasing *Trichogramma chilonis* at the rate of 5 cards per hectare 45 days after sowing to control the bollworm complex. Release of *T. bactareae* @150000/ha at weekly intervals thrice between 90-120 DAS for management of PBW.

➢ Behavioural control of pink bollworm through MDT

<table>
<tr><th colspan="3">CREMIT APPLICATION</th></tr>
<tr><td> 
</td><td>  </td><td>  </td></tr>
<tr><td>Layout for application</td><td>Field application</td><td>Dollop size</td></tr>
<tr><th colspan="3">PB Knot</th></tr>
<tr><td> 
</td><td>  </td><td>  </td></tr>
<tr><td>Layout for installation</td><td>PB knot in field</td><td>PB knot</td></tr>
<tr><th colspan="3">Mechanical Control through Mass Trapping</th></tr>
<tr><td colspan="3">  </td></tr>
</table>

3. **Behavioural control of pink bollworm through MDT**

- **SPLAT (CREMIT PBW / NATMAT PBW)**: Apply gel-based gossyplure pheromone (4%) @ 125 g/acre for 3-4 applications starting 30 to 35 DAS before square initiation. Place pea-sized dollops on 400 randomly selected plants/acre at the fifth leaf node. Repeat 3-4 times at 30-day intervals. Apply in large contiguous areas (≥10 ha) for best results and reapply if rain occurs soon after application.

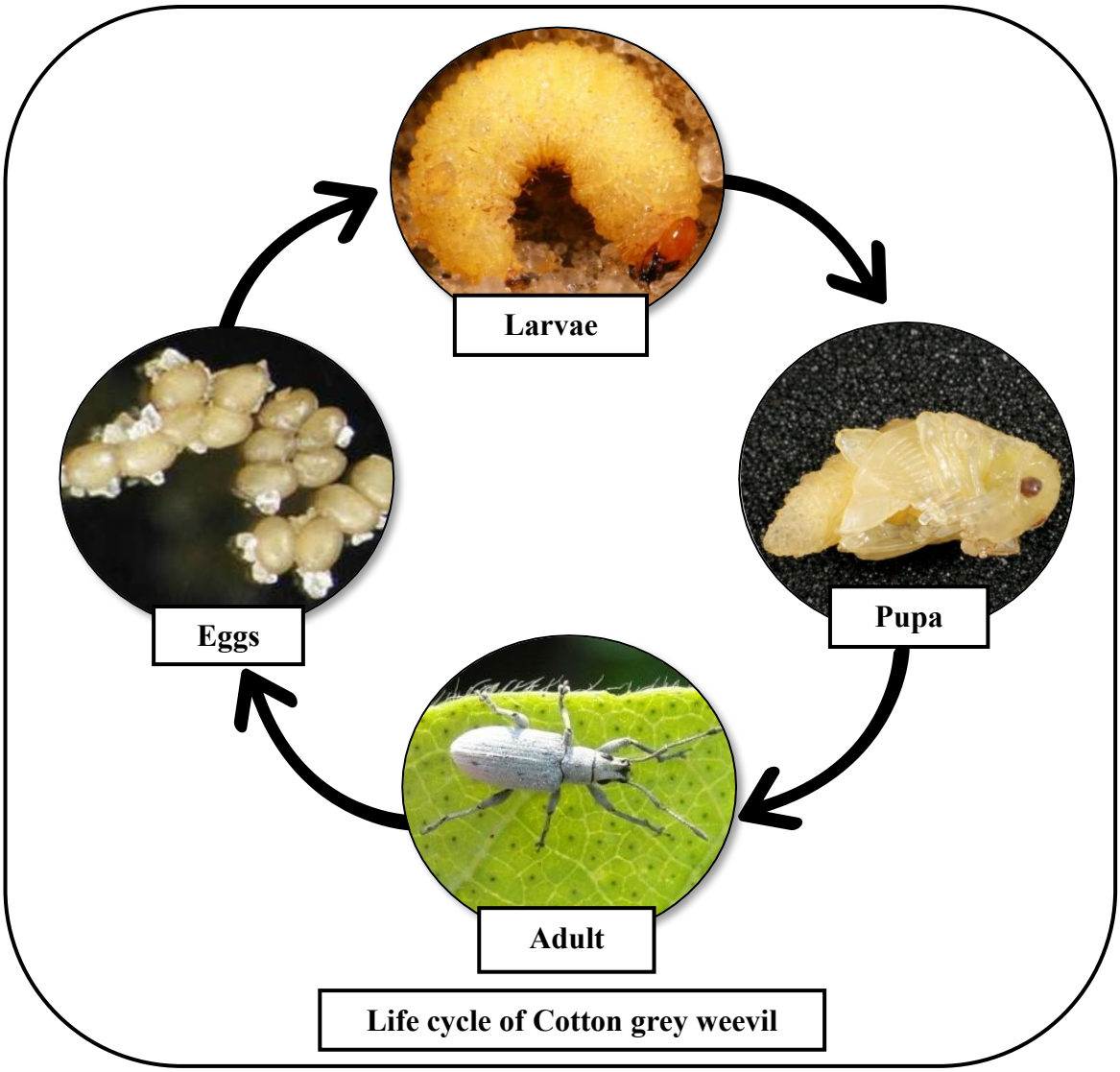
- **PB Rope-L (Mating Disruption Dispensers)**: Install PB Rope-L dispensers (gossyplure-impregnated tubes) at 35 to 40 DAS before squaring, preferably over a 25-ha block. Tie ropes on plant stems at specified spacing (border at 1 m, interior 5 m). Monitor rosette flowers and green bolls regularly; apply insecticide only if infestation exceeds ETL.

- **Mass Trapping**: Install 12 to 15 pheromone traps (low costs) per acre at 35 to 40 DAS, positioned about 15 cm above crop canopy. Replace lures every 15 days. Trapping large numbers of male moths disrupts mating, suppresses population build-up, and delays peak infestation during squaring to boll formation stages.

4. **Chemical Management:**
    - **Follow Annexure-I for present insecticides recommendation**

Other Cotton Pests and Their Managements

➢ Cotton Grey weevil



Life cycle of Cotton grey weevil

Damage symptoms

➢ Cotton Grey weevil

1. Cotton Grey weevil: *Myllocerus maculosus* (Desh.) **(**Curculionidae**:** Coleoptera) is a minor pest of cotton, polyphagous in feeding behaviour with biting and chewing type mouth parts

Life cycle: The eggs hatch in 3-12 days in May-September, and the young grubs feed on the roots of cotton and other plants. The larvae/grubs complete their development in 23-40 days. The pupal stage is 3-9 days. The life cycle is completed in 29-58 days, and the pest probably breeds 3-4 times in a year. Generally overlapping generations are found at vegetative phase of cotton i.e. July-September months.

Host range: Besides cotton, it feeds on some other host plants like bajra, maize, sorghum, guava, pigeon pea, brinjal, mango, citrus, apple, sugarcane, pomegranate and groundnut.

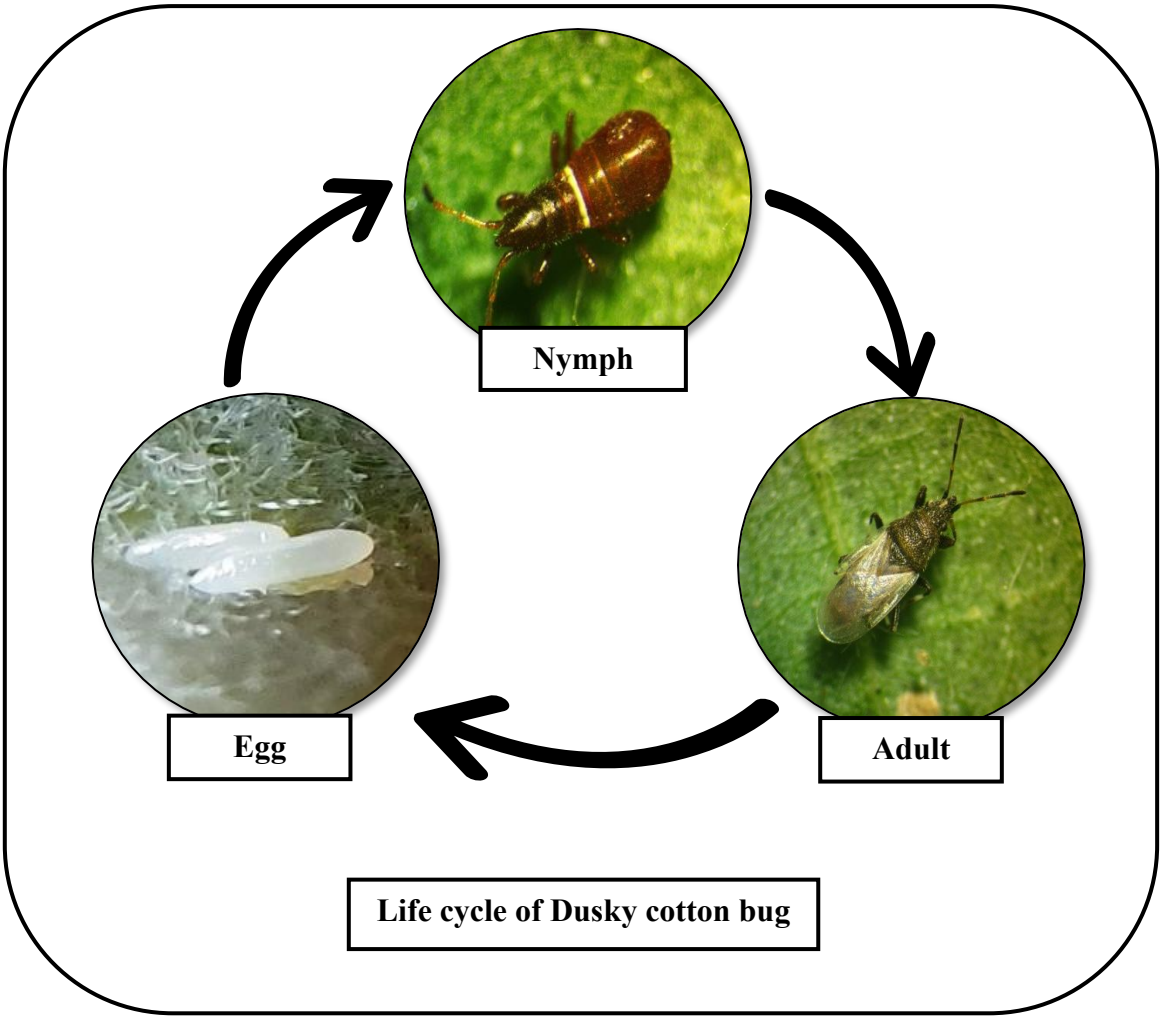
Prominent off-season Hosts: Brinjal, citrus, mango, apple, sugarcane, pomegranate etc.

Activity Period: The pest remains active in cotton from April to October and generally peak activity observed during July-August months. Adults feed on leaves, buds and flowers while grubs feed on the roots.

Damage Symptoms:

- Generally feeding or damage of grey weevil is ignored by farmers but this pest affects plant growth and leads to yield losses.
- Adults feed on margins of young leaves and causes notches on margins.
- Grubs feed on roots and affect the smooth growth of roots as well as plants which cause stunted growth of plants.
- In severe incidence conditions all leaves of plants notched at marginal ends and plants have poor and stunted growth.

➢ Dusky cotton bug



Life cycle of Dusky cotton bug

Damage symptoms

➢ Dusky cotton bug

2. Dusky cotton bug: *Oxycarenus hyalipennis* (Costa) (Lygaeidae; Hemiptera) a lint staining pest of cotton and damages the cotton seed as well as embryo with piercing and sucking type mouth parts.

Life cycle: The eggs are laid singly or in small groups loose amongst the seeds in the open boll. Each female lays around 25-40 eggs. The egg and nymphal period last for 7 and 26 days, respectively. The development period is completed in 40-50 days.

Host range: The pest attacks mainly on cotton, while malvaceous crops like okra, *Sterculia* spp. and *Ceiba* spp. are the alternative hosts.

Prominent off-season hosts: Moringa, mango, kangibooti, china rose, phalsa, sweet lemon, berseem, wheat, jasmine, chillies, eucalyptus, neem, marigold etc.

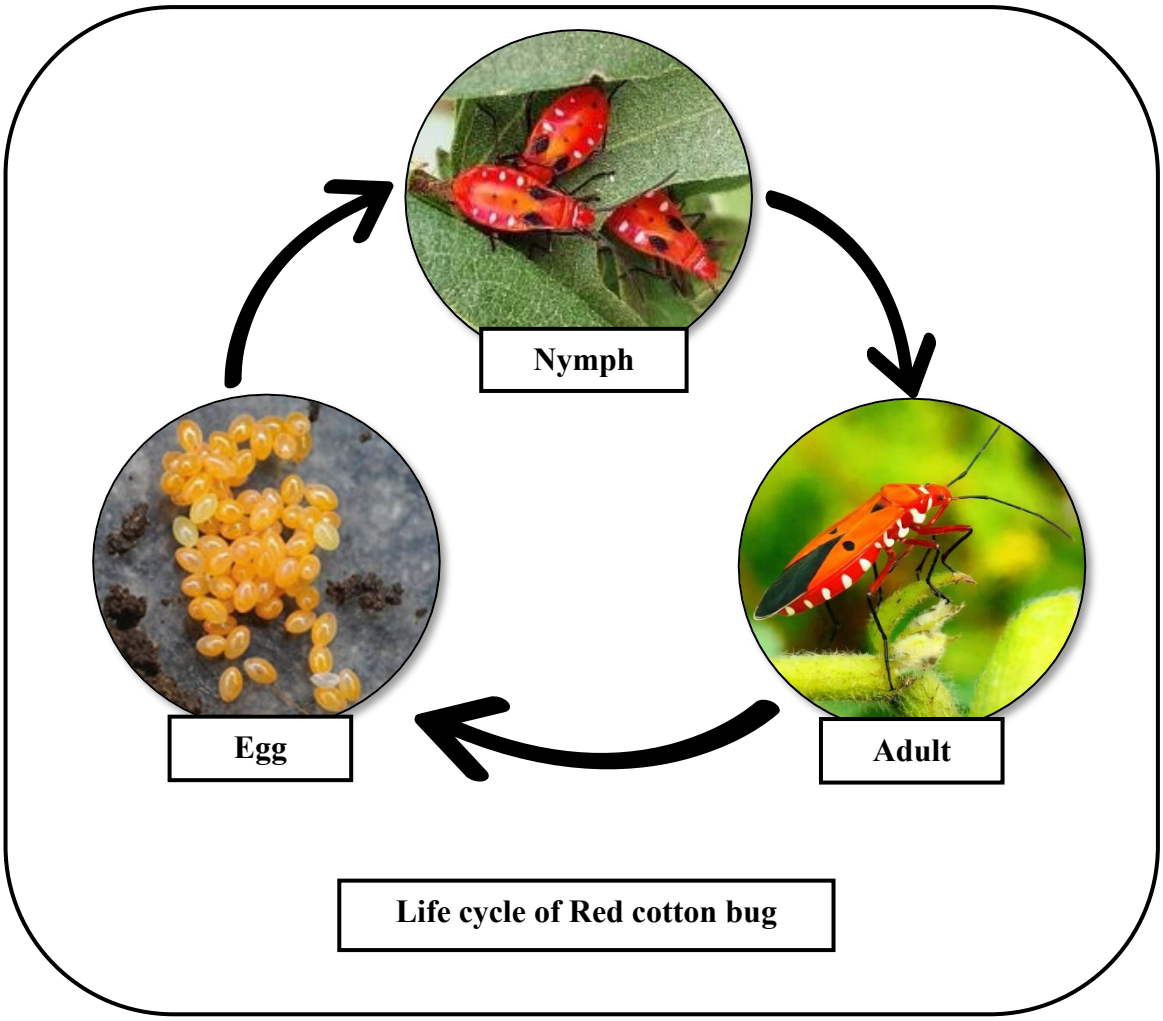
Activity period: Dusky cotton bug is active from sowing to harvest of cotton crops. The peak incidence or population activity observed during squaring, flowering and boll formation stage such as in June to August. The second peak infestation is also observed during boll opening stage i.e. October and November months. The most preferred feeding site is open bolls.

Damage symptoms:

- During early season, nymphs and adults feed on square and square turn yellow and detached from branch.
- Flare up of square is also noticed.
- Nymphs and adults suck sap from cotton seeds.
- Staining of lint (yellowish-brown spots) due to bug excreta.
- The pest damages the embryo which affects the vigor and germination of seeds.
- Reduction in seed weight and oil content.

Economic threshold level **(ETL):** 10–15 bugs per plant**,** or 20–25 bugs per 5 plants**,** or heavy congregation observed on opened bolls causing lint staining

➢ Red cotton bug



Life cycle of Red cotton bug

Red cotton bug population over cotton bolls

➢ Red cotton bug

3. Red Cotton Bug: *Dysdercus cingulatus* (Fabricius), (Pyrrhocoridae; Hemiptera) is a lint staining pest of cotton with piercing and sucking type mouth parts.

Life cycle: Red cotton bug adults measure about 12-13 mm in length and females lay 100–130 eggs in soil cracks. Eggs period is 7-8 days. Nymphs are wingless and undergo five moulting and complete nymphal period in 5-7 days**.** The life cycle is completed in 50–90 days. Adult longevity is up to 3 months in winter, shorter in summer.

Host range: Cotton, okra, sorghum, millet, hollyhock, hibiscus, milky weed, jute, kangibooti, etc.

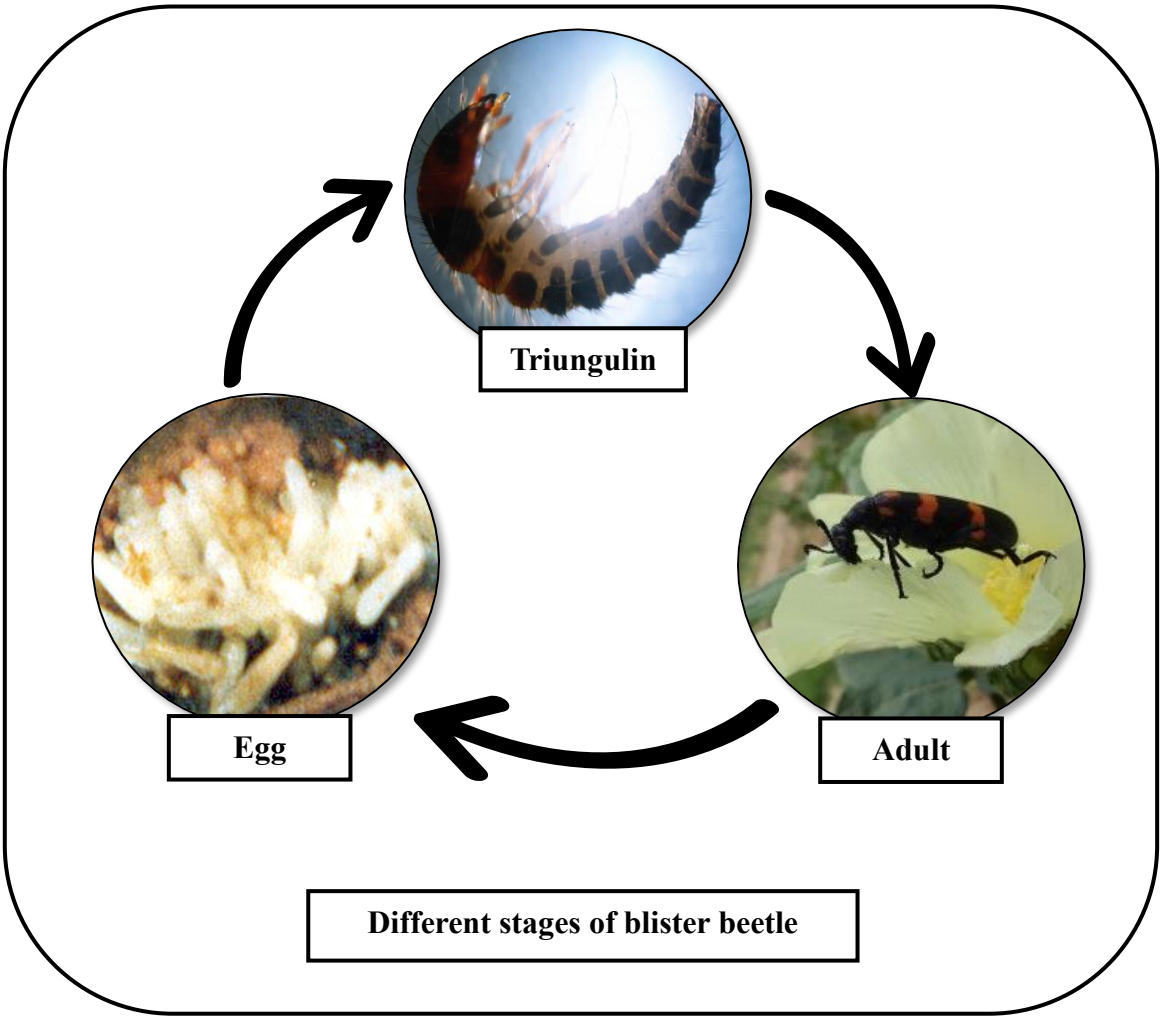
Prominent off-season Hosts: During off season, it survives on hibiscus, okra, kangibooti, etc.

Activity period: Red cotton bug infestation started in April-May months. The maximum infestation was observed during boll opening stage such as in September to November months.

Damage Symptoms & ETL:

- The Nymphs and adults of bug are gregarious in habit and attack in groups.
- Both adults and nymphs suck the sap from leaves, green bolls and seeds of partially opened bolls.
- Affected bolls opened defectively with their lint stained with the excreta or body juices.
- Rotting of the entire content, followed by discoloration of the lint to yellow or brown.

➢ Blister beetle



Different stages of blister beetle

Damage symptoms

➢ Blister beetle

4. Blister beetle: *Mylabris pustulata* (Meloidae**:** Coleoptera) is a minor pest of cotton with chewing type mouth parts.

Life cycle: Female lays 60-80 eggs deep in soil. Egg period lasts for 30-40 days. First stage larva called as triungulin and feed mainly on grasshopper eggs laid in soil. Larvae undergo hyper metamorphosis and moult five times. Pupation also occurs in soil, and adults with red, black, orange or white bands on wings emerge to attack cotton flowers and squares.

Host range: Blister beetles (*Mylabris* spp.) have a wide host range and mainly attack flowering crops. They infest cotton, pigeonpea, moong bean, blackgram, cowpea, groundnut, mustard and other oilseeds, as well as vegetables like okra, tomato and cucurbits.

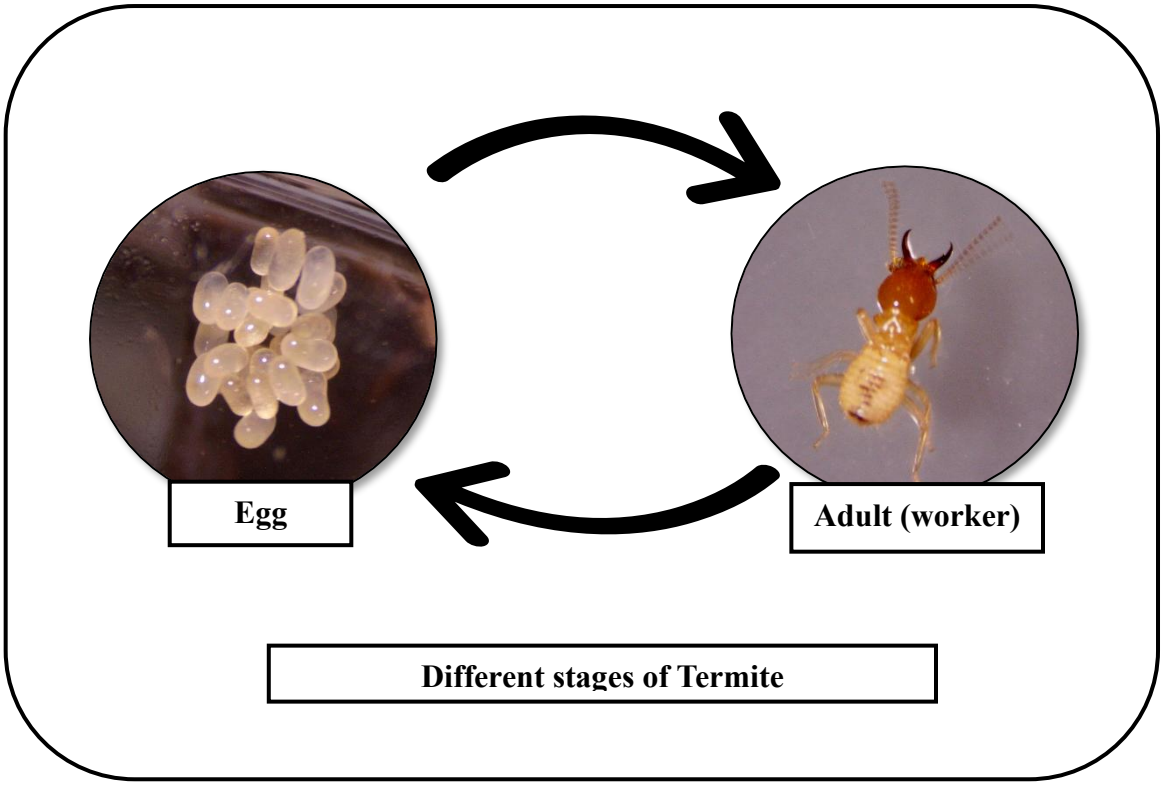
Prominent off-season hosts: Mustard, tomato and cucurbits etc.

Activity period: Blister beetle incidence commences when flowering on full swing. The population reaches its peak activity during August-September in cotton crop growing areas. The cotton plants adjoining to weeds available on roadside, water channel are more prone to be attacked.

Damage symptoms & ETL:

- Young seedlings can completely be defoliated in heavy infestations.
- Adults feed on floral parts such as petals, anthers, stigma, and ovary, which lead to cause reduction in fertilization and boll setting
- Beetles may also feed on flower buds and tender shoots, affecting flowering and boll formation.
- Adults feed on leaves, causing irregular holes and skeletonization**.**
- In cases of high infestation, they can cause severe defoliation, leaving only stems and side shoots.
- The destruction of flowers and bolls directly results in reduced cotton yield.

➢ Termites



Different stages of Termite

Damage symptoms

➢ Termites

5. Termites: *Microtermes obesi* and *Odontotermes obesus,* (Isoptera: Termitidae), is a polyphagous in nature, minor pest of cotton with chewing and biting type mouth parts.

Life Cycle: The male and female of termites take a flight after first showers in rainy season. The royal couple sheltered in soil, made a nuptial chamber, where copulation takes place. In a new established colony, female lays the first batch of eggs numbering 25-100, hatching in 40-42 days depending on the climatic conditions. The female termite then enlarge to develop as queen and lays up to 3000-4000 eggs per day. The eggs are laid singly or in double rows and glued together by a gelatinous secretion, depending on the species. The larva, cared by workers undergoes seven nymphal instars varies on species and the environmental conditions. They mature over a period of 2-6 months, depending on their species adult termites are small, 4-15 mm long and vary in color from white to tan and even black, depending on the species.

Host Plants: Major hosts of termites are cotton, sugarcane, upland rice, potatoes, sweet potatoes, groundnuts, soybean, coffee, wheat, barley, pea, sorghum, pearl millet, maize, groundnut., tea, cocoa, rubber, oil palm, coconut, kapok, some vegetables, some fruit trees like; mango, papaya, citrus, nutmeg, etc.

Prominent off-season Hosts: Wheat, barley, sugarcane, pea potatoes, sweet potatoes etc.

Activity Period: Termite population is active throughout the year but in case of cotton, incidence is noticed in seedling stage in dry conditions and maximum damage in vegetative phase during June–September coinciding with the onset of monsoon.

Damage Symptoms & ETL:

- At seedling stage of cotton, termites cut just below or at the soil surface.
- At vegetative or growing phase, feeds on roots and inside the stems at below ground level, which disturb the water and nutrient uptake systems and due to this, plants sometimes get dried.
- In initial infestation affected plants start to wither in noon due to water stress.
- In case of severe infestation, the damage start above ground level and plants show wilting symptoms. Infestation is more prone in dry season. Generally, termites attack is more prominent in rainfed areas as compare to irrigated conditions.

Predators

			
Green lacewing (Egg)	**Green lacewing (Egg Cluster)**	**Green lacewing (Larva)**	**Green lacewing (Adult)**
			
Spider (Egg Mass)	**Spider (Eggs inside Mass)**	**Spider (*Oxyopes salticus*)**	***Spider (Wedoquella spp.)***
			
Spider (*Neoscona theisi*)	*Coccinella septempunctata*	**Preying Mantis**	**Dragon fly**
			
Lady Bird Beetle (Eggs)	**Lady Bird Beetle (Larva)**	**Lady Bird Beetle (Pupa)**	**Lady Bird Beetle (Adult)**
			
Robber Fly	*Cryptolaemus montrouzieri*[*]	*Geocoris* **spp.**[*]	**Zanchius Bug**

***Source-(NBAIR)** https://databases.nbair.res.in/Featured_insects/predators.php

Natural Enemies Associated with Insect-Pests of Cotton

Natural enemies play a vital role in cotton pest management by suppressing populations of major sucking pests and bollworms including other minor pests associated with cotton.

Natural enemies population is a density dependant phenomenon associated with pests activity. In North zone during early window i.e., upto July activity of generalist predator is observed and very common in fields, while the population of parasitoids is generally observed during mid and later part of cotton season i.e. September-October in North Zone.

The conservation of available natural enemies should be considered while planning insect-pest management especially for selecting chemical pesticide sprays.

List of Predators associated with insect-pests of cotton crop.

Predators	**Target Host Insect**	**Stage of target pests**
Lady bird beetle- *Cryptolaemus montrouzieri*	Mealybug, Aphid	All stages of sucking pest
Lady bird beetle- *Coccinella septumpunctata*	Jassid, Whitefly, Mealybug, Lepidopteron larva	
Lace wing-*Chrysoperla carnea*	Aphid, Thrips, Whitefly, Jassid eggs	
Spiders-*Neoscona theisi, Oxyopes salticus*, *Wedoquella spp.*, etc.	Aphid, Whitefly, mirid bug, Lepidopteron larva	
Three-striped lady-beetle-*Brumoides suturalis*	Thrips, Whitefly, Jassid	
Big eyed bug- *Geocoris ochropterus* (Fieber)	Jassid nymphs & pink bollworm eggs	
Hover fly-*Eupeodes confrater* (Wiedemann)	Aphid	
Pentatomid bug- *Eocanthocona furcellata* (Wolff)	Larvae of bollworms and semi-looper	Immature stages

Parasitoids

Bracon Larva

Bracon Pupa

Bracon Adults

Trichogramma chilonis[*]

Trichogramma bactarae[*]

Apanteles angaleti

Chelonus blackburnii[*]

Eretmocerous spp.

Campoletis chlorideae[*]

***Source-(NBAIR)** https://databases.nbair.res.in/Featured_insects/parasitoids.php?lett=A

List of Parasitoids associated with insect-pests of cotton crop.

Parasitoids	**Target Host Insect**	**Stage of target pests**
Bracon greeni	Pink bollworm	Larva
Apanteles angaleti	Pink bollworm	Larva
Trichogramma brasiliensis, T.bactarae, T. chilonis	Spotted bollworm, Pink bollworm, Cotton bollworm	Egg
Chelonus blackburnii	Spotted bollworm	Egg-larva
Encarsia lutea, E. transvena	Whitefly	Nymph
Eretmocerous mundus	Whitefly	Nymph
Campoletis chlorideae	Cotton bollworm	Larva
Rogas aligarhensis Quadri	Spotted bollworm	Larva

Identification, Monitoring of Diseases and Their Disease Rating Scales

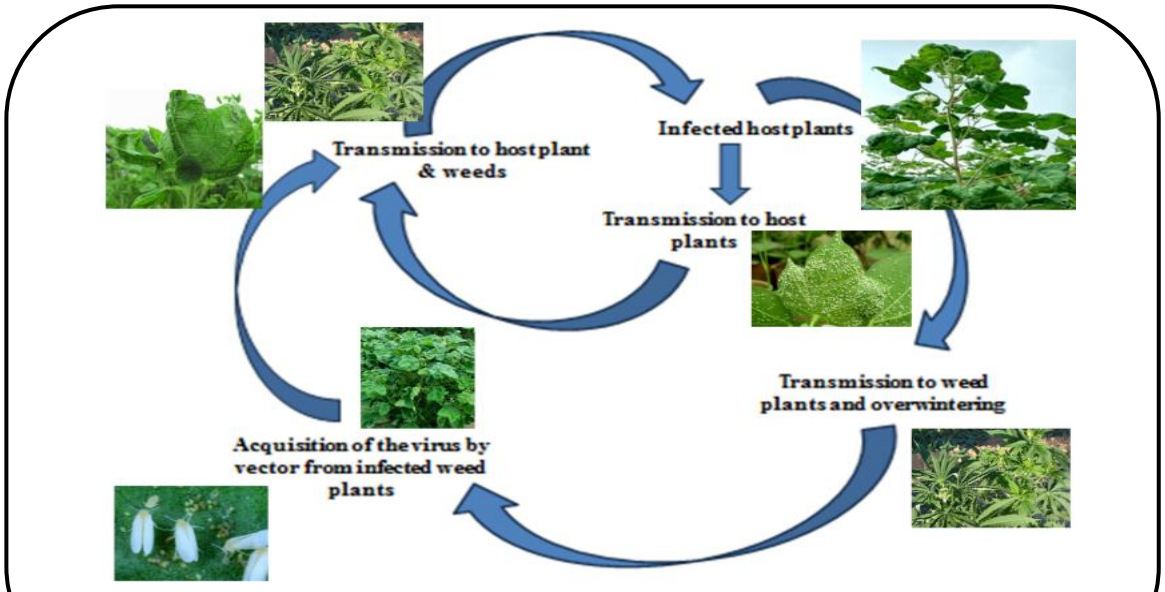
➢ Cotton leaf curl Disease (CLCuD)

Various symptoms of CLCuD

Vein thickening & upward curling	Downward curling	Leaf enation

0	1	2	3	4	5	6

CLCuD disease ratting scales



Disease cycle of cotton leaf curl disease

➢ Cotton leaf curl Disease (CLCuD)

Causal organism and its vectors: The CLCuD is caused by virus species under the genus *Begomovirus*, a monopartite virus with circular ssDNA as its genome. CLCuD virus is often associated with beta satellite (circular ssDNA) and alpha satellites (ssDNA). CLCuD transmitted by the whitefly (*Bemisia tabaci*).

Symptoms: The initial symptoms of the CLCuD are characterized by small vein thickenings on upper young leaves. Leaves show distinct upward and or downward curling along with increase in vein thickenings. Sometime infected leaves form secondary, leaf-like structures known as enation that emerge from the nectaries point. Reduced internodal length and plant stunting occur in severe infection along with considerable reduction in flowering, square formation and boll formation.

Disease rating scale

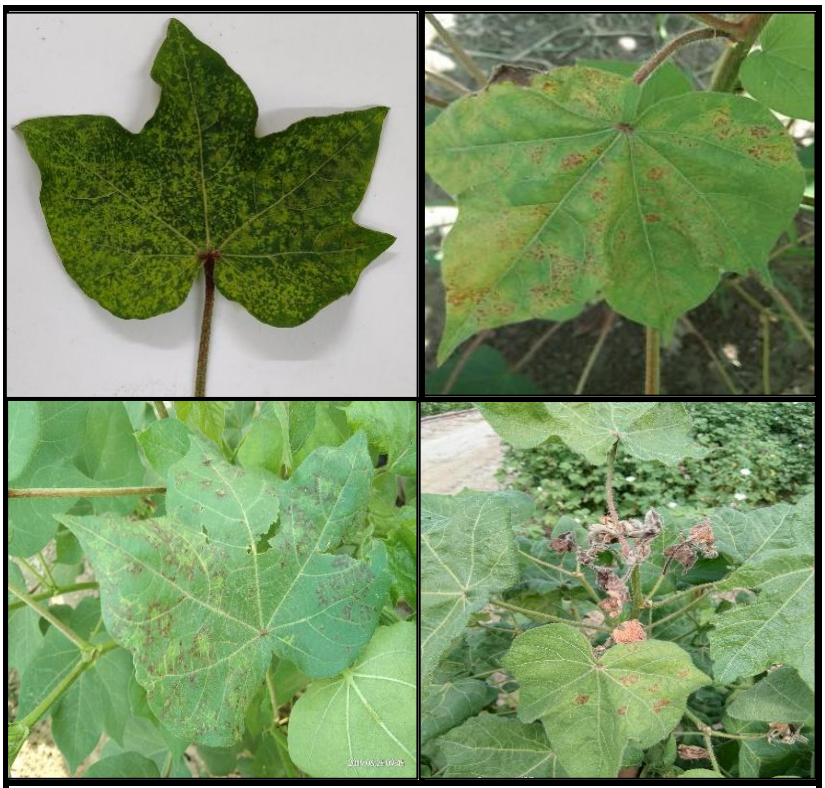
Scale	Symptoms	PDI (%)
0	Complete absence of symptoms	0.00
1	Symptoms of vein thickening on few upper leaves	16.6
2	Symptoms of vein thickening, cupping and curling on few upper leaves	33.3
3	1/4th plant affected with vein thickening, cupping and curling, leaf enations	50.0
4	1/2 plant affected with vein thickening, cupping and curling, leaf enations	66.6
5	3/4th plant affected with vein thickening, cupping and curling, leafy enation	75.0
6	Plants stunted severely and complete plants affected with vein thickening, cupping and curling and leafy enation.	>75.0

Transmission and Spread: CLCuD is exclusively transmitted by the whitefly (*Bemisia tabaci*) vector in a persistent circulative through infected cotton plants, volunteer plants and several alternate malvaceous hosts such as vegetables and weed which serve as reservoirs of the virus during the off-season. Whitefly feeds on infected plants and acquires the virus, become viruliferous and later inoculate the virus into healthy plant tissues while feeding. Infected plants/weeds serve as secondary sources of inoculum leading to rapid secondary spread field-level epidemics under favourable conditions.

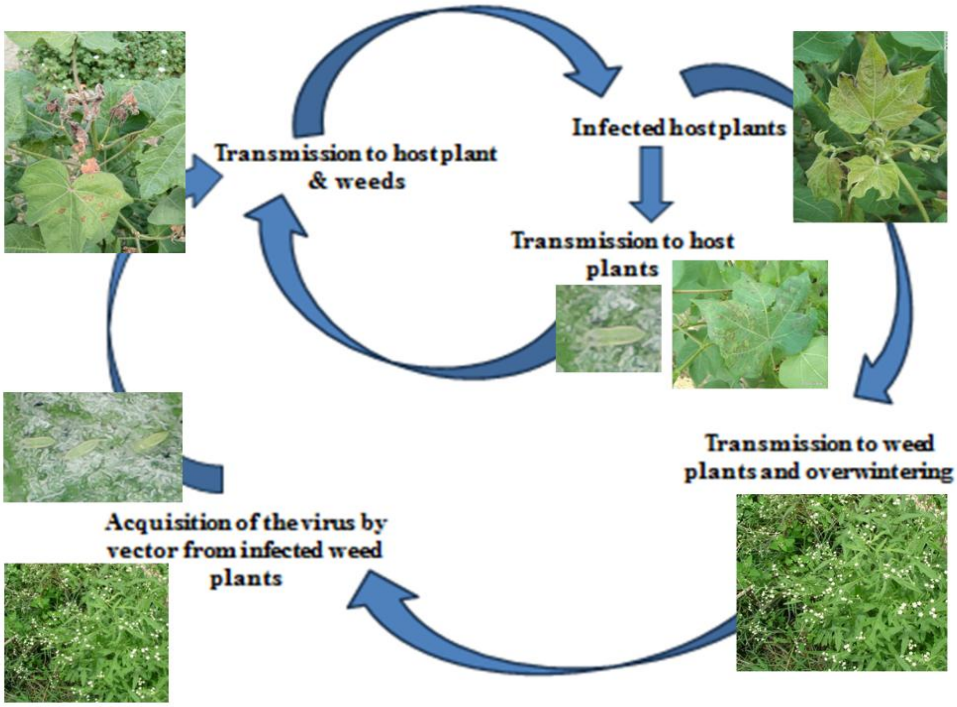
Management

- Use resistant recommended varieties/hybrids
- Adopt field sanitations, removal of alternate weed hosts.
- Continue monitoring of whitefly
- Spray recommended/window-based insecticide for whitefly management

➢ Tobacco Streak Virus (TSV)



Symptoms of TSV as twig necrosis and necrotic spots on leaves in young plants of *G. hirsutum*



Disease cycle of Tobacco Streak Virus disease of cotton of cotton

➢ Tobacco Streak Virus (TSV)

Causal organism its vector: The disease is caused by *Tobacco streak virus* (TSV), a species under the genus *Illarvirus*, family *Bromoviridae*.

Symptoms: Symptom show distinct dark purple necrotic spots and drying of squares. Typical symptoms observed in *G. hirsutum* were chlorotic with necrotic spots in young leaves and marginal necrotic streaks with leaf deformation. In mature plants, veinal necrosis, drying of squares and also in terminal shoots are observed.

Disease rating Scale

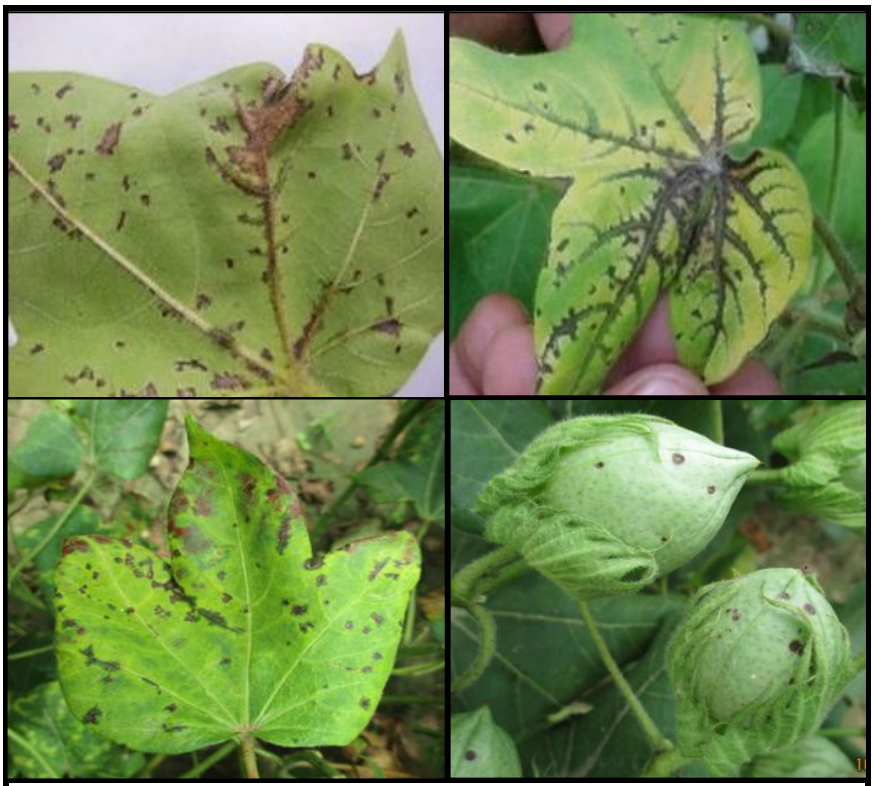
Scale	Symptoms	PDI (%)
0	Free from the disease	0.00
1	Few upper leaves showing chlorosis or necrosis	25.0
2	Moderate square drying and few branches affected	50.0
3	Severe burning of squares and more branches affected	75.0
4	Severe stunting inclusive of above symptoms	>75.0

Transmission and Spread: The combined role of *Thrips palmi* and the *Parthenium* pollen grains in the transmission of TSV. Thrips only facilitate the movement of TSV borne pollen grains and contributes to active spread of the virus. A positive correlation was observed between the mean disease incidence and the mean thrips population, and the parthenium weed population.

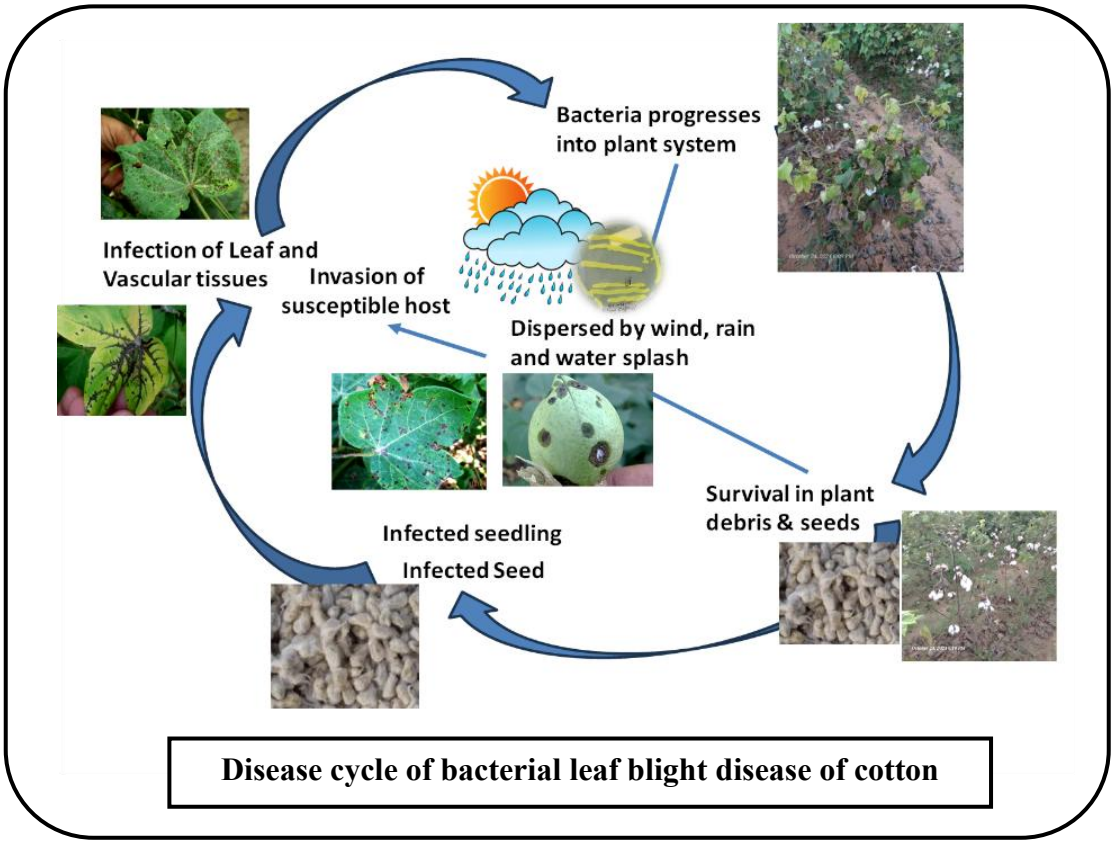
Management

- Use resistant recommended varieties/hybrids
- Adopt field sanitations, removal of alternate weeds particularly Parthenium
- Continue monitoring of thrips
- Spray recommended/window-based insecticide for thrips management

➢ Bacterial Leaf blight of cotton



Symptoms of BLB in cotton (water-soaked oily or greasy appearance underside of the cotton leaf)



Disease cycle of bacterial leaf blight disease of cotton

➢ Bacterial Leaf blight of cotton

Causal organism and favourable conditions: *Xanthomonas citri* pv. *malvacearum*.

Symptoms: Initial symptoms appear as small, water-soaked lesions on leaves of seedlings and mature plants. Lesions enlarge into characteristic angular shapes due to restriction by leaf veins. The oily or greasy appearance is most distinct on the underside of the leaf and serves as a key diagnostic feature distinguishing bacterial blight from fungal foliar diseases. On the upper leaf surface, lesions are often surrounded by a yellow halo. Older lesions turn black and increase in size, leading to premature defoliation. Vein infections result in the characteristic black arm symptom. Lesions associated with bacterial blight are generally darker than those caused by other foliar pathogens.

Disease rating Scale

Scale	Symptoms	PDI (%)
0	Plants completely free from infection	0.00
1	Few lower leaves showing few scattered spots	25.0
2	Leaf spots covering leaf area up to 10%	50.0
3	Leaf spots covering leaf area up to 11-20%	75.0
4	Leaf spots covering leaf area above 20%	>75.0

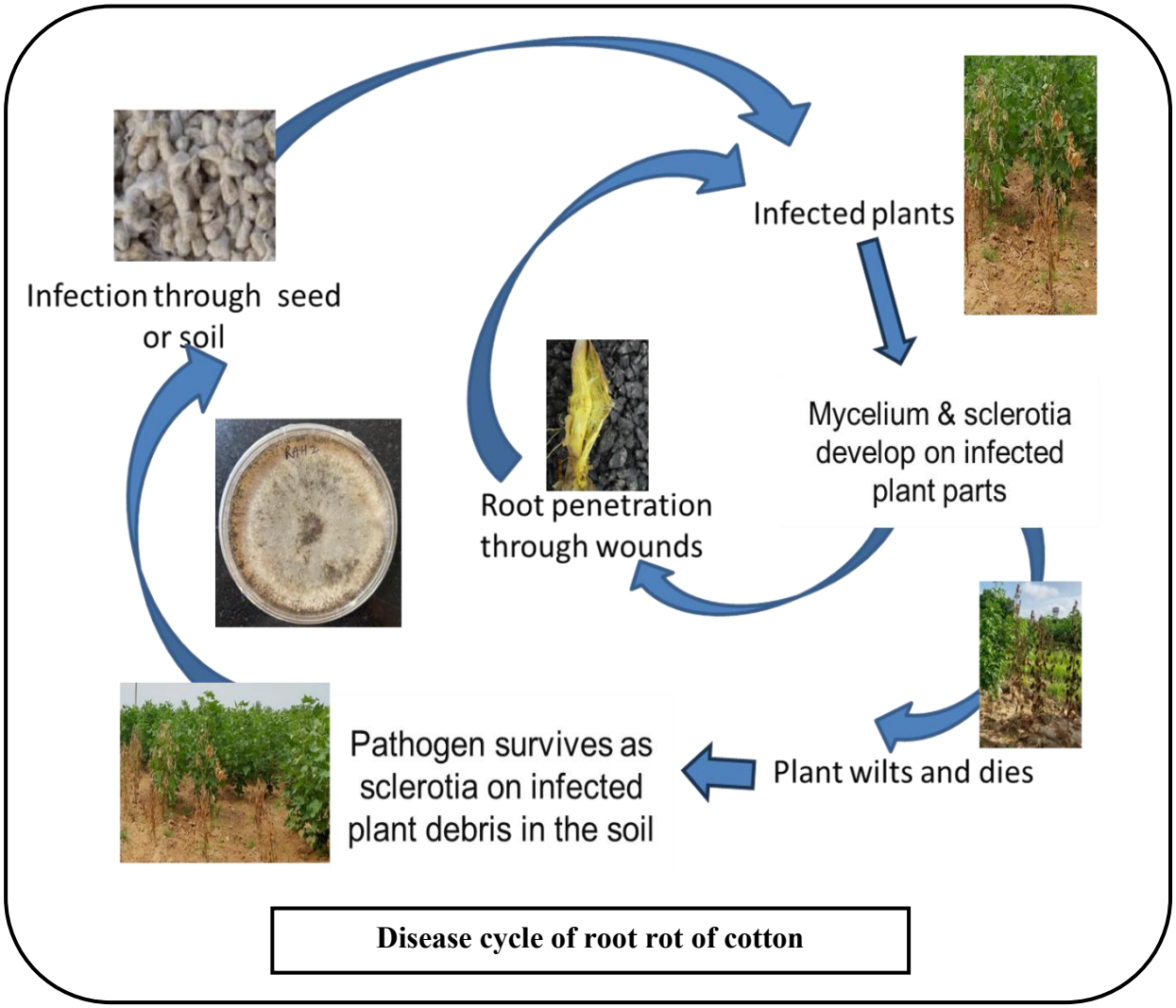
Disease cycle and epidemiology:
Bacterial leaf blight is seed and air-borne and pathogen can persist in soil for several years by feeding on contaminated, dried plant waste. The bacterium found in seeds, is where the primary infection begins. The bacteria can spread secondarily by the air, wind-blown rain splashes, sprinkler irrigation water, insect-pests, and other farm tools. The severity of BLB remains high in sub humid and semiarid regions coupled with wind, and rainfall ranging from 25.4 to 76.2 mm. High-humidity and or rain splashes favour growth and further the spread of pathogens to the new crop plants.

Management

- Use resistant recommended varieties/hybrids
- Adopt seed treatment with recommended biopesticides and chemicals
- Continue monitoring of disease
- Spray recommended/window-based chemicals

➢ Fungal Root rot Disease

Symptoms of root rot disease in American & Desi cotton



Disease cycle of root rot of cotton

➢ Fungal Root rot Disease

Causal organism and favourable conditions: The disease complex is primarily associated with *Rhizoctonia solani, Rhizoctonia bataticola*, and *Sclerotium rolfsii*.

Symptoms: The disease is marked by sudden wilting and drooping of plants from the top downward. Infected plants can be easily uprooted, as the root bark disintegrates into shreds, imparting a yellowish appearance. The causal organism can be distinguished on the basis of the nature of root discolouration and moisture content of the affected parts. Infection by caused by *R. solani* produces brown, wet, and soft roots, whereas *R. bataticola* results in black, dry, and brittle roots. In the case of *Sclerotium rolfsii*, generally profuse white mycelial growth may be observed on the roots and collar region, together with the formation of small, spherical sclerotia, finally leads to root decay and seedling death.

Disease rating Scale

Scale	Symptoms
0	All plants remains completely free from infection
1	Plants of an entry or in field sowing 5% incidence
2	Plants of an entry or in field sowing 6-15% incidence
3	Plants of an entry or in field sowing 16-25% incidence
4	Plants of an entry or in field sowing more than 26% incidence

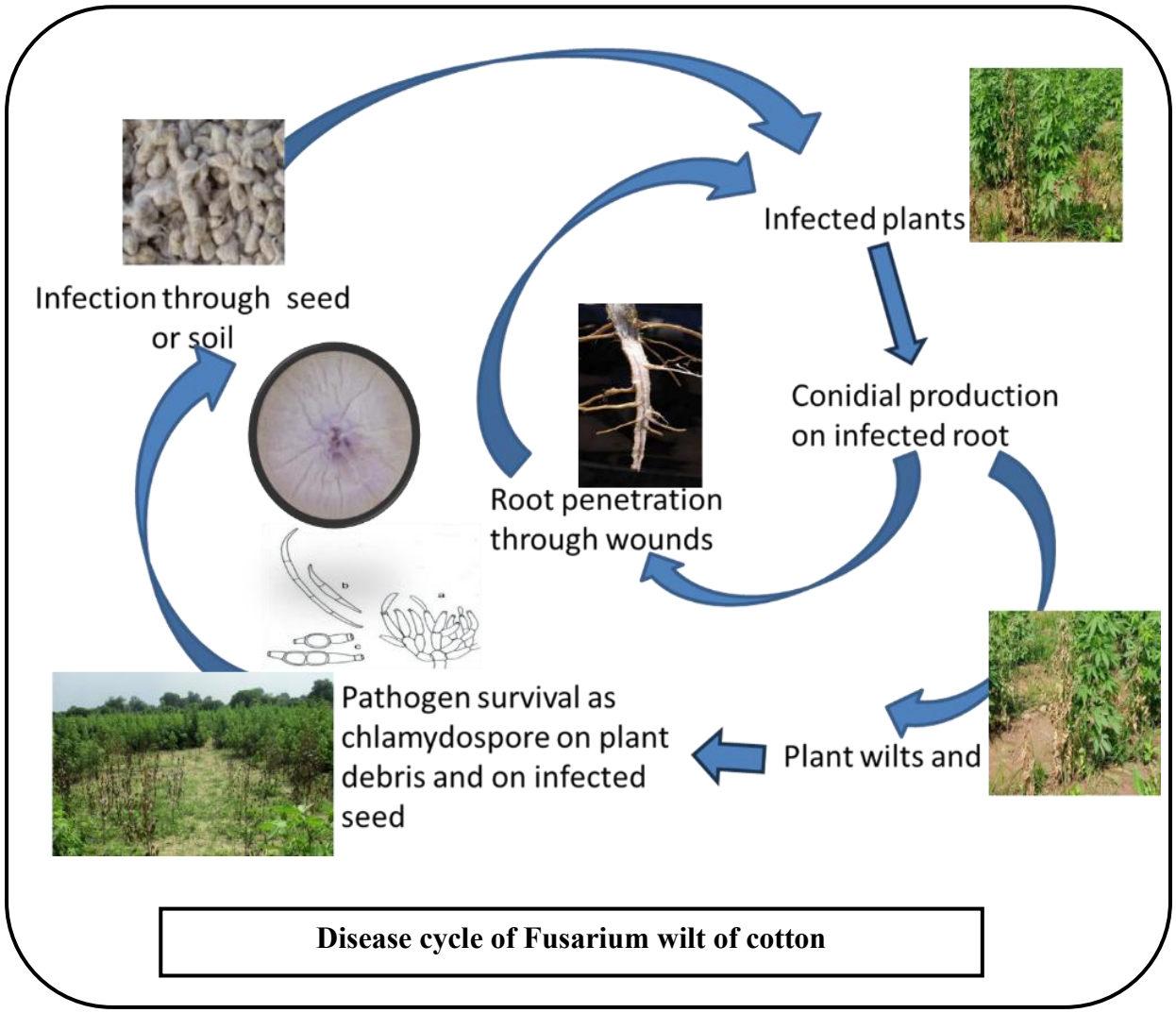
Disease cycle and epidemiology:
Root rot pathogen is seed and soil-borne, it can persist in the soil for several years by feeding on contaminated, dried plant waste. It is also found in seeds and persists on seed coat fuzz mass. The pathogen found in seeds and or soil, from where the primary infection begins. The disease secondarily spread by irrigation, rain splashes, sprinkler irrigation water, and other farm tools. The severity of disease remains high in sub humid and semi-arid regions coupled with dry conditions.

Management

- Use resistant recommended varieties/hybrids
- Adopt seed treatment and soil treatment with recommended biopesticides and chemicals
- Use crop rotation and continue monitoring of disease & field history
- Spray recommended/window-based fungicides

➢ *Fusarium* wilt disease of cotton

Plant wilting and vascular discoloration symptoms of *Fusarium* wilt in cotton



Disease cycle of Fusarium wilt of cotton

➢ *Fusarium* wilt disease of cotton

Causal organism and favourable conditions: The disease is caused by the fungus *Fusarium oxysporum* f. sp. v*asinfectum*. The disease commonly appears between 30 and 120 days after sowing, particularly in heavy black, alkaline soils. It predominantly affects *G. arboreum* (desi cotton) and *G. herbaceum* (Asiatic cotton). The pathogen has considerable variability in its virulence, and several physiological races have been reported within populations of *F. oxysporum* f. sp. *vasinfectum*. Earlier, FOV Race-01 (VCG001) and Race-04 (VCG0014) was reported to cause the disease only in *G. arboreum* cotton, however, very recently these races have been reported to cause wilt in upland cotton too.

Symptoms: Disease symptoms are often initiated at the seedling stage including necrotic lesions on the cotyledons, which further extend to the developing leaves, where reticulate necrosis may generally develop along the veins. With the disease progress affected leaves shows drooping/wilting, leads to partial or complete drying of the infected plant. Infection may occur from vegetative to boll development stages. The affected vascular tissues especially in roots, stems, and petioles, typically exhibit dark brown discolouration, when these are cut opened longitudinally. Furthermore, nematode infestation may prompt further infection and enhance disease severity at any stage of crop growth.

Disease rating Scale

Scale	Symptoms
0	All plants of an entry or in field free from infection
1	Plants of an entry or in field sowing 5% incidence
2	Plants of an entry or in field sowing 6-15% incidence
3	Plants of an entry or in field sowing 16-25% incidence
4	Plants of an entry or in field sowing more than 26% incidence

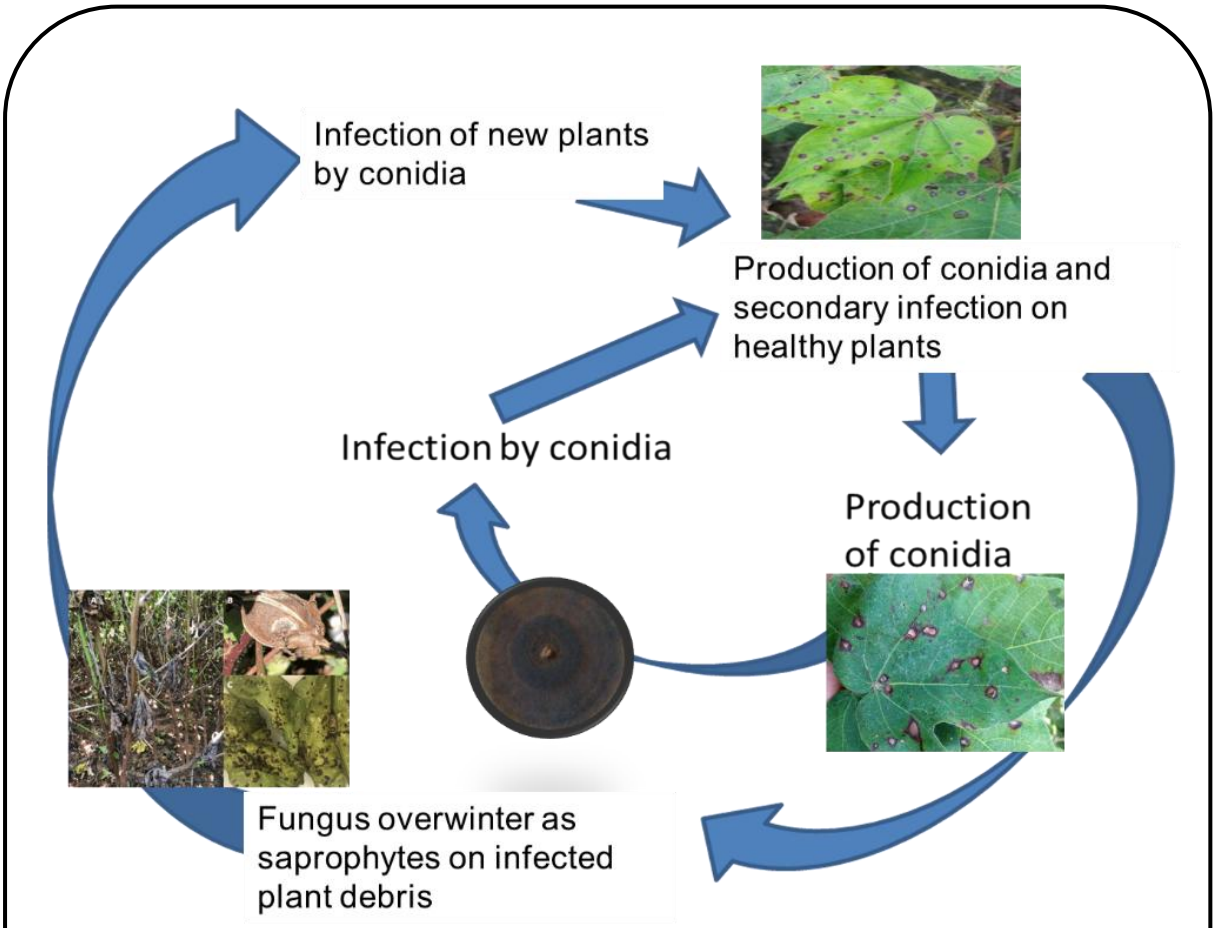
Disease cycle and epidemiology:
Pathogen is seed and soil-borne, it can persist in soil for several years by feeding on contaminated, dried plant waste. It can contaminate seeds and persists on seed coat fuzz mass. Infected seeds and or soil serves as the primary infection source and secondarily spread happens through irrigation water, rain splashes, and farm tools. The disease severity remains high in sub humid and semiarid regions.

Management

- Use resistant recommended varieties/hybrids
- Adopt seed treatment and soil treatment with recommended biopesticides and chemicals
- Used crop rotation and continue monitoring of disease & history
- Spray recommended/window-based fungicides

➢ Target leaf spot of cotton

Characteristic symptom of target leaf spot of cotton (target-shaped lesions with distinct dark spot in the center)



Disease cycle of Target Leaf Spot disease of cotton

➢ Target leaf spot of cotton

Causal organism and favourable conditions: The Target leaf spot disease is caused by fungal pathogen *Corynespora cassiicola*. The pathogen has very wide host range.

Symptoms: Initially, leaves show small circular to irregular dark red spots of 2 mm and 10 mm in size. The target-shaped lesion is the most identical symptom of *C. cassiicola* where spots are often distinctly zonate with a darker spot in the center of the lesion under favourable conditions. The lesions become necrotic and show peculiar "target spot" symptoms, with some depression at the center of the lesion. Under severe infection, the lesions get coalesced and the infected leaves show severe necrosis leading to premature senescence and defoliation under optimum conditions. At later stage the spots are observed on the square bracts. Under favourable conditions square dropping leads to poor boll setting.

Disease rating Scale

Scale	Symptoms	PDI (%)
0	Plants completely free from infection	0.00
1	Few lower leaves showing few scattered spots up to 5%	25.0
2	Leaf spots covering leaf area up to 11-20%	50.0
3	Leaf spots covering leaf area up to 21-40%	75.0
4	Leaf spots covering leaf area above 40%	>75.0

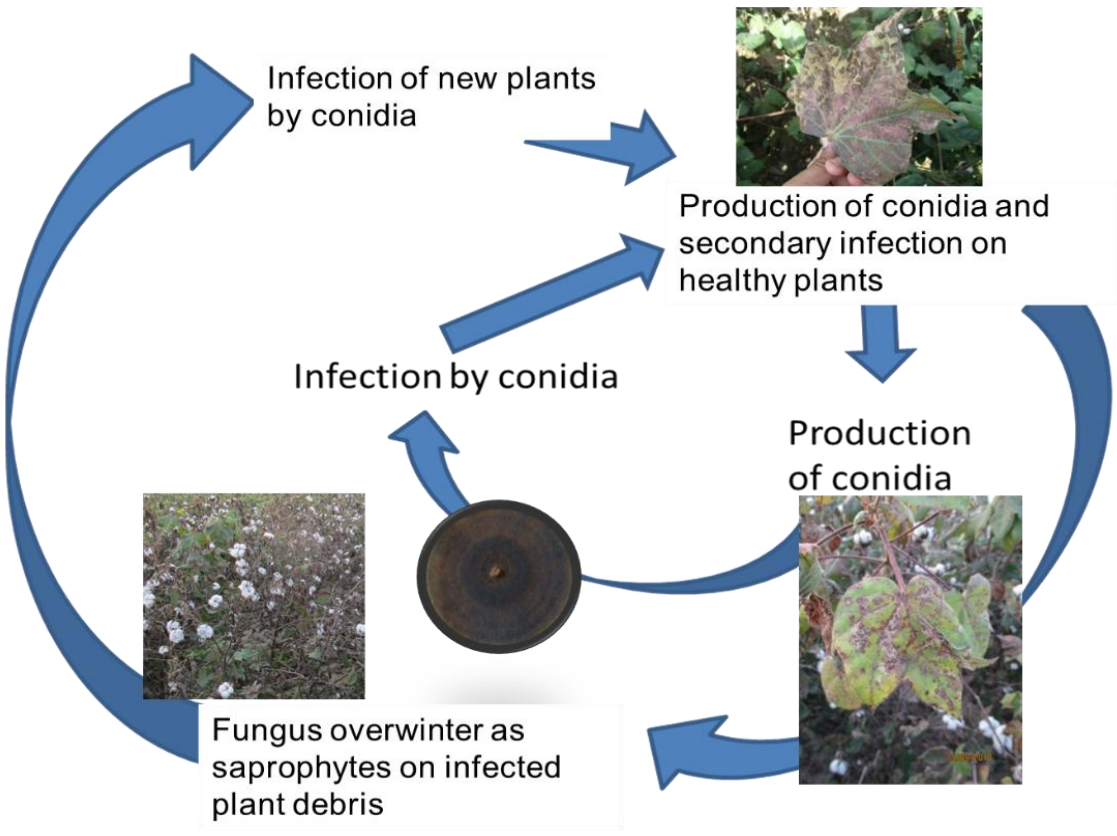
Disease cycle and epidemiology: It is a necrotrophic fungus overwinters on infected debris; seeds and some isolates survive as endophytes and saprophytes which serve as the source of primary inoculum. Chlamydospore formation helps to survive the pathogen in soil or plant debris under unfavorable conditions. Dense lower canopy coupled with high humidity and soil borne primary inoculum are the optimum conditions for infection. It is a polycyclic disease with a very short reproduction cycle that favors multiple generations in a season. Frequent showers/irrigation, dense canopy creates microclimate congenial for early disease onset which leads to rapid premature defoliation.

Management

- Use resistant recommended varieties/hybrids
- Adopt seed treatment and soil treatment with recommended biopesticides and chemicals
- Follow continue monitoring of disease
- Spray recommended/window-based fungicides

➢ Alternaria leaf spot of cotton

Symptoms of *Alternaria* leaf spot on Desi and Upland cotton



Disease cycle of Alternaria leaf spot disease of

➢ Alternaria leaf spot of cotton

Causal organism and favourable conditions: This leaf spot disease is caused by three species *Alternaria macrospora*, *A. alternata* and *A. gossypina,* and former being is the major one followed by *A. alternata*. Association of both *A. macrospora* and *A. alternata* is usually found leading to blight of cotton.

Symptoms: Initial disease symptoms are formation of small (0.5-2.5 mm), circular, brown lesions with a purple margin. Symptoms vary with the species, *A. macrospora* causes brown to greyish brown or tan colored lesions on the lower leaves measuring 3-10 mm in diameter. Later the lesions expand forming concentric rings with a cracked center. *A. alternata* forms purple lesions with purple margins and severe infection leads to drying of the foliage and finally defoliation. *A. gossypina* causes yellowing and drying of leaves, defoliation and rotting of the bolls as well. Under favorable weather conditions pathogen causes necrotic spots, defoliation, and produces numerous spores on the defoliated leaves. The disease is more severe on the lower old leaves and cotton plants with high boll load are more susceptible.

Disease rating Scale

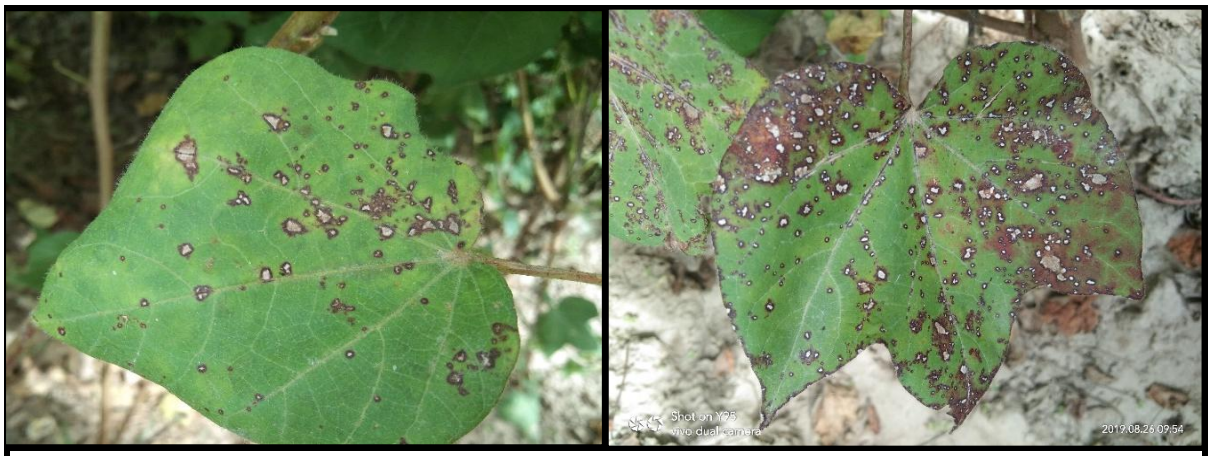
Scale	Symptoms
0	All plants of an entry or in field free from infection
1	Plants of an entry or in field sowing 5% incidence
2	Plants of an entry or in field sowing 6-15% incidence
3	Plants of an entry or in field sowing 16-25% incidence
4	Plants of an entry or in field sowing more than 26% incidence

Disease cycle and epidemiology: Disease is a polycyclic disease and completes several cycles of infection under favorable weather conditions. Infected crop debris or seed serves as the primary source of inoculum where spores survive the adverse climatic conditions. Optimum temperature for sporulation is 25-30°C and sporulation is higher on older leaves than on younger leaves. The pathogen requires longer leaf wetness period to infect at optimum temperature range of 20-30°C and can sporulate up to 35°C. Frequent rainfall with high relative humidity of 65-90% and temperature range of 20-28°C is highly conducive for disease development.

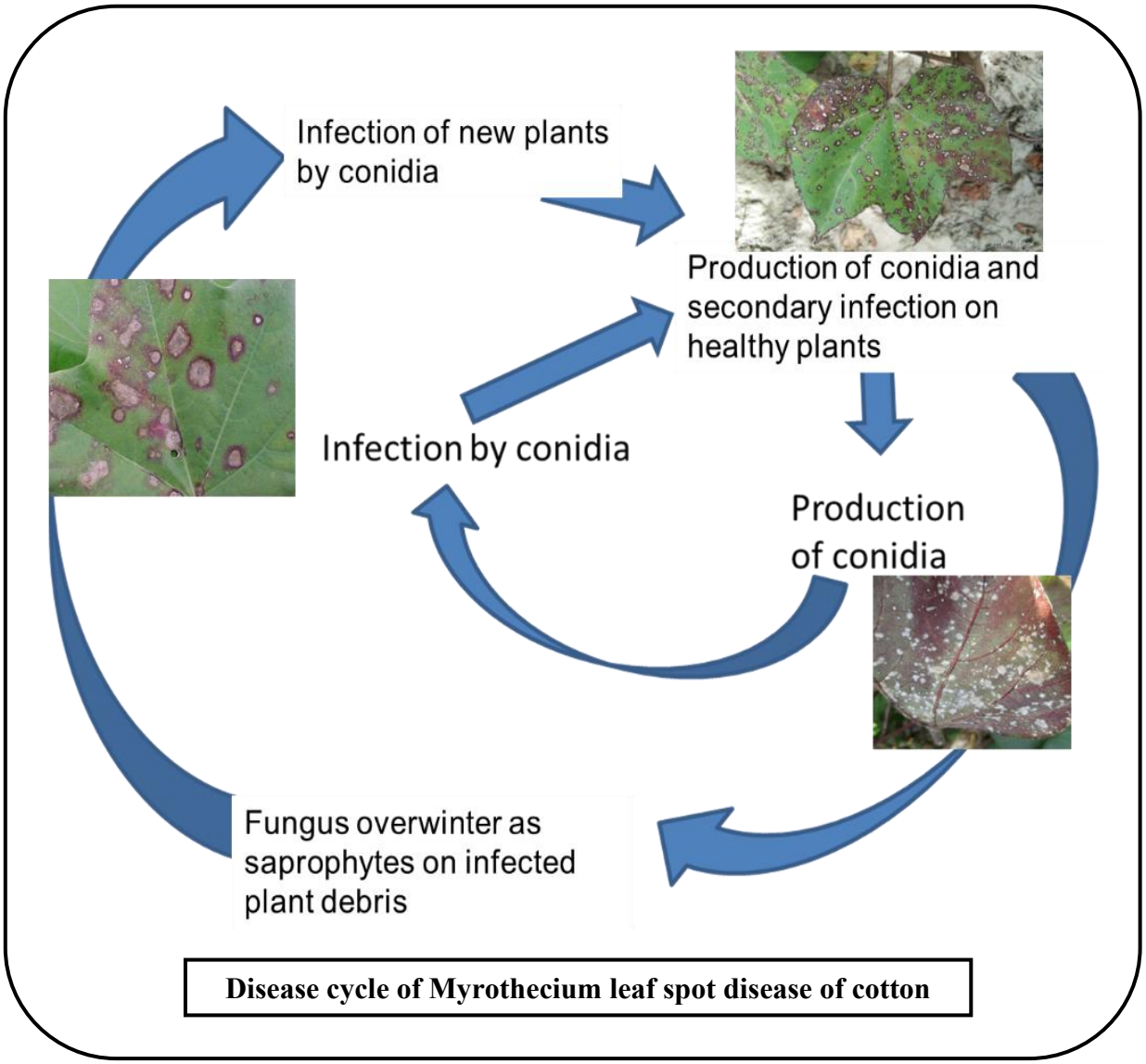
Management

- Use resistant recommended varieties/hybrids
- Adopt seed treatment and soil treatment with recommended biopesticides and chemicals
- Follow continue monitoring of disease
- Spray recommended/window-based fungicides

➢ Paramyrothecium/ Myrothecium leaf spot of cotton



Symptoms of *Myrothecium/ Paramyrothecium* leaf spot on cotton



Disease cycle of Myrothecium leaf spot disease of cotton

➢ Paramyrothecium/ Myrothecium leaf spot of cotton

Causal organism and favourable conditions: *Paramyrothecium roridum* (formerly *Myrothecium roridum)* causes severe leaf spot and blight in cotton (*Gossypium hirsutum*).

Symptoms: *Paramyrothecium* causes severe leaf spots and blight in cotton, appearing as circular or irregular, 2-10 mm spots with light brown centers and purple margins. Initially, minute-soaked, dark purple spots or streaks appear on leaves, which merge into large, necrotic, light brown, or gray patches. Infection is characterized by gray-centered, dark-margined necrotic spots, often starting from leaf margins, leading to premature defoliation. It can also affect seedlings, causing stem and petiole necrosis. In high humidity, black spore masses (sporodochia) with white tufts form on the lesions. Later, center of old lesions may fall out, creating a "shot hole" appearance. Cotton plants with high boll load are more susceptible and it can cause infection on bolls too.

Disease rating Scale

Scale	Symptoms
0	All plants of an entry or in field free from infection
1	Plants of an entry or in field sowing 5% incidence
2	Plants of an entry or in field sowing 6-15% incidence
3	Plants of an entry or in field sowing 16-25% incidence
4	Plants of an entry or in field sowing more than 26% incidence

Disease cycle and epidemiology:
The fungus survives the off-season as spores (conidia) or mycelium on infected plant debris left in the field, or occasionally on seeds. During the rainy season, spores are spread to healthy cotton leaves primarily by rain splashes, irrigation and wind. In the presence of a film of water on the leaf and high humidity (around 85%), the spores germinate and penetrate the leaf tissue. Within lesions on leaves, the fungus produces black, cushion-like fruiting bodies and spores are spread by wind and water to the upper canopy and healthy plants, during humid periods. Later on, the necrotic centers may dry out and drop to the soil, where the fungus returns to its survival phase in the debris.

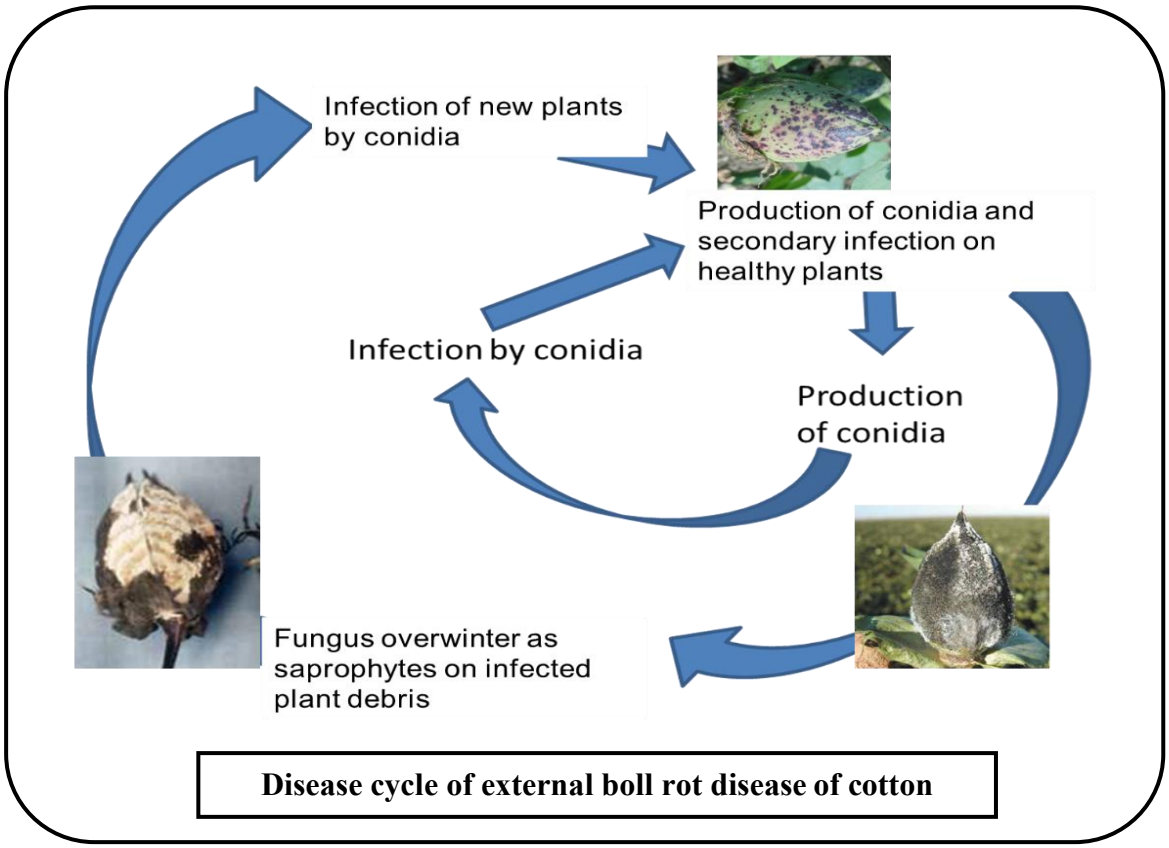
Management

- Use resistant recommended varieties/hybrids
- Adopt seed treatment and soil treatment with recommended biopesticides and chemicals
- Follow continue monitoring of disease
- Spray recommended/window-based fungicides

➢ Boll rot complex disease

A. External boll rot

Symptoms of external boll rot in cotton



Disease cycle of external boll rot disease of cotton

➢ Boll rot complex disease

Boll rot is a general term which describes variety of the symptoms developed in response to attack by several plant pathogenic microorganisms to developing bolls of cotton.

A. External boll rot

Causal organism and favourable conditions: It is caused by several fungal pathogens i.e. *Fusarium* spp., *Diplodia gossypina*, *Colletotrichum* spp,, *Myrothecium roridum, Botryodiplodia theobromae*, *Phytophthora* spp., *Phoma exigua*, *Ramularia areola*, *Phomopsis* sp., *Rhizoctonia solani*, *Corynespora cassicola*, *Alternaria* spp., *Penicillium*, *Rhizopus nigricans*, *Nematospora nagpuri*, *Aspergillus* spp. etc.

Symptoms: The disease begins as small grey-brown or black spots on developing bolls, eventually engulfing them, and spreading to internal tissues to rot the seeds and fibers. Severe infections can prevent bolls from opening or cause premature shedding. However, if the infection is limited to the exterior, only the pericarp rots. Depending on the specific fungal pathogen, infected bolls may exhibit visible mycelial growth and fruiting bodies.

Disease rating Scale

Scale	Symptoms	PDI (%)
0	All bolls free from infection	0.00
1	Bolls sowing 0.1 to 24% incidence	25.0
2	Bolls sowing 25 to 49 % incidence	50.0
3	Bolls sowing 50 to 74% incidence	75.0
4	Bolls sowing above 75% incidence	100.0

Disease cycle and epidemiology: Primary infection occurs when fungal mycelia, spores, and fruiting bodies survive in diseased bolls and soil debris. Sucking pests and insects further increase the disease by wounding developing bolls, creating entry points for pathogens. Secondary spread is driven by airborne conidia and insects, particularly during heavy rainfall and flowering. Stagnant water and high humidity create a conducive microclimate, while warm temperatures during boll development further predispose the crop to rot.

Management

- Use resistant recommended varieties/hybrids
- Adopt canopy management for proper aeration, and water drainage.
- Follow continue monitoring of disease and ignore excess soil moisture
- Spray recommended insecticides for vector/boll damaging insects
- Spray recommended/window-based fungicides

- **Boll rot complex disease**

B. Internal boll rot

Symptoms of internal boll rot in cotton

➢ Boll rot complex disease

B. Internal boll rot

Causal organism and favourable conditions: Internal boll rot is mainly caused by phytopathogenic bacteria, such as *Pantoea* spp., *Xanthomonas citri* pv. *malvacearum* and sometimes by endogenous fungi such as *Nigrospora oryzae.*

Symptoms: Early diagnosis without boll sectioning is difficult because infected bolls remain healthy outside. Locule infection is typically only visible upon cross-sectioning. Fiber maturity is compromised, and seeds may become swollen and slimy, with lint turning necrotic or reddish-brown in infected bolls. Under severe cases "hard lock" symptoms appear, where bolls fail to open and contain rotten seeds. Sometime, bolls drop prematurely or open only partially. Furthermore, water-soaked oily spots may rupture, allowing *X. citri* pv. *malvacearum* to spread throughout the internal tissues

Disease rating Scale

Scale	Symptoms	PDI (%)
0	All bolls free from infection	0.00
1	Bolls sowing slight damage 0.1 to 24% or 1-2 locules	25.0
2	Bolls sowing moderate damage 25 to 49% incidence	50.0
3	Bolls sowing severe damage 50 to 74% incidence	75.0
4	Bolls sowing total destruction above 75% incidence	100.0

Disease cycle and epidemiology: Primary infection is initiated by *Pantoea* spp., which are omnipresent in infected field bolls. *Xanthomonas citri* pv. *malvacearum* spreads through infected seeds and debris, while the *Nigrospora oryzae* infects new bolls via leftover diseased plant material. These pathogens infect plants through natural openings or wounds developed by insect. Secondary spread is facilitated by wind, rain splashes, and insect vectors, including the red cotton bug, southern green stink bug, verde plant bug (*Creontiades signatus)*, and brown stink bug (*Halyomorpha halys*). *Pantoea agglomerans* growth is favoured by 13–29°C temperature and 63–66% RH, and light rainfall (1.5–2.5 mm).

Management

- Use resistant recommended varieties/hybrids
- Adopt canopy management for proper aeration
- Follow continue monitoring of disease and ignore excess soil moisture
- Spray recommended chemical and insecticides for boll damaging insects
- Spray recommended/window-based fungicides

➢ Nematodes problem in Cotton

Symptoms of nematode infection on cotton plant

Symptoms of root knot nematode galls on roots of cotton plant

➢ Nematodes problem in Cotton

Causal organism and favourable conditions: Plant parasitic nematodes, root–knot nematode- *Meloidogyne incognita*, is dominant in Northern cotton-growing areas while reniform nematode- *Rotylenchulus reniformis* infest cotton in Central and Southern India Both these nematodes are also involved in disease complexes and increase the incidence and severity of wilt diseases and post emergence damping off caused by pathogenic fungi.

Symptoms: The damage symptom by root-knot nematode (RKN) include plant stunting, leaf chlorosis, early wilting appearance of the plant. RKN infection resulted in smaller root system with fewer lateral and feeder roots and produces galls or knots on the roots. Nematode feeding and gall formation inhibits the upward translocation of water and nutrients which together with a reduced root system produces a non-specific above ground damage resembling nutrient or water deficiency symptoms. Field infestation results in uneven, pale, stunted and sick crop resembling to deficiency symptoms. High population density of the nematode at sowing can kill the plants at seedling stage. Mature plants exhibit temporary wilting in afternoons.

Disease cycle and epidemiology: The life cycle of nematode infestation in cotton, specifically for the RKN, typically completes every 4 to 6 weeks depending on soil temperature. It follows a cycle of six distinct stages including 1st to 4th juvenile stage: Egg stage: Mature females lay egg masses in a protective jelly-like matrix on the root surface or within galls. The first molt occurs inside the egg, where the embryo develops into the J1 stage. The nematode molts into the J2 stage before hatching from the egg. This is the only mobile stage that can move through soil water to find and penetrate young cotton root tips. Once inside the root, the J2 establishes a permanent feeding site and triggers the formation of "giant cells," which swell the root and create visible galls (knots). The nematode becomes sedentary and undergoes two more molts (J3 and J4). Adult females become pear-shaped and remain inside the root to produce more eggs and Males revert to a worm-like shape, exit the root, and do not feed. They are often unnecessary for reproduction as many species are self-fertilizing.

Management

- Use resistant recommended varieties/hybrids
- Adopt deep-summer ploughing and crop rotation
- Follow continue monitoring and ignore excess soil moisture
- Spray recommended window-based biopesticides, fungicides along with nematicides.

Management of Viral Diseases in Cotton

➢ Management of CLCuD

A vigorous exercise was done by the ICAR institutions and state agricultural universities to work out management strategies. For the detection of viruses' molecular diagnostic tools were developed. Several varieties/hybrids including *Bt* cotton hybrids resistant/tolerant to this disease and its vector whitefly evolved and made available to farmers. Following approaches and practices are recommended for effective and holistic management of CLCuD:

- Use of resistant cotton varieties/hybrids is the most effective method to minimize CLCuD.
- Strict Quarantine measures should be followed while movement of planting material and import and export which will help in restricting the movement of disease from one place to other places and thereby prevent the spread.
- Removal of weeds which serve as hosts of whitefly infestation and spread of viruses from one plant to another in and around the field during the season and off-season will reduce the disease inoculum.
- Destroy ratoon crops during the off-season to eliminate the source of inoculum of disease. Encourage sowing of desi cotton in the CLCuD hot spot area or as border rows (4-8 rows).
- Adopt timely sowing as late sown crops are prone to CLCuD and avoid growing American cotton near citrus orchards and other hosts of vector which can increase the virus infection and spread the virus to other healthy cotton plants.
- Growing okra, cucurbits, tomatoes and/or other crops susceptible to whiteflies/CLCuD or *vice versa* in and around the field should be discouraged.
- Removal of infected plants and burying them at an early stage in the field or pits could help in preventing the spread of virus to healthy plants.
- The optimum dose of fertilizer is key practice to manage the disease. Excess use of nitrogen could accelerate the disease in field. Therefore, application of recommended dose of nitrogen fertilizer at appropriate time could help manage the plant growth and several diseases.
- Use yellow sticky traps for whitefly mass trapping and timely control of whiteflies which will ultimately lead to control of virus.
- Start spraying with neem-based insecticides and whitefly growth regulators (pyriproxyfen, spiromesifen for nymphs and diafenthiuron, dinotefuran, flonicamid for adults)
- The use of synthetic pyrethroids should be discouraged in cotton to avoid the problem of whitefly. Cypermethrin, fenvalerte and deltamethrin cause resurgence of whiteflies. So, avoid repeated spraying of pyrethroids.

➢ Management of TSV

- Use of resistant cotton varieties/hybrids to effectively manage TSV
- Removal of weeds especially *Parthenium hysterophorus* in and around the field during the season and off-season These weeds serve as hosts of TSV, thrips and spread of virus from one plant to another.
- Timely sowing from 15 April to 15 May should be adopted to avoid the disease, as late sown crops are prone to CLCuD.
- Removal of infected plants and burying them at an early stage in the field or pits could help in preventing the spread of virus to healthy plants.
- Encourage sowing of desi cotton in the CLCuD hot spot area or as border rows (4-8 rows).
- Use Blue sticky traps for Thrips mass trapping and timely control of thrips which will ultimately lead to control of virus.
- Use optimum dose of fertilizer especially nitrogen fertilizer to help manage the plant growth and thrips infestation.
- Start spraying with neem-based insecticides and thrips growth regulators and insecticides recommended for thrips management

Integrated Disease management in Cotton

Integrated disease management (IDM) in cotton is a holistic and sustainable approach aimed at minimizing the impact of diseases through the combined use of multiple compatible strategies rather than relying on a single control measure. Continuous cultivation, intensive cropping systems, and changing climatic conditions further influence disease emergence and severity, making effective management essential. IDM emphasizes prevention and suppression of diseases through an integrated combination of host plant resistance, cultural practices, biological control agents, and need-based chemical interventions. The use of disease-free seed, resistant varieties, crop rotation, timely sowing, balanced fertilization, and sanitation measures helps reduce initial inoculum and disease spread. Biological agents such as *Trichoderma*, *Pseudomonas fluorescens*, and *Bacillus* spp. play an important role in suppressing soil- and seed-borne pathogens, while fungicides and bactericides are used judiciously when disease pressure exceeds economic threshold levels. By integrating preventive, cultural, biological, and chemical methods, IDM provides a sustainable and effective framework for maintaining crop health, stabilizing yield, and improving the long-term productivity of cotton-based cropping systems. The management practices mentioned in **Annexure-II** are recommended as window or crop stage based advisory. These fungicides are also recommended by CIB&RC

Defoliation and clean cotton picking

Cotton crop after defoliation with ICAR-CICR defoliant

Cotton crop without defoliation

Pick only fully opened bolls

➢ Clean cotton picking

The following precautions should be taken into consideration for clean picking and storage of cotton:

- The first and last pickings are usually of low quality and should not be mixed with the rest of the produce.
- Do not keep the picked cotton on wet water channels or wet soil / fields.
- Do not through empty pouches of *Gutka* / *Pan masala*, *beeri* / cigarette endings, empty pouches / wrappers of toffees / candies etc. into the picked cotton.
- To fetch good price in the market clean and dry cotton should be picked.
- Store cotton in damp proof and rat-free room.
- Store different varieties separately.

Cotton stalk management

Cutting of cotton stalks after final picking

Grazing in stacked stalks

Loading of cotton stalks in trolley

Cotton stalks loading in trolley

Chopping of cotton stalks and loading in trolley for industrial uses

Avoid Burning of cotton stalks in field

Stack of cotton stalks in village
(to be used as domestic fuel)

Covered stalks with net

Vertical stacking of cotton stalks

Cotton stalk management

➢ Cotton stalk management (Ex-Situ)

A huge quantity of cotton crop residue (cotton stalks) is being generated across different cotton growing states in India and a large portion of it is being burnt either as domestic fuel or on farm primarily to clear the field for sowing succeeding crops and for clean cultivation. But it leads to environmental pollution and emission of greenhouses gases. Further, valuable plant material is being lost which otherwise can be used for productive purposes.

➢ Ex-Situ Crop Residue Management:

- Cotton stalks are cut from the ground level and transported to home / in villages and are being used as domestic fuel (firewood) by households as a substitute for regular firewood obtained by cutting trees.
- Cotton stalks can also be converted into briquettes and also being used as fuel in brick kilns and other industrial uses.
- Some of the farmers burn the cotton stalks within the field itself after cutting them at ground level and stacking of cotton stalks. Burning any cotton stalks is hazardous as it leads to environmental pollution by emissions of greenhouse gases. It affects air quality and visibility and leads to global warming and climate change. Heat generated due to burning kills soil microorganisms and eco-friendly insects and also leads to loss of valuable soil organic matter and nutrients. This practice should be discouraged.
- Stack cotton stalks vertically away from the field. Before stacking, remove all unopened, half-opened, and unpicked bolls by beating the stalks against the ground, and destroy the collected bolls and trash.
- Use the stored cotton stalks before the end of March. If the stalks need to be stored beyond March, again remove any unopened or damaged bolls by beating them against the ground and incorporate the collected material into the soil. After this, store the cotton stalks vertically away from the field or in the village.
- If possible, cover the stack of cotton stalks with mosquito net or plastic sheet.

➢ Cotton stalk management (In-Situ)

<table>
<tr><td colspan="2">  </td><td>  </td></tr>
<tr><td colspan="3">Grazing of field with sheep, goats and cows after picking</td></tr>
<tr><td>  </td><td>  </td><td>  </td></tr>
<tr><td>Shredding of cotton stalks with Shredder</td><td>Chopping of cotton stalks with chopper</td><td>Mixing cotton stalks in soil with Rotavator</td></tr>
<tr><td>  </td><td>  </td><td>  </td></tr>
<tr><td>Mulching of cotton stalks with Mulcher</td><td>Wheat sowing with Super Seeder in standing cotton stalks</td><td>Wheat sowing with Happy Seeder in standing cotton stalks</td></tr>
</table>

➢ In-Situ Crop Residue Management:

Instead of removing cotton stalks from field after harvest prefer to mix them in soil. Before mixing or any other stalk management operation, allow sheep and goat to graze in field after final picking to reduce the carryover of bollworms.

A wide range of machinery is available that can be used for in-situ management of cotton stalks by creating mulches, chopping and incorporation and / or by simultaneous sowing succeeding Rabi crops (like wheat and mustard etc.). The details of the machine are as follows:

- **Rotavator:** In can be successfully used to incorporate the cotton crop residues into the field. It adds organic matter and nutrients into the soil. After that sowing of *Rabi* season crops can be done with seed-cum fertilizer drills etc.
- **Mulcher:** It crushes and spreads the cotton crop residues on soil surface. It conserves the soil moisture and nutrients besides controlling weeds.
- **Multi crop shredder:** Multi crop shredder was proved to be the best as it cuts cotton stubble and unopened bolls into tiny pieces and shred in the field. Shredder also helps in collecting the chaffed stalks into a trolley and can be transported to another agricultural field for soil improvement, used as a mulch or for the manufacture of particle boards, in preparation of pulp and paper, hard boards, corrugated boards and boxes, micro crystalline cellulose and for growing edible mushroom or in biofuel programmes.
- **Super seeder:** Supper seeder incorporates the standing cotton stalks into the soil and simultaneously sows the *Rabi* crops (like wheat and mustard etc.) in a single operation. It adds organic matter and nutrients into the soil besides reducing the cost of field preparation for sowing of *Rabi* season crops.
- **Happy seeder:** Running Happy seeder is a good option for sowing *Rabi* crops (like wheat and mustard etc.) in the standing cotton stalks in field. Happy seeder can also be used after operating tractor operated mulcher can be successfully used for sowing of *Rabi* crops (like wheat and mustard etc.).

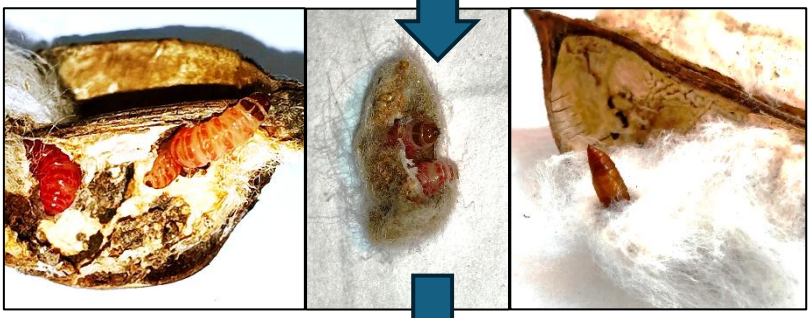
Off season monitoring and management of insect pests and disease sources

Pheromone traps installed near stalks to monitor Pink bollworm activity

Pheromone traps near ginning mill to monitor Pink bollworm activity

Pink bollworm moths collected from pheromone traps

Sample collection of unopened bolls from stacked stalks



Pink bollworm larvae and pupa found in sample bolls and seed.

Pink bollworm larvae and damaged seeds

Stored cotton inside store and cover it properly

Off season monitoring and management of insect pests and disease sources

Off-season monitoring in cotton refers to surveillance of fields and surrounding areas after crop harvest to detect and manage the carry-over stages of pests, especially pink bollworm and sucking pests, before the next cropping season.

- **Assessment of field sanitation:** Evaluate effectiveness of stalk destruction and residue management practices.
- **Inspection of stored produce:** Check stored cotton, seed cotton, and ginnery waste for pest infestation.
- **Use of pheromone traps:** Install pheromone traps near off-season survival sources such as ginning mills as well as near stack of cotton stalks to detect the presence and population trend of adult moths before sowing time.
- **Detection of overwintering pests:** Monitor crop residues, fallen bolls, and stored cotton for diapausing larvae of pink bollworm and other pests.
- **Surveillance of volunteer plants:** Observe ratoon cotton and volunteer seedlings that serve as alternate hosts and pest reservoirs.
- **Monitoring surrounding vegetation:** Examine nearby seasonal and perennial hosts including weeds that may harbor pests during off-season.
- **Early warning for next season**: Information gathered helps in planning for the timely application of control measures for the upcoming crop.

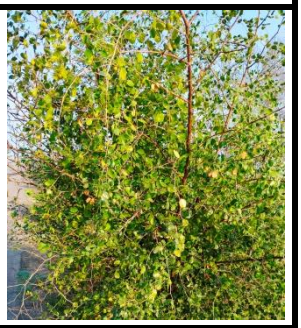
Off-season monitoring breaks the pest life cycle, prevents carry-over infestation, supports area-wide management of pink bollworm as well as other insect pest, and is a critical component of Integrated Pest Management (IPM) in cotton.

Collateral and Off-Season Survival Hosts of Insect Pests of Cotton

Crop or vegetable Hosts			
			
C.N: Wheat S.N: *Triticum aestivum* Family : poaceae	C.N: Lucerne S.N: *Medicago sativa* Family: Fabaceae	C.N: Gram S.N: *Cicer arietinum* Family: Fabaceae	C.N.- Sugarcane S.N.- *Saccharum officinarum* L. Family- Poaceae
			
C.N.- Onion S.N.- *Allium cepa* L. Family- Amaryllidaceae	C.N.- Oat S.N.- *Avena sativa* L. Family- Poaceae	C.N.- Garlic S.N.- *Allium sativum* L. Family- Amaryllidaceae	C.N.- Radish S.N.- *Raphanus sativus* L. Family- Brassicaceae
			
C.N.- Tomato S.N.- *Solanum lycopersicum* L. Family- Solanaceae	C.N.- Potato S.N.- *Solanum tuberosum* L. Family- Solanaceae	C.N.- Tinda S.N.- *Praecitrullus fistulosus* (Stocks) Pangalo Family- Cucurbitaceae	Cauliflower S.N.- *Brassica oleracea* var. *botrytis* L. Family- Brassicaceae
			
C.N.- Chilli S.N.- *Capsicum annuum* L. Family- Solanaceae	C.N.- Toria S.N.- *Brassica rapa* L. Family- Brassicaceae		

Weed Hosts			
			
C.N: Jangli bathua S.N: *Chenopodium murale* Family: Amaranthaceae	C.N: Desi Bathua S.N: *Chenopodium album* Family: Amaranthaceae	C.N: Hiran khuri S.N: *Convolvulus arvensis* Family: Convolvulaceae	C.N: Prickly sow- thistle S.N: *Sonchus asper* Family: Asteraceae
			
C.N: Congress grass S.N: *Parthenium hysterophorus* Family: Asteraceae	C.N: Kangibooti S.N: *Abutilon indicum* Family: Malvaceae	C.N: Makoy S.N: *Solanum nigrum* Family: Solanaceae	C.N: Wild sunflower S.N: *Helianthus annus* L. Family: Asteraceae
			
C.N: Jangli palak S.N: *Rumex dentatus* Family: Polygonaceae	C.N: Canary grass S.N: *Phalaris minor* Family: Poaceae	C.N: Tecoma S.N: *Tecoma stans* (L.) Family: Bignoniaceae	C.N: Lantana S.N: *Lantana camara* L. Family: Verbenaceae
			
C.N: Hibiscus S.N: *Hibiscus rosa - sinensis* Family: Malvaceae	C.N: Palakiya ghas		

Ornamental or Aromatic plants as Hosts			
			
C.N: Marua/ Ban Tulsi S.N: *Origanum majorana* Family: Lamiaceae	C.N: Guldaudi S.N: *Chrysanthemum spp*. Family: Asteraceae	C.N: Marigold S.N: *Tagetes spp*. Family: Asteraceae	C.N: Dianthus S.N: *Dianthus caryophyllus* Family: Caryophyllaceae
			
Marua S.N.- Eleusine coracana (L.) Gaertn. Family- Poaceae			

Trees and shrubs			
			
C.N.- Peepal S.N.- *Ficus religiosa* (L.) Family- Moraceae	C.N.- Nagfani S.N.- *Opuntia ficus-indica* (L.) Mill. Family- Cactaceae	C.N.- Nimbu S.N.- *Citrus limon* (L.) Osbeck Family- Rutaceae	C.N.- Ber S.N.- *Ziziphus mauritiana* Lam. Family- Rhamnaceae
			
C.N.- Mango S.N.- *Mangifera indica* L. Family- Anacardiaceae	C.N.- Bargad S.N.- *Ficus benghalensis* L. Family- Moraceae	C.N.- Guava S.N.- *Psidium guajava* L. Family- Myrtaceae	C.N.- Neem S.N.- *Azadirachta indica* A. Juss. Family- Meliaceae
			
C.N: Ardu S.N: *Ailanthus excelsa* Family: Simaroubaceae			

Annexure - I

Window Based Management of Cotton Insect-Pest

(Present Insecticides Recommendations)

Sucking pests and Bollworm management	
Pest	**Pest Management Advisory**
Crop growth stage: 0-60 Days After Sowing (DAS)	
Sucking pests & Bollworm	• Use botanical and initially apply NSKE 5% (50ml) or Neem oil 5 ml or neem oil-based formulation 5 ml /litre (300 or 1500 ppm) + 1.0gm/ litre water laundry detergent emulsion (Initial 2 sprays) for sucking pests and bollworms if approaching ETL. • Do not use any chemical insecticide during the early period (0-60DAS) to conserve natural enemies. • In case cotton field is adjacent to off-season source of survival, apply one spray of safer insecticides at initiation of squaring in 10 percent of cotton plants.
Crop growth stage: 61-90 Days After Sowing (DAS)	
Sucking pests	• Apply recommended insecticides whenever whitefly (18-24 adults/3leaves), thrips (30-40 nymphs & adults/3 leaves) and jassids (6 nymphs/3leaves) are above ETL. ➢ **Insecticides against adult whitefly** • Diafenthiuron 50% WP (500 g/ha) **or** afidopyropen50G/L @ 1000 ml/ha **or** pyrifluquinazon 20 WG (500 gm/ha) **or** dinotefuran 20 SG (150g/ha) **or** flonicamid 50 WG (200 g/ha). ➢ **Insecticides against the whitefly nymphs** • Pyriproxyfen 10 EC (1250 ml) /ha **or** buprofezin 25 SC(1000 ml/ha) **or** spiromesifen22.9 SC(500 ml /ha) in 500 liters of water/ha. • For Jassids, apply tolfenpyrad 15 EC (1000 ml/ha) **or** fenpyroproximate 5EC (750 ml/ha) **or** dinotefuran 20 SG (150g/ha) **or** flonicamid 50 WG (200 g/ha) **or** thiamethoxam 25 WG (100 gm/ha.). • For Thrips, apply emamectin benzoate 5SG (250 gm/ha.) **or** spinetoram 11.7 SC (425 ml/ha) **or** profenophos 50EC (1250 ml/ha)in 500 litre water/ha. • **Insecticides effective against mixed infestation of sucking pests** If mixed infestations of **whitefly and thrips** either **or** both are observed above ETL after 60 days old crop, spray diafenthiuron 50 WP (500g/ha) **or** spinetoram 11.7 SC (425 ml/ha) **or** profenophos 50EC (1250 ml/ha)in 500 litre water/ha to manage both the sucking pests

	• If the mixed infestation of **whitefly and leafhopper** either or both are observed above ETL, apply flonicamid 50 WG (200 g/ha) **or** dinotefuran 20 SG (150g/ha) in 500 liters water/ha. • If whitefly count is observed many times above the ETL (appearance of sticky leaves or sooty mold or presence of whitefly on the upper surface of leaves), spray the cotton crop immediately targeting the adults first and subsequently the nymphs (3-5 days after spray applied for adults)as using below mentioned insecticides. • **In case Sooty mould develop**-- Three Prophylactic/therapeutic sprays of propiconazole 25EC @1ml/L **or** copper oxychloride (COC) 50 WP @ 2.5 g/L at 15 days interval may be applied.
Bollworm	• In case of PBW, ETL either through trap catches (8 moths/trap for 3 consecutive nights) or observed fruiting body damage (flower **or** green boll) is >10%, spray cotton crop with emamectin benzoate 5SG (250 g) **or** profenophos 50EC (1250-2000 ml) **or** spinetoram 11.7 SC (425 ml/ha) **or** thiodicarb 75 WP (750-1000 ml/ha.) **or** chlorpyrifos 20 % EC (1250 ml) or indoxacarb 14.5SC (500ml) **or** per hectare. • In case of arboretum (Desi) cotton for spotted bollworm (*arboreum*) apply a prophylactic spray at initiation of flowering in 10 % plants or in first week of July with cypermethrin10 EC @ 500 ml **or** cypermethrin 25 EC @ 200 ml **or** deltamethrin 2.8 EC@ 400 ml **or** fenvalerate 20 EC@ 250 ml **or** fenpropathrin10 EC @ 750 ml per hectare.
Crop growth stage: 91-120 Days After Sowing (DAS)	
Sucking pests	• Apply diafenthiuron 50% WP (500 gm/ha) **or** pyrifluquinazon 20 WG (500 gm/ha) or afidopyropen 50G/L(1000 ml/ha) **or** dinotefuran 20 SG (150g/ha) **or** flonicamid 50 WG (200 g/ha) for whitefly adult's control. • If a higher population of eggs and nymphs of whitefly is observed under the leaves as indicated by sticky leaves, then application of buprofezin 25 SC(1000 ml) **or** spiromesifen 22.9 SC(500 ml) **or** pyriproxyfen 10 EC (1250 ml) per hectare is advisable.
Bollworm	• **For PBW**- emamectin benzoate 5SG (250 g) or profenophos 50EC (1250-2000 ml) **or** spinetoram 11.7 SC (425 ml/ha) **or** thiodicarb 75 WP (750-1000 ml/ha.) **or** chlorpyrifos 20 % EC (1250 ml) **or** indoxacarb 14.5SC (500ml) **or** quinalphos 20 AF (1750-2500 ml) per hectare is advisable. • In arboreum or American cotton, in case the incidence of spotted bollworm or cotton bollworm observed apply spinosad 45SC @150ml/ha **or** indoxacarb14.5 SC @500ml/ha **or** spinetoram 11.7

	SC (425ml/ha) **or** chlorantraniliprole18.5SC 150 ml/ ha. If incidence of cotton bollworm alone then apply emamectin benzoate 5SG (250 g) **or** indoxacarb14.5 SC @500ml/ha **or** chlorantraniliprole18.5SC 150 ml/ha. **or** flubendiamide 480 SC @ 100 ml/ha is advisable.
Crop growth stage: 121-150 Days After Sowing (DAS)	
Sucking pests	• To manage the second flush of whitefly (later part of season after 15th September) restricted use of ethion 50EC (2000 ml/ha) is advisable
Bollworm	• For pink bollworm control, spraying the crop with Ethion 50 EC (2000 ml/ha) **or** fenvalerate 20 EC (250-500 ml/ha) **or** lambda-cyhalothrin 5 EC (500 ml/ha) **or** cypermethrin 10 EC (500-750 ml/ha) **or** cypermethrin 25 EC (200-250 ml/ha) **or** deltamethrin 2.8 EC (400-500 ml/ha) **or** alphamethrin 10 EC (250-310 ml/ha) **or** fenpropathrin 10 EC (750 ml/ha).

Annexure - II

Window Based Management of Cotton Diseases

(Present Fungicides Recommendations)

Disease Name	Advisory for management
Crop growth stage: 0-60 Days After Sowing (DAS)	
Root rot, wilt, bacterial leaf blight	▪ Seed treatment with Carboxin 37.5% + Thiram 37.5% DS @3.5 g per kg or Sedaxane 2.5% w/v + Fludioxonil 2.5% w/v + Thiamethoxam 26.25% w/v FS @ 4 ml (to be diluted in 8-10 ml water) per kg of seeds for root rot and bacterial leaf blight (BLB) disease Or *Pseudomonas fluorescens* WP @10 g/kg seeds for bacterial leaf blight (BLB) disease Or Fluxapyroxad (333 g/L FS) @1.5 ml/kg seed for seedling disease Or Tetraconazole 11.6% W/W (12.5% w/v) SL @1.5 ml/ kg of seeds for seed-borne fungal disease management. ▪ Drenching early symptomatic plants and surrounding plants with *Trichoderma* spp. (*T. harzianum or T. viride*) 1% WP @50g Or Carbendazim 50%WP @ 20 g/ 10 L of water ▪ Seed treatment by 4hr seed soaking in 40-50 ppm solution of Streptomycin Sulphate 9% + Tetracycline Hydrochloride 1% for seedling blight, angular leaf spot or black arm disease
Tobacco streak virus	▪ Continuous monitoring of the crop during early stage (40-75 DAS) to avoid the transmission of TSV. ▪ Apply biorationals and insecticides recommended for thrips management.
Cotton leaf curl viral disease (CLCuD)	▪ 3-5 foliar spray of salicylic acid (200 ppm) or buttermilk 5% or Cow urine + Calcium nitrate (6.6%+0.5%) or mustard oil (3.0%) at 15 days intervals starting from 30 days after sowing. ▪ Measures suggested for whitefly vector control should be followed.
Parawilt	▪ 2-3 drenching with solution of Copper oxychloride 50 % WP @ 250 g or Carbendazim 50%WP @ 120 g plus Urea 2 kg per 100 liters of water at one-week interval starting immediately after symptom development. ▪ Apply foliar spray of Cobalt chloride @10 ppm or sodium benzoate @ 50ppm immediately after the appearance of the wilting symptoms on the affected plants (within 24 hours).
Crop growth stage: 61-120 Days After Sowing (DAS)	
Bacterial leaf blight	▪ 1-2 foliar spray of Copper oxychloride 50 % WP @ 25 g Or Carbendazim 12+ Mancozeb 63% WP@25 g Or Copper

	sulphate 47.15% + Mancozeb 30% WDG @ 50 g per 10 liters of water at weekly interval.
Target leaf spot, Alternaria leaf spot, Myrothecim leaf spot,	▪ Prophylactic spray of Propineb 70 WP@25-30 g Or Azoxystrobin 18.2%w/w + Difenoconazole 11.4% w/w SC@ 10 ml Or Fluxapyroxad 167 g/l + Pyraclostrobin333 g/l SC@ 6g Or Carbendazim 50% WP@20 g Or Propiconazole 25% EC @10 ml Or Pyraclostrobin 5% + Metiram 55% WG @20 g per 10 litres water.
Crop growth stage: 90-150 Days After Sowing (DAS)	
Boll rot (External fungal boll rot)	▪ Foliar spay with Fluxapyroxad 167 g/Litre + Pyraclostrobin 333 g/Litre SC @ 6 g Or Metiram 55% + Pyraclostrobin 5% WG @ 20 g Or Propineb 70% WP @ 25 g or Copper sulphate 47.15% + Mancozeb 30% WDG @ 50 g or Azoxystrobin 18.2%w/w + Difenoconazole 11.4% w/w SC@ 10 ml per 10 litres of water
Boll rot disease (Internal)	▪ The dried petals sticking to the developing bolls should be removed. ▪ Prophylactic sprays of Copper oxychloride 50%WP @25 g/10L Or Carbendazim 12+ Mancozeb 63% WP@ 25 g/10L is suggested during early boll developmental stages at 15 days interval if cloudy weather, high relative humidity, flash and drizzle rain occurred during squaring, flowering and boll development stage. ▪ Manage sucking pests with recommended insecticides.
Sooty mold	▪ Two to three prophylactic/therapeutic sprays of Propiconazole 25%EC @10ml/10L Or Copper oxychloride (COC) 50%WP @ 25g or Carbendazim 12+ Mancozeb 63% WP@ 25 g /10L at 15 days intervals may be applied.

Abbreviations

AICRP	All India Coordinated Research Project
AF	Aqueous Formulation
B	Boron
BLB	Bacterial Leaf Blight
BST	Blue Sticky Trap
Bt	Bacillus thuringiensis (transgenic cotton trait)
Ca	Calcium
CIB&RC	Central Insecticides Board and Registration Committee
CICR	Central Institute for Cotton Research
CLCuD	Cotton Leaf Curl Disease
CLCuV	Cotton Leaf Curl Virus
COC	Copper Oxychloride
DAP	Di-Ammonium Phosphate
DAS	Days After Sowing
EC	Emulsifiable Concentrate
ETL	Economic Threshold Level
Fe	Iron
FS	Flowable concentrate for Seed treatment
GMS	Gentic Male Sterility
HDPS	High Density Plant Stand
ICAR	Indian Council of Agricultural Research
IDM	Integrated Disease Management
IPM	Integrated Pest Management
K	Potassium
KNO_3	Potassium Nitrate
MB	Mould Board (plough)
MDT	Mating Disruption Technology
MEC	Microencapsulated Concentrate
Mg	Magnesium
MOP	Muriate of Potash
N	Nitrogen
NAA	Naphthalene Acetic Acid
NBAIR	National Bureau of Agriculturally Important Insects and Resources
NSKE	Neem Seed Kernel Extract
P	Phosphorus
PBW	Pink Bollworm
PDI	Per cent Disease Incidence
RH	Relative Humidity
S	Sulfur
SAU	State Agricultural University
SC	Suspension Concentrate
SG	Soluble Granule
SL	Soluble Liquid
SMW	Standard Meteorological Week
SPAC	Soil-Plant-Atmosphere Continuum
SPLAT	Specialized Pheromone and Lure Application Technology
SSP	Single Super Phosphate
TSV	Tobacco Streak Virus
WDG	Water Dispersible Granule
WG	Wettable Granule
WP	Wettable Powder
WS	Water-based Suspension for seed treatment
YST	Yellow Sticky Trap
Zn	Zinc