



Integrated Pest Management in Bt cotton

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National Information System for Pest management

(NISPM, Bt Cotton)

NCIPM



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FOREWORD

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Farmers continuously seek efficient and effective means to reduce the negative impact of pests in agriculture. Growing food needs, decreasing arable land and climatic changes tends to orient farmers towards using more pesticides to manage insect pests and diseases and thereby increase yield. Dependence on pesticides to raise agricultural productivity however has negative side effects on human and environmental health. Therefore, there is an urgent need to give more emphasis to change from high external agriculture inputs to environmentally compatible, socially and economically acceptable agricultural practices. Integrated pest management (IPM) has gained popularity as an alternative to increased pesticides use in agriculture. Changing pest scenario has become more common in the recent times with rapidly changing cropping systems and environment. Cotton scenario in India is now dominated by Bt cotton in which some pests have been impacted negatively (e.g. Helicoverpa bollworms due to Bt mechanisation), while minor pests are emerging as major pests (e.g. mealy bug). IPM is a system which incorporates regenerative practices that improve yields and ensure long term sustainability of farming system and emphasizes appropriate decision making and requires continuous refinement and validation before implementation. IPM extended the concept of integrated control to all classes of pests and was expanded to include tactics such as host plant resistance and cultural manipulations etc. other than just chemical or biological control alone and added the multidisciplinary element, involving entomologists, plant pathologists, nematologists, and weed scientists.

I am extremely happy that this publication on IPM in Bt cotton which is the need of the hour is brought out. This document will be useful for scientists, agriculture functionaries and for all those interested in promoting and disseminating IPM technologies in Bt cotton.

I complement authors for bringing out this excellent publication.

O.P.Gill
(O.P.Gill)

INDEX

S.No.	Topic	Page No.
1	Introduction	1
2	Disease & insect pests monitoring methods	2-3
3	Important insect pests in cotton	3-7
4	IPM practices for management of insect pests of cotton	7-9
5	Economic threshold level (ETL) for important insect pests of cotton	10
6	Major diseases & IPM practices in Bt cotton	11-13
7	Stage wise IPM practices in Bt cotton	13-16
8	Calculation of formulated chemical products	17
9	Guidelines for safe use of pesticides	18

1. Introduction:

Integrated pest management (IPM) is an integrated approach of crop management to solve ecological problems when applied in agriculture. These methods are performed in three stages: *prevention*, *observation*, and *intervention*. It is an ecological approach with a main goal of significantly reducing or eliminating the use of pesticides while at the same time managing pest populations at an acceptable level. For their leadership in developing and spreading IPM worldwide, Dr. Perry Adkisson and Dr. Ray F. Smith received the 1997 World Food Prize.

Definition:

By FAO “ *Integrated pest control is a pest management system that in the context of associated environment and population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains pest populations at levels below those causing economic injury* ”.

One commonly used definition that is easy to understand is the following:

“IPM is a decision-making process that utilizes all available pest management strategies, including cultural, physical, biological and chemical control to prevent economically damaging pest outbreaks and to reduce risks to human health and the environment.”

Tools of IPM

Monitoring : Keep tracks of the pests and their potential damage. This provides knowledge about the current pests and crop situation and is helpful in selecting the best possible combinations of the pest management methods.

Pest resistant varieties : Breeding for pest resistance is a continuous process. These are bred and selected when available in order to protect against key pests.

Cultural pest control : It includes crop production practices that make crop environment less susceptible to pests. Crop rotation, cover crop, row and plant spacing, planting and harvesting dates, destruction of old crop debris are a few examples. Cultural controls are based on pest biology and development.

Mechanical control : These are based on the knowledge of pest behaviour. Hand picking, installation of bird perches, mulching and installation of traps are a few examples.

Biological control: This includes augmentation and conservation of natural enemies of pests such as insect predators, parasitoids, pathogen and weed feeders. In IPM programmes, native natural enemy population are conserved and non-native agents are released with utmost caution.

Chemical control : Pesticides are used to keep the pest population below economically damaging levels when the pests cannot be controlled by other means. It is applied ONLY when the pest's damaging capacity is nearing to the threshold.

2. Disease and Insect pests monitoring methods:

A. Ground truth Analysis (GTA)

GTA is an approach, which can be gainfully employed by extension functionaries and farmers to analyze field situations with regard to pests, defenders, soil conditions, plant health, the influence of climatic factors and their interrelationship for growing healthy crop. Such a critical analysis of the field situations will help in taking appropriate decision on management practices. The basic components of GTA are:-

1. Plant health at different stages.
2. Built – in – defense abilities of the plants.
3. Pest and predator population dynamics.
4. Soil conditions.
5. Climatic factors.

B. Survey / Field Scouting

The objective of surveys through roving surveys is to monitor the initial development of pests and diseases in endemic areas. Therefore, in the beginning of crop season survey routes based upon the endemic areas are required to be identified to undertake roving surveys. Based upon the results of the roving surveys, the State extension functionaries have to concentrate for greater effort at block and village levels as well as through farmers to initiate field scouting. Therefore, for field scouting farmers should be mobilized to observe the pest and disease occurrence at the intervals as stipulated here under. The plant protection measures are required to be taken only when pests and disease cross (Economic Threshold Level) ETL as per result of field scouting.

Roving survey: - Undertake roving survey at every 10 km distance initially at weekly intervals and thereafter at 10 days intervals (depending upon pest population). Record incidence of bollworms on all host crops of the locality. Observe at each spot diagonally criss cross 20 plants/acre at random. Record the population potential of different biocontrol fauna. Record the major disease and their intensity.

Field scouting: - Field scouting for pests and biocontrol fauna by extension agencies and farmers once in 3 – 5 days should be undertaken to workout ETL. For sucking pests, population should be counted on three leaves (top & middle portion) per plant. For whitefly, third and seventh leaves from the top of the plant should be observed for nymphs and adults. For bollworm eggs terminal leaves should be observed. Observe larvae on fruiting bodies and leaves per plant. For percent bollworm incidence count total and affected fruiting bodies on the plant and also in the shed material and work out the percent infestation.

The State Departments of Agriculture should make all possible efforts by using different media, mode and publicity to inform the farmers for field scouting in the specific crop areas having indication of pest or disease build up.

C. Pest Monitoring through Pheromones / Yellow Pan / Sticky Traps etc.

Certain pests require positioning of various kinds of traps like pheromones, yellow pan and sticky traps to monitor the initial pest build up. Therefore, the State Department of Agriculture is to initiate action for positioning of different kinds of traps based upon the results of roving surveys at the strategic location at village level. While the concept needs

to be popularized amongst farming community, the State Department of Agriculture is to take greater initiatives for pest monitoring through specific pheromone trapping methods as per following details.

Pheromone trap – monitoring: - Use pheromone traps for monitoring of American bollworm, spotted bollworms, pink bollworm and *Spodoptera*. Install pheromone traps at a distance of 50 m @ six traps per ha for each insect pest. Use specific lures for each insect pest species and change it after every 15 – 20 days. Trapped moths should be removed daily. ETL for pink bollworm is 8 moths per days per trap consecutively for 3 days. ETL for American bollworm is 4 – 5 moths per day per trap.

Yellow pan / sticky traps :- Set up yellow pan / sticky traps for monitoring whitefly @ 25yellow pans / sticky traps per ha. Locally available empty yellow palmoline tins coated with grease / vasline / castor oil on outer surface may also be used.

3. Important Insect Pests in cotton

Cotton ecosystems throughout the world harbor a wide variety of insects. One hundred and sixty two species of phytophagous insects have been recorded on the crop in India, of which 24 species have attained pest status and nine are key pests in one or more cotton growing zones of the country. The life history and damage symptoms for important insect pests are briefly described here.

Sap Sucking Pests

Jassids

***Amrasca biguttula biguttula* (Ishida) (Hemiptera: Cicadellidae)**

Cotton Jassids is the most destructive sucking pest of American cotton in the North Zone and is present throughout the country. Besides cotton it also feeds on okra, potato, brinjal and some wild plants. Adults are about 3 mm long and greenish yellow during the summer, acquiring a reddish tinge in the winter. The female lays about 15 yellowish eggs on the undersurface of the leaves, embedding them into the leaf veins. They suck cell- sap from the undersurface of leaves and pass through six stages of growth in 7-21 days. *Chrysoperla* sp. (Chrysopidae) and spiders feed on nymphs and adults of the cotton jassids.

Both the nymphs and adults suck sap from the leaves. The attacked leaves turn pale and then rust-red. With change in appearance, the leaves also turn downwards, dry up and fall to the ground. Owing to the loss of plant vitality, the cotton bolls also drop off resulting in yield reduction.

Cotton whitefly

***Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae)**

Cotton whitefly emerged as a serious pest of American cotton after the introduction of synthetic pyrethroids during 1980s particularly in the dry areas. It also acts as a vector of the dreaded leaf curl virus disease. They have two pairs of pure white wings and prominent long hind wings. The female lays eggs singly on the undersurface of the leaves, averaging more than 100 eggs per female. The life-cycle is completed in 14-122 days. The insect breeds throughout the year completing up to 11 generations. The whitefly acts as a vector of the cotton leaf-curl virus, which has spread, to large areas of the northern zone. Even low population of whitefly is capable of spreading the disease and must be controlled at the early crop stage to prevent spread of the disease.

Cotton Aphid

***Aphis gossypii* Glover (Hemiptera: Aphididae)**

Cotton aphid is a sporadic pest of cotton. It also feeds on potato, cucurbits, chilli and many ornamental plants. The total life cycle is completed in 9 to 64 days with an average of 28 days. Both young and adult cotton aphids suck plant sap. Infested plants become weak and the tender shoots, leaves fade gradually and may become blighted due to appearance of sooty mould on middle canopy leaves in case of severe attack. Dry conditions favor rapid increase in pest population and younger plants are more susceptible than the older ones. Coccinellid beetles, *Coccinella septumpunctata* Linnaeus and *Menochilus sexmaculata* (Fabricius) are common predators of cotton aphid.

Cotton Thrips

***Thrips tabaci* Linnaeus and *Scirtothrips dorsalis* (Hood) (Thysanoptera: Thripidae)**

Cotton thrips are commonly found on cotton and vegetable crops. The adults are slender and yellowish brown. The pest breeds on cotton during May-September. The adult female lays 50-60 kidney-shaped eggs, singly into green plant tissue, at the rate of 4-6 eggs per day. The eggs hatch in 3-8 days. The nymphs and adult thrips lacerate the surface tissues of the foliage and then feed on the exuding sap. The affected leaves curl and give silvery brown appearance. Prolonged dry spell during May-June often results in high build up of the pest on the young plants. In severe infestation, the seedlings shed leaves and may dry up.

Defoliators

Tobacco Caterpillar

***Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae)**

Tobacco caterpillar is traditionally a pest of Soybean crop in Rajasthan but in recent years it has caused damage to cotton crop in the southern zone. It is also sporadically recorded on castor, groundnut, tomato, sunflower, etc. The damage is done only by the

caterpillars, which measure 35-40 mm in length at maturity. They are velvety black with yellowish-green dorsal stripes and lateral white bands. The female lays about 300 eggs in clusters. These clusters are covered over by brown hairs and they hatch in about 3-5 days. They pass through 6 stages and are full-fed in 15-30 days. The full grown larvae enter the soil where they pupate. The life cycle is completed in 32-60 days and the pest may complete eight generations in a year. The larvae feed on leaves and fresh growth and are mostly active at night. In case of severe infestation the buds and bolls may also be attacked. In southern Rajasthan, severe attack on cotton crop is usually recorded in second fortnight of September-first fortnight of October.

Green semi-looper

***Anomis flava* (Fabricius) (Lepidoptera: Noctuidae)**

Green semi-looper is widely distributed sporadic pest of cotton and sometimes causes a serious damage to the crop particularly in Gujarat and Rajasthan. Besides cotton, the larvae also feed on a number of other malvaceous plants. The emergence of moths coincides with the warming up of the season. The female lays up to 600 eggs on leaves during an oviposition period of 8-12 days. The larvae which move around with a characteristic semi-loop crawl and feed on leaves. They complete development by passing through 5 instars within a period of 18-20 days. The young larvae congregate in small groups and move actively and feed on leaf lamina making small punctures. The grown-up larvae feed voraciously on the entire leaves, leaving only the main veins. The caterpillars also eat the tender shoots, buds and bolls. Sometimes, the attack is heavy and the plants may be completely defoliated.

Bihar hairy caterpillar

***Spilosoma obliqua* Walker (Lepidoptera : Arctiidae)**

The Bihar hairy caterpillar prefers to feed on a number of pulse crops, oilseeds, some vegetables and cotton. The pest breeds from March to April and again from July to November. It passes the hottest part of the summer (May-June) and peak winter (December-February) in the pupal stage amidst plant debris. Adults emerge from over wintering pupae in March. The female lays 400- >1200 light green spherical eggs in clusters on the underside of leaves. The eggs hatch in 8-13 days and the tiny caterpillars feed gregariously for the first few days. Afterwards they disperse widely in search of food. The life cycle is completed in 6-12 weeks and the pest passes through 3 or 4 generations in a year. The caterpillars feed on the leaves and soft portion of stem. In severe infestation, the plants may be completely denuded of leaves.

Leaf perforator

Serpentine leaf miner

***Liriomyza trifolii* (Burgess) (Diptera : Agromyzidae)**

Larvae of the serpentine leaf miner tunnel into the leaves and form mines. In case of severe attack at the seedling stage, the plants may be killed.

Bollworms

Bollworms are the most damaging pests of all fruiting bodies including squares, buds, flowers and bolls. Severe bollworm attack, if not properly managed, may mean complete failure of the cotton crop as all fruiting bodies may be destroyed. The bollworms include a number of species as given below.

Pink Bollworm

Pectinophora gossypiella (Saunders) (Lepidoptera: Gelechidae)

Pink bollworm is one of the most destructive pests of cotton in the Punjab, Haryana and to some extent in Rajasthan. The damage is caused by the caterpillars only. They are pink and are found inside flower buds, panicles and the bolls of cotton or the fruits of okra and other allied plants. The adult is a deep brown moth having blackish spots on the fore wings, and margins of the hind wings are deeply fringed.

Soon after emergence, the larvae enter the flower buds, the flowers or the bolls. The holes of entry close down, but the larvae continue feeding inside the seed kernels. Within one week, the moths emerge to start the life cycle all over again. By October-November, 4-6 generations are completed. They cut window holes in the two adjoining seeds and join them together, forming what are known as the '*double seeds*'. Such damaged bolls are generally left unpicked in the field. Later, they fall to the ground and form a major source of infestation for the next year. Damage is caused in various ways. There is excessive shedding of the attacked fruiting bodies. The attacked young bolls fall off prematurely and the older ones which do mature do not contain good lint. The damaged seed-cotton gives a lower ginning percentage, lower oil extraction and inferior spinning quality.

Trichogramma achaeae Nagaraja & Nagarkatti (Trichogrammatidae) parasitizes the eggs of this pest. The parasitoid appears late in the season and is common in area where pesticides are used sparingly.

Spotted Bollworms

Earias insulana (Boisduval) and *E. vitella* (Fabricius) (Lepidoptera: Noctuidae)

These two species of bollworms cause heavy damage to American cotton and are also found on okra and some other malvaceous plants. In the larval stage, they bore into the growing shoots, the flower buds, flowers and fruits of cotton and okra, either killing the growing points of the plants or causing heavy shedding of the fruiting bodies. In the attacked bolls, the lint is spoiled by larval feeding.

Trichogramma sp. parasitizes the eggs of spotted bollworms. When cotton plants are young, the larvae bore into the terminal portions of the shoots, which wither away and dry up. Later on, they cause shedding of the fruiting bodies. The infested bolls open prematurely and produce poor lint, resulting in lower market value.

American Bollworm

***Helicoverpa armigera* (Hübner) (Lepidoptera : Noctuidae)**

American bollworm which is traditionally a pest of chickpea and other pulse crops now regularly attacks American cotton crop in the North Zone. The moth is stoutly built and is yellowish brown. There is a dark speck and a dark area near the outer margin of each forewing. The fore wings are marked with grayish wavy lines and black spots of varying size on the upper side and a black kidney shaped mark and a round spot on the underside. The hind wings are whitish and lighter in color with a broad blackish band along the outer margin. The female lays eggs singly on upper aside of tender foliage of the plants. The larvae attack fruiting bodies and cause severe shedding. Unlike spotted bollworms, clean circular holes bored into fruiting bodies are free from excretory pellets/ frass. Even large sized bolls are eaten up by the grown up larvae. The larvae have a habit of moving from boll to boll and damage much more than what they actually consume.

A Nucleopolyhedrovirus (NPV) causes significant mortality among the infected larvae depending on environmental conditions.

Lint Stainers

Red Cotton Bug

***Dysdercus koenigii* (Fabricius) (Hemiptera: Pyrrhocoridae)**

Red cotton bug is a minor pest of cotton in the North Zone. The bugs are elongated slender insects, crimson red with white bands across the abdomen. The membranous portion of their fore wings, antennae and scutellum is black. The pest is generally serious at the boll bursting stage. Heavily attacked bolls open badly and the lint is of poor quality. The bugs stain the lint with their excreta or body juices as they are crushed in the ginning factories. The staining of lint by the growth of certain bacteria inside the bolls is also believed to be initiated by these bugs.

4. IPM Practices for management of Insect pests of Bt cotton

1. Jassids/Aphids: (ETL 2-3 nymphs per random leaves)

Cultural practice- Use resistant or tolerant varieties for sowing. Do not use high doses of N fertilizers

Biological control-Release *Chrysoperla* predator eggs @ 50000 eggs/ha. Repeat it after flowering

Chemical control- Seed treatment with Imidacloprid 600 FS @ 1.25 G./Kg. seeds. Follow the spray schedule:

0.2 ml Imidacloprid 17.8 SL/lit water OR

0.5 ml Thiomethaxam 25 WG/ lit water OR

1 liter Dimethoate 30 EC or methyl demeton 25 EC or Monocrotophos 36 SL or Formathion 25 EC @ 500- 750 ml/ ha

2. Whitefly/Thrips: (ETL 2-3 nymphs per random leaves)

Cultural practice- Early sowing (15 April-15 May) reduce its population. Use resistant or tolerant varieties for sowing and adopt crop rotation with non host crop. Cultivate alternate host crop such as tomato and castor at bunds to trap and destroy them.

Set yellow sticky board at various places at canopy height in the field.

Biological control- Release predators such as *Chrysoperla*, Coccinellids, etc.

Chemical control- Seed treatment with Imidacloprid 70 WS @ 5 g/kg seeds. Follow the spray schedule:

0.2 ml Imidacloprid 17.8 SL/lit water OR

0.5 ml Thiomethaxam 25 WG/ lit water OR

1 liter Dimethoate 30 EC or methyl demeton 25 EC or Monocrotophos 36 SL @ 500- 750 ml/ ha

Apply neem oil + Teepol @ 3-3.5 lit + 500 ml/ha

1. *Spotted bollworm:* (1 larvae/ plant)

Biological control- Erect 5-7 pheromone traps/ha. to capture male moth. Release *Chrysoperla* predator eggs @ 50000 eggs/ha. Repeat it after flowering. Release Trichogramma predator @ 1,50,000 eggs/ha.in the evening period. Apply thrice at weeks interval.

Chemical control- Spray 1 lit Monocrotophos 36 SL or 450 ml Fenvelarate 20 EC or 1.25 lit Endosulphon 35 EC per ha. OR Spray Chloropyriphos 20 EC or Quinalphos 25 EC @ 1ml/lit water

2. *American bollworm:* (5% flower damage)

Biological control- Erect 5-7 pheromone traps/ha. to capture male moth. Release *Chrysoperla* predator eggs @ 50000 eggs/ha. Repeat it after flowering. Release Trichogramma predator @ 1, 50,000 eggs/ha.in the evening period. Apply thrice at weeks interval. Spray NPV 450 LE/ha. Spray 10% neem oil.

Chemical control- Spray 1 lit Monocrotophos 36 SL or 450 ml Fenvelarate 20 EC or 1.25 lit Endosulphon 35 EC per ha. OR Spray Chloropyriphos 20 EC or Quinalphos 25 EC @ 1ml/lit water

3. *Pink bollworms:*

Biological control- Erect 5-7 pheromone traps/ha. to capture male moth

Chemical control- Spray 1 lit Cypermethrin 25 EC or 750 ml Thiodicarb 75 WP or 25 g λ -Cyhalothrin 5 EC or 2.5 kg Carbaril 50 % WP or 500 g Profenophos 50 EC per ha.

4. Mealy bug:

Cultural methods: Scrap out the insect from the stems and leaves at the initial stage or remove the affected plant and bury it in a pit. Remove weeds form the crop surrounding. Do not pile the stalks of previous cotton crop near the field as it harbours the mealy bug.

Chemical control: Spray profenophos @ 3ml/lit water and 1 tea spoon surf in 15 lit water as sticker. Repeat spray twice.

Table Natural Enemies and Microbes against insect pests of Bt Cotton

Pest	Natural enemy	Pathogens
Pink bollworm	<i>Trichogramma achaeae</i> <i>Trichogramma chilonis</i> <i>Apantelus angaleti</i> <i>Goniosus</i> sp. <i>Chelonus</i> sp. <i>Bracon greeni</i>	
American bollworm	<i>Trichogramma chilonis</i> <i>Trichogramma achaeae</i> <i>Campoletis chlorideae</i> <i>Eucelatoria bryani</i> <i>Microchelonus versatilis</i> <i>Eocanthonota furcellata</i> <i>Palexorista laxa</i> <i>Eriborus argenteopilosus</i>	Virus: Nuclear polyhedrosis virus (NPV) Bacteria: <i>Bacillus thuringiensis</i> Fungus: <i>Beauveria bassiana</i> <i>Nomureae rileyi</i>
Tobacco caterpillar	<i>Telenomus rowani</i> <i>Apantelus</i> sp. <i>Eocanthonota furcellata</i>	Virus: Nuclear polyhedrosis virus (NPV) Bacteria: <i>Bacillus thuringiensis</i> Fungus: <i>Beauveria bassiana</i> <i>Nomureae rileyi</i>
Spotted bollworm	<i>Trichogramma achaeae</i> <i>Rogus aligarhensis</i>	
Whitefly	<i>Eretmocerus</i> sp. <i>Brumoides suturalis</i> <i>Scymnus</i> sp. <i>Chrysoperla carnea</i> <i>Geocoris bicolor</i>	
Mealy bug	<i>Aenasius bambawalei</i> <i>Prochiloneurus pulchellus</i> <i>Promuscidea unfasciativentris</i> <i>Cryptolaemus montrouzieri</i>	Fungus: <i>Verticillium lecanii</i> , <i>Metarrhizium anisopliae</i> , <i>Beauveria bassiana</i>

5. Economic Threshold Levels (ETL) for Important Insect Pests of Cotton

Insect pest	Age of the crop (days)	ETL
Jassids*	1-50	2-3 nymphs/leaf
Aphids*	1-50	10 aphids/leaf or 15-20% infested plants
Whiteflies*	35-110	8-10 adults or 20 nymphs/leaf before 9 am
Thrips*	1-30	10 thrips/leaf or 15-20% infested plants
Spotted bollworm** <i>(E. vitella)</i>	35-110	One larva per plant, 10% or more of attacked shoots
Spotted bollworm ** <i>(E. insulana)</i>	35-110	One larva per plant, 10% or more of attacked shoots, or on an average 3 flared up squares/plant
American bollworm**	65-110	1 egg/plant or 1 larva/plant, or 5-10 % damaged fruiting structures, or 3 falred up squares/plant.
Pink bollworm**	65-110	10% or more of attacked flowers or bolls. Eight moths/trap per day for 3 consecutive nights
Stem weevil*	25-60	10% or more plants with galls
Spodoptera***	30-110	One egg mass/ skeletonised leaf/10 plants

*Number of pupa/adult /three leaves (top and middle)

** Total number of eggs /larvae / plant

*** Total number of eggs /larvae / 10 plants

(No action thresholds exist for foliage feeders, but treatments are advocated if a significant proportion of cotton stand is destroyed.)

- Economic threshold based sprays for jassid control when nearly 50 per cent of the total plants show yellowing and curling on the margins of leaves in the upper canopy (II garde injury level).
- Economic threshold based sprays for bollworms control when 5 per cent of shed fruiting bodies appear to be damaged by bollworms.

6. Major diseases and IPM practices in Bt cotton

(i) Bacterial disease:

(I) Angular leaf spot/ black arm/ bacterial blight (*Xanthomonas axonopodis* pv. *malvacearum*): It is one of the widely prevalent diseases of cotton and causes quantitative yield losses. Disease is more serious in humid and rainy weather. The pathogen may survive in the seed or on plant debris in the soil.

Symptoms: The disease attacks all the above ground plant parts at all stages of plants growth. The disease appears as water soaked lesion of varying sizes water soaked, surfaces of the leaves. The lesions on leaves are angular and water soaked, turning brown to black, delimited by the small vein-lets of the leaves. Sometimes large areas are formed by coalescing a number of spots leading to death and shedding of leaves. The lesion of the stems and petioles are dark brown, elongated and sunken. The affected stems show cracks and gummosis which may cause girdling or death of the affected organs. The lesions on bolls are water soaked, sunken and associated with bacterial exudation. The lesions on balls may coalesce later and extends to whole tissues, where the lint may be damaged and destroyed.

Control measures:

Soak the acid delinted seeds in Streptomycin sulphate @10 g in 10 lit of water solution for 8-10 hours before sowing. Give 2-3 sprays of streptomycin sulphate 0.005% (5 gm in 100 lit of water) + 0.15% copper oxy –chloride (150 gm in 100 lit of water) at 15 days interval from the appearance of the disease. Collect and destroy plant debris after harvest.

(II) Fungal diseases

(i) Wet root rot (*Rhizoctonia solani* Kuhn.): The disease is common during seeding stage and high soil moisture favours the disease development. The disease occurs in patches.

Symptoms: Infected plants show sudden death by wilting. The leaves showed drooping without the sign of discoloration. Roots of infected plants rot and show shredding of the bark.

Control measures:

Seeds treatment of carbendazim @ 2.5 g/kg or *Trichoderma harzianum* @ 10 g/ kg seed. Green manuring, crop rotation with non host crops and application of proper recommended dose of NPK. Apply *T. harzianum* 1.5 kg + 60 kg organic manure in furrow before sowing.

Drenching of carbendazim @10 g/10 lit water or Dithane M-45 @ 3g/lit water in soil near root zone at the appearance of the disease in standing crop.

(i) Vascular wilt (*Fusarium oxysporum* f.sp. *vasinfectum* (Atk.) Snyder & Hansen):

The disease is more severe during the boll setting and maturity of the crop. The fungus survives in the soil as chlamydospores.

Control measures:

Grow resistant varieties. American cottons are more resistant to the disease. Sowing the healthy seeds from healthy plants. Apply organic manures and potash in sufficient amount in the field before sowing. Follow the crop rotation with non-host crop like; millets, groundnut and sorghum.

(iii) **Dry root rot (*Rhizoctonia bataticola*)**: The disease is common during the boll formation and maturity of the crop.

Symptoms: Infected plants show drying and wilting. The leaves showed drooping. Roots of infected plants rot and show black discoloration and shredding of the bark. Secondary roots are dried such plant can be pulled up easily.

Control measures:

Give seed treatment of carbendazim @ 2.5g/kg or *Trichoderma harzianum* @ 10 g/ kg seed. Apply *T. harzianum* 105 kg + 60 kg organic manure in furrow before sowing.

Drenching of carbendazim @ 25 g/10 lit water to the soil near root at the appearance of the disease. Apply proper recommended dose of NPK. Follow crop rotation for two to three years, green manuring, use of organic manure, proper irrigation and mix cropping with moth bean and black gram.

(iv) **Anthracnose (*Colletotrichum gossypii*)**: The disease is more severe during humid and hot weather particularly in the month of September and October. The pathogen is seed borne in nature.

Symptoms: The disease appears as reddish or dark brown lesions on the leaves, stem and bolls to shed-off. Often the boll infection result to boll rot.

Control measures:

Seed treatment with carbendezim @ 2.5/kg seed. Spray the crop with carbendezim @2.5g/lit water at the appearance of the disease at 10-15 days interval.

(v) **Alternaria leaf spot (*Alternaria alternata*)**: The disease incidence is observed more during capsule formation and maturity. The fungus survives as mostly circular lesions with concentric rings reddish borders on the affected leaves, bolls and bracts. The lesions may coalesce to form larger lesions and results in extensive defoliation of infected parts.

Control measures:

Spray the crop with Propineb or mancozeb 0.2% at 12-15 days intervals as per the need. Destroy the disease plant debris after harvest.

(vi) **Grey mildew (*Ramularia areola* Atk)**: This is also known as areolate mildew, false mildew or dahiya. The disease appears during cool winter and crop maturing stage as high humidity and low temperature help in the spread of the disease.

Symptoms: The disease appears first on the lower canopy leaves. Lesions are 3-4 mm in width bounded by the vein lets, giving as irregular or angular outline to the appearance of the lesions. It usually appears on plants, which are coming to maturity. The lesions are light green to yellow-green in colour on the upper leaf surface but on the under surface, profuse sporulation gives them a white mildew like appearance. Under humid condition lesions become white on the upper surface also. Once active sporulation ceases, the lesion becomes necrotic and dark brown in colour. Similar lesions may also develop on the bracts. Severe infection may result in defoliation which may cause premature opening of balls and deterioration of fibers.

Control measures:

Destroy the infected-plant debris. Avoid continuous cultivation of cotton. Spray of carbendazim or tridemorph, 0.1% wettable sulphur, 0.2% or karathane @ 1ml/lit water at the disease initiation and ad per the need.

7. Stage wise IPM practices in Bt cotton

Pest monitoring

Monitoring for pests and diseases is a fundamental first step in creating a proper integrated pest management (IPM) program. There are many ways to monitor for insect pests in cotton crop and one popular method is pheromone traps. Pheromones are chemicals produced by a female to attract a mate. Pheromones are most well known for Lepidoptera (moths and butterflies). Use separate traps for each kind of lure and keep them at least 40m from any traps set up for monitoring other species. Traps should be checked twice a week on the same days each time.

Based on the incidence/observation of the traps, a second release of the egg parasitoids and predators should be done

Setup pheromone traps (5/ha) at the distance of 50 meters to lure the adult moths for monitoring.

Undertake community level monitoring to know change in distribution and abundance of pest.

Organise regular pest monitoring and assess bio control potential at every 10 days interval.

Record pest incidence at every 5to10 km distance at 12 spots/ha and 5 plants/spot selected randomly.

Use pheromone traps for monitoring of American, spotted & pink bollworm and spodoptera, at a distance of 50 m @ 5 traps/ha.

Set up yellow pan/sticky traps for monitoring whitefly @ 25 yellow pans/sticky traps/ha.

Monitor the incidence of sucking pests and apply botanical pesticides if the seed treatment fails to offer desired level of protection.

IPM practices at Pre sowing stage

Deep ploughing in summer :

- Summer ploughing exposes the pupae surviving inside the soil. Depth of ploughing should be more than 6 inches. Exposed pupae will die due to excess heat (or) eaten away by birds

Removal of weeds and alternate hosts:

- Remove and destroy weeds which serve as alternate or collateral hosts (*Lagusca mollis*, *Xanthium* spp., *Trianthema* spp., *Sida* spp., *Hibiscus* spp., *Abutilon* spp., and other malvaceous plants)

Growing of Trap crops:

- Grow yellow flower Marigold (tall growing plants are preferred) and Castor around field, ensure flowering before main crop completes vegetative stage

Border crop:

- Sow 2 rows of tall growing Maize (at 30 cm between rows and 30cm between plants). This will provide enabling environment for friendly insects and it also prevents

Delinting

- Acid delinting of seeds should be done before sowing (with commercial sulphuric acid @ 0.1 l/kg of seed) and fumigate with celphos @ 3g/cum for 48 hrs and get thoroughly air dried.

Seed and soil treatment

- Seed treatment with Bavistin @ 2g/kg seeds followed by Imidacloprid or thiomethaxam. Soil application of antagonistic fungi *Trichoderma viride*, *T. harzianum* and *Gliocladium virens* to protect against the rot and wilt diseases.

IPM practices at Post sowing stage

Growing of Trap crops:

- Grow yellow flower Marigold (tall growing plants are preferred) and Castor around field, ensure flowering before main crop completes vegetative stage

Border crop:

- Sow 3 rows of tall growing Jowar or Bajra or Maize (without any gap in the row). This will provide enabling environment for friendly insects and it also prevents

White and Yellow sticky traps:

- Arrange 15-20 Yellow and White sticky traps per acre. Green leaf hoppers and thrips stick to these traps. Clean these traps once in two days and add sticky material to traps for effective trapping. Height of these traps should be the same with the plant height.

Bird perches:

- Arrange 10-15 bird perches per acre immediately after transplanting and remove these at grain filling stage (60 days after transplanting). Bird perches will attract birds and birds will eat pests. Broad costing of yellow rice will attract more birds. Height of bird perches should be more than the height of plants.

Pheromone traps:

- Keeping 5-10 Pheromone traps in zigzag way to mass trapping of boll worms. Lure has to be changed once in a month or after the expiry date

Non – Pesticide Management in Cotton:

Sucking pests: For managing different kinds of sucking pests spray 5 % NSKE solution (5 kg neem seed or 5 kg neem leaves in 100 lts. water). Immediately after germination of crop arrange 10-15 Yellow and White sticky traps per acre at 1 feet height. *Chrysoperla* sp. (Chrysopidae) and spiders like *Distina albida* L. feed on nymphs and adults of the cotton Jassid. Coccinellid beetles, *Coccinella septumpunctata* is a common predators of cotton aphid.

Red spider mite: For managing, spray 2 lt. tobacco leaf extract(2 lt. tobacco leaf extract with 100 lt. water) ensure that bottom of leaves wetted properly with spray solution.

Heliothis: For managing Heliothis, spray chilli garlic solution. For mass trapping arrange 5 – 10 pheromone traps. A Nucleopolyhedrovirus (NPV) causes significant mortality among the infected larvae depending on environmental conditions.

Spodoptera: Arrange 5 – 10 spodoptera Pheromone traps per acre, 45 days after sowing.

Pink boll worm: *Trichogramma achaeae* Nagaraja & Nagarkatti (Trichogrammatidae) parasitizes the eggs of this pest.

Spotted bollworm: *Trichogramma* sp. parasitizes the eggs of spotted bollworms or spray 5 % NSKE solution.

Release egg parasitoids *Trichogramma* sp. @ 1.5 lakh/ha at 40-45 DAS followed by second release after a week to parasitize the eggs of bollworms and larval parasitoids like *Chelonus blackburni* or *Bracon kirkpatricki* @ 3000 adults/ha.

Spray HaNPV @ 250 LE/ha to manage the larval population of American bollworms and Spodoptera below the ETL level.

Spraying of agrimycin, agallool, streptomycin, copper oxychloride against bacterial diseases and carbendazim, mancozeb against fungal diseases for effective control of diseases. However application should be need based.

Allow grazing by animals after the last picking.

Other IPM practices Bt cotton crop

Judicious use of irrigation and fertilizers

Sowing of maize interlaced with cowpea along the borders of cotton fields to conserve and promote activities of natural enemies.

Growing one row of Setaria between the 9th and 10th row of cotton as an attractant of insect predatory birds.

Effective boll formation period was determined for different varieties and calendar based sprays were recommended during this period for management of bollworms

Sheep and goats were allowed to feed on unpicked bolls and burs left in the cotton fields after the last picking.

Cotton sticks were removed from the cotton fields after the crop season. Cotton sticks are used as fuel wood by the farmers and unpicked bolls on these sticks are the main source for carryover of the pink bollworm.

8. Calculation of formulated chemical products

The leaflet/ literature supplied with the product will provide details on per cent active ingredient contents and dose of active ingredient required per hectare. Using this we can work out the quantity of formulated product required for spraying one hectare of land by using the following formula;

$$\text{Commercial Product (g/ha)} = \frac{\text{Dose in g.a.i./ha} \times 100}{\% \text{ a.i. in the Kg/L formulation}}$$

Examples:

1. Solid formulation like WP, Dust- To calculate quantity of Antracol 70 WP required to cover 1 ha of land @ 840 g active ingredient /ha;

$$\begin{aligned} & 840 \text{ g a.i./ha} \\ & = \dots\dots\dots\dots \times 100 \\ & 70 \text{ a.i. in 1 kg} \\ \\ & = 1200 \text{ g/ha} \end{aligned}$$

2. Liquid formulations like EC, SC, SL – To calculate quantity of Conidor 17.8 SL required to cover 1 ha of land @ 25 g a.i. /ha

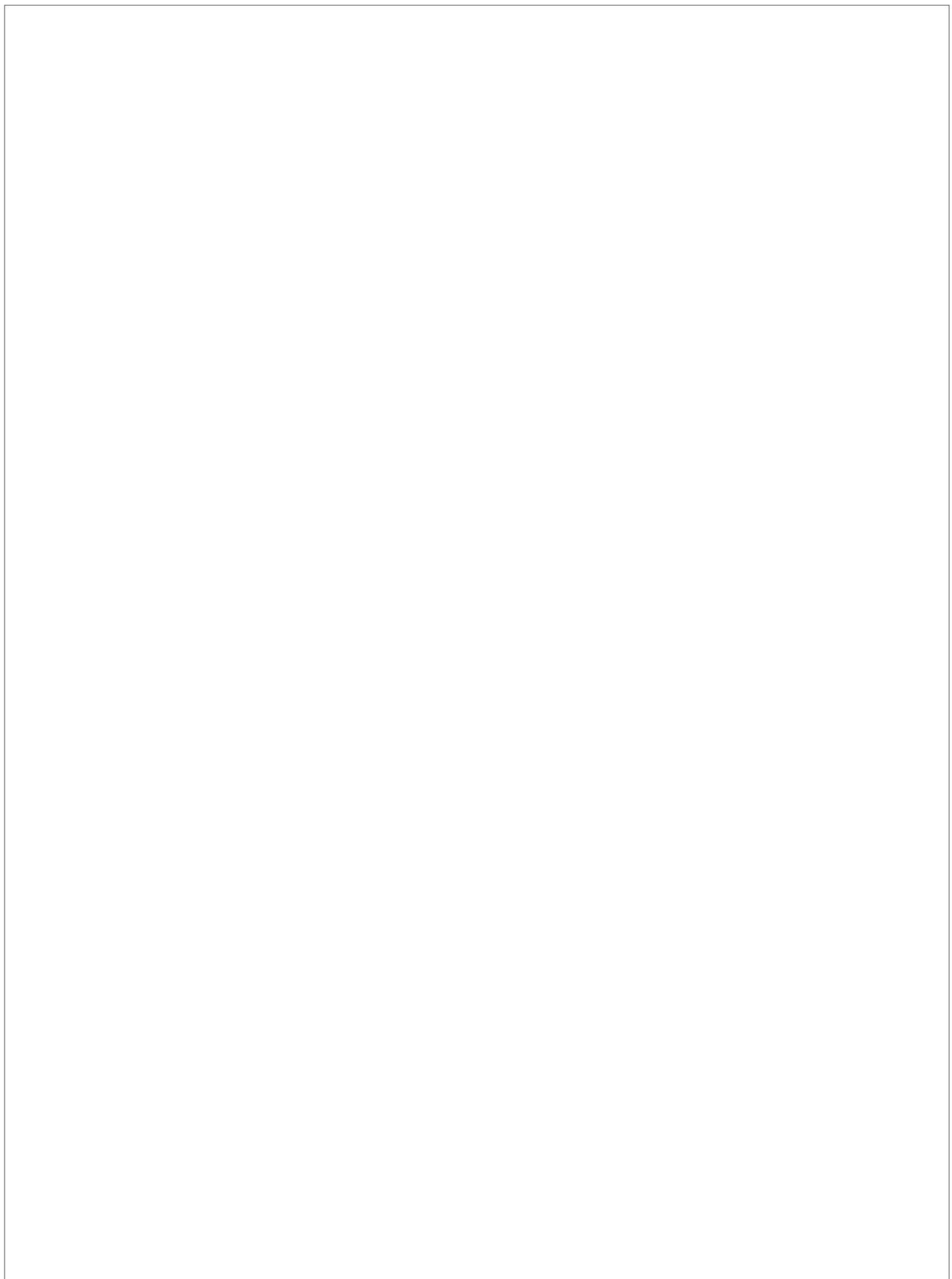
$$\begin{aligned} & 25 \text{ g.a.i/ha} \\ & = \dots\dots\dots\dots \times 100 \\ & 17.8 \text{ g a.i. in 1 lit} \\ \\ & = 140.4 \text{ ml/ha} \end{aligned}$$

3. Granule formulation- To calculate quantity of Regent 0.3 GR required to cover 1 ha of land @ 50 g a.i per ha.

$$\begin{aligned} & 50 \text{ g a.i./ha} \\ & = \dots\dots\dots\dots \times 100 \\ & 0.3 \% \text{ a.i in 1 kg} \\ & = 16667 \text{ g/ha (16.67 Kg)} \end{aligned}$$

9. Guidelines for safe use of pesticides

1. Store under lock and key
2. Keep out of reach of children
3. Buy pesticides in original packing
4. Read leaflet and label before use
5. Wear protective clothing
6. Measure recommended quantity
7. Use funnel and fill without spillage
8. Mix thoroughly in water using stick
9. Spray along wind
10. Do not blow with your mouth to clean the nozzle
11. Do not smoke drink or eat while spraying
12. Do not allow children to spray
13. Wash hands and mouth before eating, drinking or smoking
14. Destroy and bury empty containers
15. Avoid environmental contamination





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