ARTS ’08 BATCH

IPM in Sugarcane

Assignment part of module B.XII - 2009

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1. Introduction

Integrated pest management can be understood as a systematic ecological approach, wherein biological and synthetic materials and means are used to achieve minimal economic damage to the crops by any natural pest/s. Integrated pest management (IPM) takes into account all the six crop protection mechanisms, namely:

Table 1: six main branches of crop protection mechanisms

Chemical measures	Application of chemical materials onto plants, soils or seeds. fungicides, nematicides, insecticides, herbicides, bio-regulators etc
Biological measures	Beneficial arthropods, pathogens (viruses, bacteria, fungi), use of antagonists, resistant cultivars, induced resistance, organic fertilizers etc.
Bio-technical measures	Physical and/or chemical attractants, use of pheromones, insect hormones for fertility an growth, sterile male techniques, etc.
Agronomic practices	Location and melioration, cultivation, crop rotation, elimination of inoculums sources, or alternative and intermediate hosts, proper seeding and planting, etc.
Physical procedures	Mechanical, thermal, exclusions (nets, etc), radiation
Plant quarantine	Import and export control, intermediate quarantine, post-import quarantine, etc.

Armed with these crop protection mechanisms, the principles of IPM are as follows:

Action Threshold: a point at which either the pest population or the environmental factors indicate the need for action, it is imperative to understand that pests and plants belong to the same system and each sustains the other, so action is only necessary if the pest population can cause large damage to the plantation i.e. economically or in production. So one must determine the threshold level, at which action is to be taken, based on the knowledge of local pest life cycles and their interaction with the environment.

Monitoring and Identifying the Pests: it is absolutely crucial to identify the pests and the right kind of pesticide or bio-control to deal with it. Especially when it comes to bio-control mechanism, one must take additional care to understand the all behavioural aspect of the control species, mistakes can be quiet expensive and at times disastrous for the native flora and fauna. More over many of the weeds, insects or pests are harmless and do not require any control.

Prevention: there are several simple cultural methods that can be used to effectively and cost-efficiently deal with preventing the spread of disease or pests. Hence IPM causes least or no hazards to people, property and environment.

Control: when the preventative methods are rendered ineffective, with information from the above steps IPM evaluates the best control mechanism and the risks of using it. In IPM the emphasis is on control and not eradication of the pest population, which most often is impossible to achieve additionally it may have unpredictable consequences for the natural environment. Control of the disease or pest can be achieved with one or more bio-control or chemical agents, such as pheromones or chemical pesticides or combinations of them. Depending on the situation, initially less risky control mechanisms are used, if the problem persists then the scale and strength of the materials used is increased. More often than not, several crop protection mechanisms are put into practice simultaneously that the comprehensive effectiveness is guaranteed or achieved with ease.

2. *Saccharum* L. (Sugarcane)

Figure 1: Sugarcane plantation

Saccharum or sugarcane is a genus of tall perennial grass with 6 species and as many as 37 hybrids. The origin of these species are from south Asia and south East Asia, New Guinea being the most probable according to archeological evidence (6000 BC), ***S.officinarum*** and ***S.edule*** owe their genetic evidence to the country, from where it is thought to have spread to mainland Asia through human migration. India on the other hand has had a very long history of sugarcane production, at least 3500 to 4000years. The Artha Veda (1500 BC) has the earliest reference to the crop, as *'iksha'* and ***S.barberi*** certainly has its origin in the Indian subcontinent. It is here that the production of processed sugar by boiling the cane juice was discovered in the first millennium BC.

It is a long term crop with a growing period as long as 12 -18 months but varies with location and variety. The crop needs plenty of sun and water (min. 600mm of rain per annum, 1200 to 1800mm without irrigation, though water logging is not tolerated), pH of 6 – 7.5 is deemed as suitable soil, it can grow up to 6 – 7 meters in height and 2 to 4 inches in girth. Sugarcane is considered as one of the most efficient photo-synthesizer in the plant kingdom, classified as a C4 plant it converts 2% of incident solar energy into biomass.

Yields differ with location, species and the farming practices, in Brazil 75 tons of raw sugarcane is produced per annum per hector (single crop). The burnt and cropped (leaves burnt and roots cut off) represents 77% of the raw sugarcane, which then is ready for further processing, resulting in an average of 58 tons per hector per annum. Each 1000kgs of B&C sugarcane yields 740kgs of juice, with the total heating value of 4.7GJ, of the 740kgs of juice 135kgs is sucrose which is equivalent to 70liters of ethanol with the combustion energy of 1.7GJ, giving the conversion efficiency of 76%.

Some species of sugarcane are found to fix atmospheric nitrogen in the soil, in association with the bacterium *Acetobacter diazotrophicus*.

Sugarcane is a main source of sugar to majority of human population; it is consumed in a variety of ways, ranging from direct chewing to extracted juice and from different forms of processed sugar to alcoholic beverages i.e. rum, cachaca etc.

Table 2: World production and consumption of sugar (FAO)

		2006/07	2007/08 *Estim*	2008/09 *f'cast*	Change: 2008/09 over 2007/08
		million tonnes			*%*
WORLD BALANCE					
Production		**166.1**	**169.8**	**160.9**	**-5.2**
Trade		**46.7**	**45.3**	**47.6**	**5**
Utilization		**154**	**159.6**	**163**	**2.2**
Ending stocks		**71.4**	**78.1**	**76.5**	**-2**
SUPPLY AND DEMAND INDICATORS					
Per caput food consumption:					
World	***kg/year***	**22.5**	**23.1**	**23.4**	**1.3**
LIFDC	***kg/year***	**12.9**	**13.4**	**13.7**	**1.8**
World stock-to-use ratio	**%**	**46.4**	**48.9**	**46.9**	**-4.1**

The world wide sugar production is at 163 million tons with a 5 % yearly deviation, the deviation is usually due to demand, however in the recent years political policy especially in European Union (3rd phase of quota reduction scheme) and farmers switching to alternative cash crops for higher financial returns driven by the biofuel boom i.e. soy bean and maize, has resulted in lower production and low prices at the world market.

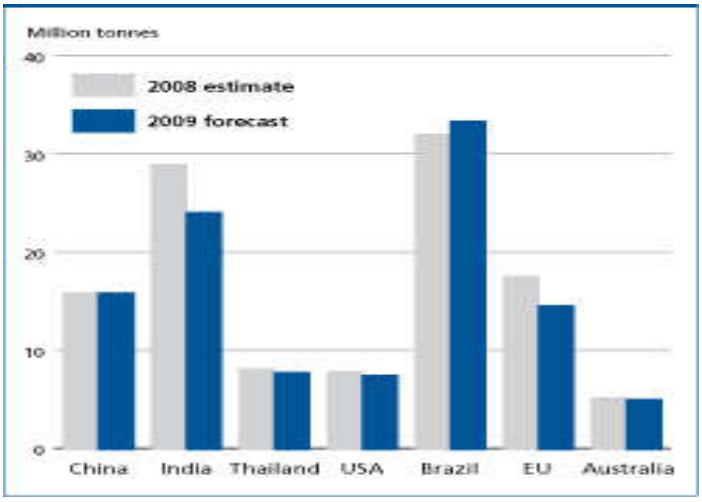

Figure 2: Sugar production by major producing countries (FAO)

3. Pests and Diseases

Because of the long growth duration that sugarcane crop needs, it is extremely vulnerable to insect pests and diseases, some estimates suggest that 20.0% and 19.0% is the actual decline in production due to pests and diseases respectively.

Table 3: Losses in sugarcane production due to different insects and pests in India

Name of Pest	**% reduction in cane yield**	**% reduction in sugar recovery**
Early shoot borer	22 to 33	2 CCS
Internode borer	34.88	1.7-3.07
Top shoot borer	21-37	0.2-4.1
Stalk borer	upto 33	1.7-3.07
Gurdaspur borer	5 - 15	0.1-0.8
Rood borer	35	0.3-2.90
Scale insect	32.6	1.5-2.5
Mealy bug	poor germination upto 35	brix loss 16.20
Black bug	31.6	0.1-2.8
Pyrilla	14.7	2.0-3.0
Arboridia sp.	86	1.0-1.5
White Fly	80	1.4-1.8
White grub(H)	100	5.0-6.0
Whiter grub(L)	33	complete drying
Termite	22.27	4.5
Rodents	7 to 39	-
Sugarcane woolly aphid		1.2-3.43

There are approximately 288 insects that infest sugarcane of which about 24 of them cause heavy losses in quality as well as in quantity. The scenario of insect pests and diseases varies with location e.g. borers and stalk borers are pre-dominantly found in subtropical areas, whereas diseases like rust & eye spots along with pests such as internodes borer and shoot borer are common in tropical areas.

Table 4: Economic threshold of some major pests in Sugarcane

Name of the pest	**Economic threshold level**
Early shoot borer	15.0 - 22.8% for late variety, 16.8% for early variety.
Pyrilla	3 - 5 individuals / leaf or one egg mass 1 leaf+
Stalk borer	17 bored internodes 1 row of 6 m. Length
Internode borer	16.15 to 28.39 bored canes 1 row of 6 m. length
Top borer	15 - 22% incidence
White grub	15 beetles / host tree
Rodents	15 live burrows / ha.

The variety and species of pests in sugarcane crop is astonishing, as mentioned nearly 288 insects from the following orders and families are found in this crop.

Table 5: Some examples of over-ground insect pests in sugarcane

Common Name	**Scientific Name**	**Order or Family**
Root stock borer	*Emmalocera depressalis*	Pyralidae
Pink borer	*Sesamia inferens*	Noctuidae
Stem borer	*Diatraea saccharalis*	Pyralidae
Mexican rice borer	*Eoreuma loftini*	Pyralidae
Sugarcane borer	*Chilo terrenellus*	Pyralidae
Sugarcane thrips	Fulmekiola serrata	Thripidae
Cane Aphid	Melanaphis sacchari	Aphididae
Grasshopper	Oxya chinensis	Acrididae

Table 6: Some examples of underground insect pests in sugarcane

Common Name	**Scientific Name**	**Order or Family**
Sugarcane grub	Tomarus subtropicus	Scarabaeidae
Giant termite	Mastotermes darwiniensis	Mastotermitidae
Ants	All species	Formicidae
Sugarcane whitefly	Aleurolobus barodensis	Stratiomyidae
Burrowiung bug	Scaptocoris talpa	Cydnidae
Field Cricket	Gryllus pennsylvanicus	Gryllidae

Table 7: Some examples of diseases in sugarcane

Common Name	Scientific Name	Order or Family
Red rot	Glomerella tucumanensis Physalospora tucumanensis	Fungi
Smut	Sporisorium scitamineum	Fungi
Wilt	Cephalosporium sacchari	Fungi
Grassy shoot	Mycoplasma like organism	MLO
Mosaic	Sugarcane Mosaic Virus	Virus
Root knot	Meloidogyne spp	Nematodes
Ratoon stunting disease	Leifsonia xyli	Bacteria
Red stripe (top rot)	Acidovorax avenae	Bacteria

4. IPM in Sugarcane borer: *Diatraea saccharalis*

Sugarcane borer is native to the western hemisphere but seems to have been introduced to the United States of America (USA), where it inhabits the warmers states. It is also found through the Caribbean, warmer parts of South America, including Argentina and Brazil. It belongs to the order of Lepidoptera and the family of Pyralidae, it is a average size moth.

Figure 3: Sugarcane borer (William White, Bugwood.org)

This insect is of great importance in terms of economics, for the sugar-alcohol industry in the Americas where it causes maximum damage by: the larvae bores through the cane making it less productive in terms of commercial cane sugar (CCS) or sucrose.

The eggs are deposited on the leaves, stems or cryptically in dried leaves; it might be laid singly or in batches. Initially the instar larvae feeds on leaves, whorls or other succulent plants tissues, but in later stages the larvae feeds exclusively in tunnels. The larval stage is the most important for control of this species.

In the following sections we will study the complete life cycle of the insect and its effect on the plant at each stage, we will also discuss possible methods and mechanisms to control this pest.

Life cycles

Eggs are deposited on both upper and lower surface of the leaves, either singly or in clusters of 50, in an overlapping fashion i.e. fish scales or roof tiles. The eggs are 1.2 mm in length and 0.8 mm in width, usually whitish when deposited, slowly turning reddish or dark brown when close to hatching. The eggs hatch in 4 – 9 days.

Figure 4: Mature sugarcane larvae (http://edis.ifas.ufl.edu)

Larvae tend to emerge or hatch simultaneously at least within a few hours of one another and move into the whorl to feed. They develop in several stages called instar, which is highly variable with climatic conditions, usually there are about 6 instar stages but it can be anything between 3 to 10 instar stages. In warm conditions it takes 25 days for the larvae to complete its development; otherwise it may last up to 35 days. Initially the larvae are white in colour with a black head about 1 to 2 mm long, at later stages they become creamy in colour with prominent brown spots (only the summer form display spots) bearing stout hairs in each section of the body. After the first or second molt they borrow into the stems, from third instar onwards they feed exclusively inside the stem tunnels causing extensive damage to the plant, mature larvae can be 30 mm in length. Overwintering larvae arrest their development for that period.

Pupation may occur wherever the larvae of the final instar happens to be feeding, the larvae cleans and expands the tunnel prior to pupation, leaving only a thin layer of plant tissue for the moth to break through at emergence. The pupa is 16 to 20 mm in length, slender and elongate in form and yellowish brown to mahogany brown in colour. Pupation is usually 8 to 9 days but under cool conditions it may last up to 22 days.

The adult moths are yellowish or straw coloured with thin brown lines along the length of the forewings, the hind wings in females are white but slightly darker in males. The female wingspan is 27 to 40 mm and males with 18 to 30 mm. They are nocturnal and are hidden in vegetation during the day, oviposition commences as dusk falls and continues well into the evening for up to 4 days, a single female will lay up to 700 eggs in a life time: which is 3 to 8 days.

Figure 5: Adult sugarcane moth (http://www.padil.gov.au)

a) in warm conditions the sugarcane borer can complete its life cycle within 25 days, however in cool conditions it may last up to 200 days.

b) 4 to 5 generations are possible in a single growing season, depending on weather conditions.

Damage

The sugarcane moth larvae bore into the stems feeding exclusively in tunnels, these tunnels may be aligned vertically as well as horizontally, usually extending across many internodes. Stem boring interferes with the translocation of nutrients and water, causing the plant to starve. Larval feeding in the whorl of leaves results in the death of the growing point, a condition known as 'dead heart'. If seed cane is attacked, the tunnelling by borers makes the piece susceptible to fungus infection by stalk root pathogens e.g. root rot fungus (*Physalospora tucumanensis*). Also, generally the holes left behind by the stem borer exposes the plant to infections by fungus, bacteria and virus

Figure 6: Stem borer tunneling in sugarcane

Tunnelling weakens the plants, thus causing it to lodge, in mature plants the top may die off or break off'. It may also cause loss of stalk weight (tonnage/acre) but the greatest threat posed by the stem borer is the reduction in yield of sucrose quantity and quality, 10 – 20% loss in sucrose quantity can be expected from infested plantation.

Step 1: Action Threshold

The best way to determine the pest population is regular scouting; it needs begin early in spring before the overwintering larvae become active, and before the next generation takes root. A 40 acre plot needs to be examined one in 2-3 weeks regularly starting spring, at least in 4 locations. At each location 5 stalks are randomly sampled from 5

plants spaced 3 meters apart. Telltale signs of infestations are pinholes in leaves, tiny holes in the midribs, holes into stalks and frass (light brown fibrous material) at these holes. Despite these characteristics signs, an infestation isn't confirmed until the sugarcane larvae are spotted. Careful examination of leaves, whorls, behind leaf-sheaths and stalks (split stalks to detect the borers tunnelling inside), is deemed adequate to find an infestation.

During the 1990's the action threshold for a chemical treatment was 10% leave sheath by young larvae. However improved studies have established the co-relation between number of larvae found in the sample and the percentile of infestation.

Detecting 2 to 3 live larvae for per 100 stalks examined, is thought to be adequate for action but the larvae have to be dissected to determine level of parasitism if more than 50% of them are infested then there is no need for chemical action. Otherwise 2 to 3 live larvae is considered as the action threshold.

Also when 25 % or more of the plants are observed with eggs clusters, control measures need to be implemented.

Step 2: Monitoring and Identification

a) Natural predators: there are several natural predators of sugarcane borer some examples are as follows.

Table 8: List of natural predators of Sugarcane borer

Name of Species	**Order or Family**
Trichogramma sp*	Hymenoptera: Trichogrammatidae
*Lixophaga diatraeae**	Diptera: Tachinidae
Agathis stigmaterus	Hymenoptera: Braconidae
Cotesia flavipes	Hymenoptera: Braconidae
Orgilus elasmopalpi	Hymenoptera: Braconidae
Apanteles diatraeae	Hymenoptera: Braconidae
Apanteles impunctatus	Hymenoptera: Braconidae
Euplectrus plathypenae	Hymenoptera: Eulophidae
Syntomosphyrum clisiocampe	Hymenoptera: Eulophidae
*Solenopsis invicta**	Hymenoptera: Formicidae
Pheidole dentate	Hymenoptera: Formicidae
P. floridana	Hymenoptera: Formicidae

Each of these species has been tested extensively in laboratory as well as in the fields in America, but none have been successful in adopting or establishing themselves in

their foreign environment. After a few years even the successful ones seem to disappear to dissipate completely, augmentative realise has been found successful but not consistent.

Hence most farmers and large scale producers tend to release the predators on a yearly basis, based on the life cycle of the pest and predator, i.e.

- The wasps of the ***Trichogramma,*** **spp,** are active early on in the season and can cause complete destruction of sugarcane borer eggs by autumn. The adult wasps lay their eggs inside the eggs of the sugarcane borer, and as the larva of the wasp develops it consumes the egg.
- The Cuban fly, ***Lixophaga diatraeae,*** has the potential to cause high levels of damage on the sugar cane borer but does not persist well.
- The red imported fire ants species ***Solenopsis invicta,*** has been the most promising option as up to 90% reduction in borers have been recorded. Once established they can virtually clear an area of all invertebrates and most ground dwelling animals, thus leading to an environmental catastrophe.

There are several predator groups that feed on different life stages / cycles of sugarcane borer, such as Formicidae, Carabidae, Forficulidae, Elateridae, Chrysopidae, and Araneae. Despite artificial breeding and yearly releases, most of the predators have been largely unsuccessful in colonizing the territory it is assumed that climatic conditions are the major hindrance. None of the predator species is able to suppress the sugarcane borer and other such pest population in a consistent manner. For bio-control to be effective a large variety of predators in enormous numbers are required especially in foreign environments, which usually has high costs.

b) Moth traps (light and pheromone) can be used to identify the species, because the southern maize stalk borer looks and causes similar symptoms but react to very different treatments. Discrimination between the two species can be achieved by microscopic examination of the mouth parts.

Step 3: Prevention

Prevention of sugarcane borer spreading can be easily achieved by:

1) Completely burning the cane thrash in winter to destroy the overwintering population.

2) Flooding the fields after harvest will kill the pest larvae in crop debris.

3) Crop rotation with non-graminaceous species with avoid overwintering population, although principally it is a pest of sugarcane it attacks all grasses from the Graminae family.

4) Good plant growth management techniques such as proper fertilization and scheduled irrigation is undoubtedly an advantage, as it has been observed that stem borers tend to more severely damage stressed plants than unstressed plants although this relationship has not been proved i.e. weather it is due to higher stem borer density or degradation of plants natural tolerance.

5) Use of pheromones to disrupt mating, permeating the area with female sugarcane borer pheromones is designed to confuse the adult male insect, so that they are unable to locate and mate with the female. In Mexico it has been successfully tested in the fields.

6) Plant resistance has been a topic of research for close to 2 centuries, the wild progenitors seem to be less prone to stem borers and other such pests whereas the commercial species seem to be caught off guard. Some cultivars of sugarcane show considerable resistance to stem borers. Generally there are other plant resistance that can be used before opting for an alternative species, these are:

- Leaf pubescence has been shown to deter ovulation by insects, thus reducing stem borer population.
- Plants with the ability to self-trash (shed lower leaves and sheaths) and leaf midrib hardiness, have been hailed as resistant characteristics, because the neonate and young larvae must establish within the leaves, midribs and sheaths, and gain sufficient nutrients before they move into the stems, so severing of foliar by the plant would kill the neonate larvae thus reducing the infestation.
- Resistance against the larvae may be achieved with plants that have higher rind hardiness, larger stem diameter and physical attributes of the interior parts of the stem. These attributes offer enough resistance to the larvae which has to enter the stem, become established, tunnel within the stem, aggregate adequate nutrients, complete its development cycles and emerge as a fecund, mature adult, and any hindrance to these processes by the plant can be deemed as resistance.
- The studies carried out by W.H. White confer that stem borer prefer certain genotypes more than others with in the same cultivar. Though this would be tolerance, nevertheless it has been argued as resistance as certain genotypes possessing high levels of injury such as bored internodes, but lower levels of damage such as dead tops, adventitious shoots, and cane weight loss, have been positively identified. So these can be adopted to combat the sugar cane borer.

Step 4: Control

In the American state of Louisiana, farmers have been using 10 % of internodes bored at harvest as the economic damage level and to maintain the 10% ED, the economic threshold level has been indicated as 5 % of infested stalks. So the economic threshold level of 5 % justifies the costs of insecticides and labour. Proper sampling and identifications are carried out before embarking on chemical spraying or treatments.

Weekly application of organophosphate such as monocrotopho, at different seasonal intervals has been found to be successful in terms of reduced bored internodes injuries and increased sugarcane yield and quality, compared to untreated plots. However this insecticide has been proven to highly dangerous to the environment and aquatic life form, the WHO and USEPA classified monocrotopho as IB and I in the hazardous class chemicals respectively and it has been banned by both organizations as well as many countries. Suggestions for alternatives from WHO and USEPA are:

Moderately hazardous:

- chlorpyrifos
- diazinon
- dimethoate
- fenitrothion

Slightly hazardous:

- azamethiphos
- malathion

Other organophosphates such as Azinphos-methyl have been in use since the early 1960's when it replaced endrin and later synthetic pyrethroid cyfluthrin. Both have been proven successful in significantly reducing the percentage of internodes bored but rarely been shown to increase the yield in terms of stalk weight and/or the commercially recoverable sugar (sucrose). Azinphos-methyl has been proven to be environmentally dangerous as well for all life form especially aquatic organisms. It has been banned in EU since 2006, but legislations allow the usage of these chemicals in USA till 2012.

Insecticides applied on foliage of sugarcane, are most effective during the incubation period or just after the eggs have been laid. Otherwise the insecticide treatment needs to be done right after the egg of the sugarcane borer start hatching as there is only a window of few hours before they bore into the stems. Correct timing is imperative as results have shown significant increase in yields; at later stages the chemicals are only vaguely effective

as the larvae comes into contact with the insecticide only when it ventures out to clean the tunnel.

5. Conclusion

Although sugarcane stem borer is one of the prominent insect pests of sugarcane, it is still part of group of insects that infest this highly valued crop. In order to control it and others alike a multi-tactic system of pest control needs to be implemented, which should include predators, resistant genotypes, culture practices and finally insecticides. Because the insect is restricted to its life cycles, it would be of great value to understand the same so that exploitation is effective. For example release of right kind of predators at the right time of the season according the timing of the pests, similarly the use of chemicals needs to be put to use in an effective way. The sugarcane stem borer can be easy controlled if the above listed suggestions are followed.

Yearly management schedule pests and diseases

Table 9: Pest management schedule for sugarcane crop in subtropical India (http://dacnet.nic.in)

Crop stage	Pests covered	Control measures
Selection of crop for seeding	Borers and Scale Insects	Seed stalk should be collected from incidence free fields
Seed Selection	Borers and Scale Insects	Seed stalks showing symptoms of borer attack should be destroyed completely (burned to ashes)
Seed Treatment	Scale insect	Immerse the seed stalks in 0.1 % malathion and I 0.08 % dimethoate solution for 15 minutes
During planting	Termites, Shoot Borers and Root Borers	Application of chlorpyriphos or endosulfan at 1.0 Kg i.e. per hectare over cane the seed stalks is recommended.
April - May	Shoot borers	Release S. *inference* @ 125 Pregnant females per ha. And GV spraying with dimethoate 0.04%
	Thrips	Spraying with dimethoate 0.04%
June - July	Top borer	Soil application of 3 G carbofuran @ 1 Kg or 10 G.phorate @ 3kgs per hectre against third brrod of the pest. 2nd and 4th week of June in eastern Uttar Pradesh and Bihar respectively. 1st week of July in western Uttar Pradesh, Haryana and Punjab. Also release of laboratory bred Isotima iavensis

July - August	White grubs	Hand collection of adult beetles and grubs. Soil treatment with quinalphos 5 G @ 2.5 kgs per hectare, should be done at the time of emergence of adults.
July - September	Gurudaspur borer, Plassy borer	In a large campaign, mechnaical control of the plants must be carriedout at larval stage as the insect larvae are gregarious
	Pyrilla	Redistribution and Colonization of *E. melanoleuca* cocoons or eggs masses. Foliar Spray of M.anisopliae @ 107 spores per 1 ml and the release of pyrilla adults seeded with M. Anisopliae @ 250 adults per hectare.
July - October	Stalk borers, Internode borers, Gurudaspur borers and Root borers	Release *T. chilonis* @ 50,000 per ha at 10 day intervals.
October - November	Stalk borers	Detrashing of dried leaves 2 times at 30 days intervals. Removal of late shoots at 15days intervals till harvest. Spraying sugarcane stalk with monocrotophos @ 0.75kg per hectare following detrashing.
November - December	Stalk borers	*Beauria bassiana* spraying @ 10^{7} spores per ml to control the carry over borer population
	Black bug	Release of adults seeded with spores of Beauria bassiana @ 5000 per hectare to control the carry over population.
Harvesting	For pests in general (scale insects, mealy bugs, black bugs and pyrilla)	Deep harvesting must be done. Removal of water shoots or late shoots. Trash/residue burning

Table 10: Insect pest management schedule of sugarcane for tropical India (http://dacnet.nic.in)

Crop stage	**Pests**	**Control practices**
Land preparation	White grub	Expose the grub stages by deep ploughings for predation. Apply 1 kg. of 2 % methyl parathion dust in 1 cart load of FYM or compost.
	Termite	Destroy the termitoriam present on the bunds and nearer to the field
	Sugarcane woolly aphid (SWA)	Paired or wider row planting
Selection of seed crop	Scale insect, Mealy bugs, White flies, Borers, Sugarcane woolly aphids.	Seed should be selected from the infestation free stalks and plots must be thoroughly disinfected of pest insect larvae and eggs, either by burning or deep tillage or by flooding.

Seed selection	Scale insects, Mealy bugs, White flies, and Borers.	Sugarcane seed stalks damaged by borers, scale insects etc. should be destroyed. The discarded seed stalks, leaves left after seed preparation should be either buried or burnt thoroughly.
Sett treatment	Scale insect, mealy bug, SWA	Immerse the seed stalks in 0.1 % malathion and I 0.08 % dimethoate solution for 15 minutes
At planting (January)	Termite, shoot borer and root borer	Soil application of 6 G lindane or 4:4 G sevidol @ 1 kg / ha. or Caldan 4 G @ 0.5 kg / ha. Drenching of 20 EC chlorpyriphos @ 1 kg. in 1000 lit. of water per ha. or soil application of 5 G quinalphos @ 1.5 kg / ha.
21 days after planting (January)	Shoot borer	Release Trichogramma chilonis @ 3 to 500, 000 parasitized eggs per hectare, at 15 days intervals in suitable installments. Placement of pheromone sleeve traps @ 25 per hectare for C.infuscatellus control & destroy adult males.
	Spittle bug	Spraying of 0.08 % dimethoate
45 days after planting (February)	Shoot borer	Vague earthing up followed by trash mulching. Do plant Maize or Sorghum as intercrops; suitable alternatives are Coriander, Garlic, and Onion. Paired row system is preferable for plantation
	White grubs and SWA	Collect and destroy the grubs during weeding. Need based application of insecticide.
	Root borer	Drenching of 20 EC chlorpyriphos @ 1 kg. / ha in 1000 litre of water per ha. or soil application of 5 G quinalphos @ 1.5 kg / ha.
60 days after planting (March)	White fly Leafhopper	Remove 2 - 3 leaves containing pest stages per plant. Spray 0.08% monocrotophos or DDVP with addition of 2.5 % N in spray solution or spray neemark @ 5 litres per ha.
	Pyrilla	Release 1000 viable cocoons of Epiricaniaparasites per ha.
	White grub (L) Scale insect and mealy bug, SWA	Apply 10 G phorate @ 2.5 kg / ha. and Detrash the lower dry leaves and spray 0.08 % dimethoate.
	Rodents	Apply bromadiolone cake 0.005 % in rodent burrows or bait stations continuously for two days.
90 - 120 days after planting, (April - May)	White grub (H)	Collection and destruction of beetles from neem trees during night time immediately after first heavy showers.
	Internode borer	Release T. chilonis @ 3 to 5 lakh parasitized eggs per ha. at 15 days intervals in suitable instalments
	Topshoot borer	Destroy the egg masses and remove the affected canes along with pest stages.
	White fly	Avoid excess use of N fertilizers before earthing up.

150 - 180 days after planting (June - July)	White grub (H) & Pyrilla	Collect beetles from or under the Neem tree after the first heavy showers at night time and destroy them. Soil application of 10 G phorate @ 2.5 kg / ha or 2 % methyl parathion dust @ 2 kg / ha.
	SWA	Release 1000 viable cocoons of Epiricania parasites per ha. and/or Spot spraying of bio-pesticide like Verticillium
	Grasshopper	Dusting of 2 % methyl parathion dust @ 40 kg / ha in sugarcane and on bunds.
210 - 240 days after planting (August to September)	White fly	Remove 2 - 3 leaves containing egg and pupal stages. Spray 0.08 % DDVP or monocrotophos with addition of 2.5 % N in spray solution or spray neemark @ 5 lit 1ha. or release 1000 adults of Chrysoperla carnae predator per ha.
	Pyrilla	Release 1000 viable cocoons of Epiricaniaparasites per ha.
	SWA	Augmentation of predators like Dipha, Micromus and Syrphid fly @ 1000 larvae or cocoons per ha.
	White grub (L)	Collection and destruction of adults from sugarcane. Apply 10 G phorate @ 2.5 kg / ha.
	Army worm	Collection and destruction of larvae during rainy season.
	Leafhopper	Remove 2-3 leaves containing pest stages. Spray 0.08 % DDVP or monocrotophos.
	Rodents	Apply bromadiolone cake 0.005 % in rodent burrows or bait stations continuously for two days
	Nematodes	Soil application of 3 G carbofuran @ per kg / ha. Cleaning of bunds and fields,
	Snails	Collection and destruction of snails, dusting of lime on snails. Metaldehyde and iron phosphate baiting.
240 days onwards till harvest.	Internode borer	Release Trichogramma chilonis @ 3 to 5 lakh parasitized eggs per ha. at 15 days interval in suitable installments and use of pheromone traps.
	Pyrilla	Release 1000 viable cocoons of Epiricaniaparasites per ha.
At harvest	Root borer	Harvesting at ground level to destroy the pest stages. Destroy stray of plants
Post harvest	White fly	In heavily affected fields burn the trash after the harvest
	Root borer, White grub, Snail	Do not keep the ratoons in heavily affected fields.
		Use rotavator and sub-soiler to destroy the pest stages
	SWA	Proper crop rotation

Table 11: Selected diseases of sugarcane and their management (http://dacnet.nic.in)

Name of disease	**Causal agent**	**Symptoms**	**Disease management.**
Red rot	*Glomerella tucumanensis*	The spindle leaves (3rd &14th) display drying, at a later stage, stalks become discoloured and hollow. Acervuli (black fruiting bodies) develop on rind and nodes. After splitting open the diseased stalk, a sour smell emanates. The internal tissues are reddened with intermingled transverse white spots. In advanced stage of the disease, the colour becomes earthy brown with pith cavity in the centre showing white cottony hyphae and sometimes fruiting bodies of fungus (acervuli). In rainy season, the disease spreads so fast that whole crop dries and not a single malleable cane is obtained	Resistant or moderately resistant varieties should be used. Any seed stalk showing reddening at the cut ends or at the nodal region should be discarded. Healthy seed should be planted. Such seed must be produced from crop raised from heat treatment *of* seed canes in moist hot air at 54℃ for 2.5 hour at 99% humidity. As soon as disease' is noticed, the affected clump along with root system should be uprooted and burnt. Bunding of affected field should be done to avoid movement of rain or floodwater. Ratooning *of* diseased crop should be avoided. Diseased crop should be harvested as early as possible. Crop rotation should be followed in affected fields.
Smut	*Ustilago*scitaminea	The new sprouts are lean and lanky, profuse in number and the growing point projects out of a long black whip covered with black spores. Affected plants have slender and thin canes with erect and pointed leaves. Such plants can be easily located before the production of smut whip.	Resistant or modera tely resistant varieties should be used. Healthy seed (as mentioned under red rot) should be planted. Pre-treatment of seed pieces by dipping in 2.5% organomercurial fungicide helps reduce the incidence. Removal of affected clump showing smut whip during tillering phase effectively reduced the disease incidence.

Wilt	*Cephalosporium sacchari*	Wilt symptoms usually appear after monsoon. Infected clumps, individually or collectively, show stunting and yellowing of top leaves. In severe cases, whole clump dries, cane becomes hollow and lighter in weight. Red discolouration in internodes is more intense towards nodes which do not emit specific odour.	Healthy seed (as mentioned under red rot) should be planted. Seed stalks may be treated with *organomercurial* fungicide before planting. Crop rotation should be followed in affected field.
Grassy shoot	Mycoplasma like organism (MLO)	Large number of lean and lanky, pale sprouts in the clump appear like a 'bunchy grass'. Nor mal stalks are not formed.	Resistant or moderately resistant varieties should be planted. Healthy seed (as mentioned under red rot) should be used. Seed stalks may be treated with antibiotics like *Achromycin, Terra mycin, Tylan, Erythro mycin* @ 250 ppm.
Mosaic	Sugarcane Mosaic Virus (SCMV)	Young leaves of the crown held against the light source display chlorotic and normal green area imparting mosaic pattern. The chlorotic area may show reddening or necrosis. Leaf sheath may also display such symptoms.	Seed should be obtained from disease free plant crop. Secondary transmission of the disease by insect vectors can be controlled by application of Malathion(0.1%) or Dimecron(0.2%)

Table 12: List of sugarcane diseases (http://www.apsnet.org)

BACTERIAL DISEASES	
Gumming disease	*Xanthomonas campestris* pv. *vasculorum* (Cobb) Dye
Leaf scald	*Xanthomonas albilineans* (Ashby) Dowson
Mottled stripe	*Pseudomonas rubrisubalbicans* (Christopher and Edgerton) Krassilnikov
Ratoon stunting disease	*Clavibacter xyli* subsp. *xyli* Davis *et al.*
Red stripe (top rot)	*Pseudomonas avenae* Manns / = P. rubrilineans (Lee et al.) Stapp
FUNGAL DISEASES	
Banded sclerotial (leaf) disease	*Thanatephorus cucumeris* (A.B. Frank) Donk
	Pellicularia sasakii (Shirai) Ito (anamorph: Rhizoctonia solani Kühn)
Black rot	*Ceratocystis adiposa* (E.J. Butler) C. Moreau, (anamorph: Chalara sp.)
Black stripe	*Cercospora atrofiliformis* Yen *et al.*
Brown spot	*Cercospora longipes* E.J. Butler
Brown stripe	*Cochliobolus stenospilus* Matsumoto & W. Yamamoto, nom. inval. (anamorph: Bipolaris stenospila (Drechs.) Shoemaker)
Downy mildew	*Peronosclerospora sacchari* (T. Miyake) Shirai & K. Hara = Sclerospora sacchari T. Miyake
Downy mildew, leaf splitting form	*Peronosclerospora miscanthi* (T. Miyake) C.G. Shaw = Sclerospora miscanthi T. Miyake. Mycosphaerella striatiformans N.A. Cobb
Eye spot	*Bipolaris sacchari* (E.J. Butler) Shoemaker. = Helminthosporium sacchari E.J. Butler in E.J. Butler & Hafiz Khan
Fusarium sett and stem rot	*Gibberella fujikuroi* (Sawada) Ito in Ito & K. Kimura (anamorph: Fusarium moniliforme J. Sheldon), G. subglutinans (E. Edwards) P.E. Nelson et al.
Iliau	*Clypeoporthe iliau* (Lyon) Barr = Gnomonia iliau Lyon, (anamorph: Phaeocytostroma iliau (Lyon) Sivanesan)
Leaf blast	*Didymosphaeria taiwanensis* Yen & Chi
Leaf blight	*Leptosphaeria taiwanensis* Yen & Chi, (anamorph: Stagonospora taiwanensis Hsieh)
Leaf scorch	*Stagonospora sacchari* Lo & Ling
Marasmius sheath and shoot blight	*Marasmiellus stenophyllus* (Mont.) Singer, Marasmius stenophyllus Mont.
Myriogenospora leaf binding (tangle top)	*Myriogenospora aciculispora* Vizioli
Phyllosticta leaf spot	*Phyllosticta hawaiiensis* Caum
Phytophthora rot of cuttings	*Phytophthora* spp. and P. megasperma Drechs.

Pineapple disease	*Ceratocystis paradoxa* (Dade) C. Moreau, (anamorph: Chalara paradoxa (De Seyn.) Sacc. = Thielaviopsis paradoxa (De Seyn.) Hohn.)
Pokkah boeng (that may have knife cut symptoms)	*Gibberella fujikuroi* (Sawada) Ito in Ito & K. Kimura, (anamorph: Fusarium moniliforme J. Sheldon), G. subglutinans (E. Edwards) P.E. Nelson et al.
Red leaf spot (purple spot)	*Dimeriella sacchari* (Breda de Haan) Hansf. ex E. Abbott in S.J. Hughes *et al.*
Red rot	*Glomerella tucumanensis* (Speq.) Arx & E. Müller = Physalospora tucumanesis Spec., (anamorph: Colletotrichum falcatum Went)
Red rot of leaf sheath and sprout rot	*Athelia rolsfii* (Curzi) Tu & Kimbrough = Pellicularia rolfsii E. West), (anamorph: Sclerotium rolfsii Sacc.)
Red spot of leaf sheath	*Mycovellosiella vaginae* (Kruger) Deighton = Cercospora vaginae Kruger
Rhizoctonia sheath and shoot rot	*Rhizoctonia solani* Kühn
Rind disease (sour rot)	*Phaeocytostroma sacchari* (Ellis & Everh.) Sutton, = Pleocyta sacchari (Massee) Petr. & Syd., = Melanconium sacchari Massee in Speq.
Ring spot	*Leptosphaeria sacchari* Breda de Haan (anamorph: Phyllosticta sp.)
Root rots	*Marasmius sacchari* Wakker. Pythium arrhenomanes Drechs., P. graminicola Subramanian, Rhizoctonia sp., Unidentified Oomycete*
Rust, common	*Puccinia melanocephala* Syd. & P. Syd., = P. erianthi Padw. & Khan
Rust, orange	*Puccinia kuehnii* (Kruger) E. Butler
Schizophyllum rot	*Schizophyllum commune* Fr.:Fr.
Sclerophthora disease	*Sclerophthora macrospora* (Sacc.) Thirumalachar *et al.*
Seedling blight	*Alternaria alternata* (Fr.:Fr.) Keissl., Bipolaris sacchari (E.J. Butler) Shoemaker, Cochliobolus hawaiiensis Alcorn, (anamorph: Bipolaris hawaiiensis (M.B. Ellis) Uchida & Aragaki), C. lunatus R.R. Nelson & Haasis (anamorph: Curvularia lunata (Wakk.) Boedijn), Curvularia senegalensis (Speg.) Subramanian, Setosphaeria rostrata K.J. Leonard, (anamorph: Exserohilum rostratum (Drechs.) K.J. Leonard & E.G. Suggs = Drechslera halodes (Drechs.) Subramanian & P.C. Jain)
Sheath rot	*Cytospora sacchari* E.J. Butler
Smut, culmicolous	*Ustilago scitaminea* Syd. & P. Syd.
Target blotch	*Helminthosporium* sp. Priode
Veneer blotch	*Deightoniella papuana* D. Shaw
White rash	*Elsinoe sacchari* Lo (anamorph: Sphaceloma sacchari Lo)
Wilt	*Fusarium sacchari* (E.J. Butler) W. Gams = Cephalosporium sacchari E.J. Butler in E.J. Butler & Hafiz khan
Yellow spot	*Mycovellosiella koepkei* (Kruger) Deighton
= *Cercospora koepkei* Kruger	
Zonate leaf spot	*Gloeocercospora sorghi* Bain & Edgerton

MISCELLANEOUS DISEASES OR DISORDERS	
Bud proliferation	Undetermined
Bunch top	Undetermined
Cluster stool	Undetermined
Internal stalk necrosis	Undetermined
Leaf freckle	Undetermined
Leaf stipple	Undetermined
Multiple buds	Undetermined
Stem galls	Undetermined
NEMATODES, PARASITIC	
Lesion	*Pratylenchus* spp.
Root-knot	*Meloidogyne* spp.
Spiral	*Helicotylenchus* spp. & Rotylenchus spp. & Scutellonema spp.
VIRUS DISEASES	(Also mycoplasmalike organisms [MLO])
Chlorotic streak	Virus (putative)
Dwarf	Sugarcane dwarf virus
Fiji disease	Sugarcane Fiji disease virus
Grassy shoot	MLO
Mosaic	Sugarcane mosaic virus
Sereh	Virus (putative)
Streak disease	Maize streak virus, sugarcane strain
White leaf	MLO

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