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SUGARCANE PESTS AND THEIR MANAGEMENT







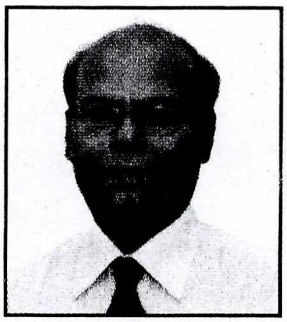

J. Srikanth
K.P. Salin
R. Jayanthi

SUGARCANE BREEDING INSTITUTE
(INDIAN COUNCIL OF AGRICULTURAL RESEARCH)
COIMBATORE - 641 007

Prof. Swapan Kumar Datta
Deputy Director General
(Crop Science)

Indian Council of Agricultural Research
Krishi Bhavan, Dr. Rajendra Prasad Road
New Delhi 110 114

MESSAGE



As the second most important cash crop after cotton and cultivated in about 5 million hectares, sugarcane plays a key role in the socioeconomic development of rural India. The rapid growth of sugar industry in the last couple of decades and the prospects of further expansion due to diversification raise the targets of productivity and production to be achieved within the available resources. Although improved varieties and crop production technologies enhance sugarcane productivity significantly, crop protection plays an important role in preventing cane and sugar yield losses inflicted by biotic factors.

Insect and non-insect pests damage sugarcane in both tropical and subtropical India. While stem borers and subterranean pests occur endemically, sap feeders such as the invasive woolly aphid can attack the crop in epidemic proportions. Basic and applied research over the years has led to significant developments in the field of integrated management of sugarcane pests with emphasis on environment-friendly biological control. Effective application of integrated management technologies by the end-user requires precise and timely diagnosis of the pest under question based on field symptoms of damage and life stages of the pest. A pictorial handbook with descriptions of damage symptoms and management practices for various pests is a long felt need. In this context, the present publication **Sugarcane Pests and their Management** featuring comprehensive information on various pests with color illustrations is a commendable effort. The book would serve as a useful tool in the hands of sugarcane entomologists, pest management advisers, cane personnel and progressive growers to realize the objective of minimizing losses due to sugarcane pests.

I congratulate the Institute and authors on their timely effort in bringing out this publication.

S. K. Datta

(SWAPAN K. DATTA)

Dr. N. Vijayan Nair
Director

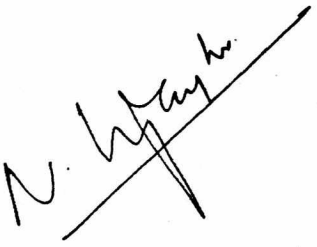
Sugarcane Breeding Institute
Coimbatore 641007

FOREWORD

Pests constitute an important biotic stress in the cultivation of sugarcane and a serious limiting factor in the productivity of the crop, despite occupying a position next to diseases in severity. The rapid expansion of sugarcane cultivation alongside the growth of sugar industry led to large tracts of monocultures of sugarcane, which harbors a variety of pests in the germination, tillering, grand growth and maturity phases spanning over 12 months. More than 200 species of insect and a few species of non-insect pests have hitherto been recorded on sugarcane in the country with considerable temporal and spatial isolation. Close to a dozen of them assume major pest status in a given geographical area and these include aerial pests such as tissue borers, sap feeders and defoliators, and subterranean pests such as root borer, white grubs, termites and rats. Tropics and subtropics, the two agro-climatic regions of the country from sugarcane cultivation point of view, display both uniqueness and overlap in their pest profiles. While shoot borer, top borer, pyrilla, scale insect and mealybugs display nationwide distribution, internode borer, Gurdaspur borer and Plassey borer are restricted to specific regions. Some groups of pests such as white grubs are common to both the regions but show species differences with broad spatial isolation. With diverse feeding habits and nature of damage, these pests inflict varying levels of losses on cane and sugar yields in the tropics and subtropics. Despite the stability offered by the crop system and low pesticide usage enforced by the hostile canopy, established pests such as internode borer, white grubs and rats have shown a tendency to proliferate in a region specific manner for a variety of reasons. Besides, invasive pests such as woolly aphid wreak havoc when inadvertently introduced in to new crop zones. Also, local disturbances in the crop habitat often prompt occasional outbreaks of pests such as whitefly, pyrilla, yellow mite and scale insect. Protection of the crop against the onslaught of these pests calls for timely diagnosis of the problem and application of appropriate management tactics. In this context, an illustrative compendium of the field symptoms and stages of the causative pests, together with the management options available for

various situations, would serve as a useful tool in the hands of field entomologists and cane personnel.

The present publication titled **Sugarcane Pests and their Management** is a compilation of information pertaining to the nature and extent of damage, bioecology and management practices for 17 major sugarcane pests from both tropical and subtropical regions of the country. The book features color photographs of the symptoms of damage and life stages of the different pests dealt with. Besides, the book also pictorially depicts selected management practices recommended for these pests, furnishes symptom based dichotomous keys to identify the pest under question and provides a ready reckoner that summarizes notes on different pests. It undoubtedly serves as a useful handbook or guide for field and extension personnel, and helps in the proper identification of the pest problem and implementation of control measures. It would also serve as a reference manual for sugarcane and non-sugarcane entomologists. I compliment the authors for assiduously compiling information related to the identification of sugarcane pests and their management, together with photographs of symptoms and pest stages, in this handbook which would benefit extension personnel of sugar industry.



(N. VIJAYAN NAIR)

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1. The crop

Sugarcane in India is cultivated in both subtropics and tropics which represent two different agro-climatic zones of the country from the point of view of its cultivation. Subtropics are characterized by extremes of weather conditions and short growing season, and consequent low productivity levels. The warm tropical climate with long growing season provides ideal conditions where the crop gives high yields. For example, Tamil Nadu State leads several states in terms of yield with an estimated average of 102.0 t/ha during 2010-11. Despite such significant performance, the productivity is affected by biotic factors like pests which can cause losses estimated to be around 20 per cent in cane yield and 15 per cent in sugar recovery. Although pests are generally more devastating in the subtropics, tropical India also experiences seriousness of pests under specific situations necessitating deployment of strategies to maintain them below damaging levels.

2. Pest scenario

About a dozen of the more than 200 species of insect and non-insect pests recorded on sugarcane crop in different parts of the country are economically important. Borers and sucking pests are the major aerial pests whereas termites and white grubs constitute the subterranean pests. Among the aerial pests, shoot borer is a key pest throughout the country; internode borer generally prevalent in southern states; stalk borer and top borer in Punjab, Haryana, Uttar Pradesh and Bihar; root borer, though a pest of the subtropics, invaded some areas of tropical India a decade ago but subsequently became negligible; scale insect in Andhra Pradesh, Gujarat and Maharashtra; pyrilla in subtropical sugarcane belt; the introduced woolly aphid briefly attained major pest status in tropical India in recent times. Of the subterranean pests, white grubs are endemic to some areas while termites cause economic damage in isolated pockets. Defoliators are of minor importance, except for grass hoppers in some areas. In the non-insect category of pests, rats are becoming more frequent in drip-irrigated crop whereas yellow mite is frequently appearing in tropical sugarcane. Table 1 enumerates the common pests of the crop in the tropical and subtropical regions of the country. Among these, shoot borer, termites, black bug and mites often proliferate under drought-like situation of extended summer.

Table 1. Common pests of sugarcane in India

Pest	Scientific name	Geographical distribution[#]
Borers		
Early shoot borer	*Chilo infuscatellus*	T, ST
Internode borer	*Chilo sacchariphagus indicus*	T
Top borer	*Scirpophaga excerptalis*	T, ST
Stalk borer	*Chilo auricilius*	ST
Root borer	*Emmalocera depressella*	T, ST
Gurdaspur borer	*Acigona steniellus*	ST
Plassey borer	*Chilo tumidicostalis*	ST
Sucking pests		
Foliage feeders		
Pyrilla	*Pyrilla perpusilla*	T, ST
Woolly aphid	*Ceratovacuna lanigera*	T
Whitefly	*Aleurolobus barodensis*	T, ST
Black bug	*Cavelerius sweeti*	ST
Cane colonizers		
Scale insect	*Melanaspis glomerata*	T, ST
Mealybug	*Saccharicoccus sacchari*	T, ST
Subterranean pests		
Termite	*Odontotermes obesus*	T, ST
	Microtermes obesi	T, ST
White grub	*Holotrichia serrata*	T
	Holotrichia consanguinea	ST
	Heteronychus sublaevis	ST
Non-insect pests		
Rat	*Bandicota bengalensis*	T, ST
Mite	*Oligonychus sacchari*	T, ST
	Aceria sacchari	

[#] T tropical; ST subtropical

3.4.3. Biological control

The stable crop system and low pesticide load provide ideal conditions for both natural and applied biological control. The general crop-pest equilibrium in sugarcane is often disturbed by the introduction of new pests like root borer or woolly aphid. Conversely, disturbance in the system due to unknown causes could result in the outbreak of secondary or introduced pests. One way of managing such pests is to introduce native natural enemies and colonizing them in the invaded areas. The process can be expedited by adopting mass multiplication systems for potential natural enemies. Redistribution has been successfully practiced or recommended for native pests like pyrilla and whitefly. Regular pests like internode borer can also be targeted through augmentative approach with efficient natural enemies.

3.4.4. Chemical control

Insecticides prevent the rapid buildup of pest populations to economic injury levels. Despite the minimal usage, there is a need to select appropriate insecticide and formulation, and adopt correct method and time of application for different seasons and situations. For example, dust formulations are useful under dry conditions when water based sprays are difficult to follow. The appropriate stage of the insect should be targeted as in the case of white grub wherein third instar grub is less susceptible than first and second instar larvae. Improved methods of placement in target sites such as furrow application of chlorpyriphos and lindane for shoot borer and termite control, respectively, spot application of sprays instead of granules for woolly aphid and treatment of border rows where whitefly begins its attack are some examples.

4. Bioecology and management of pests

4.1. Borers

4.1.1. Early shoot borer

Nature and extent of damage

Early shoot borer or shoot borer is widely distributed in all sugarcane growing areas of the country. The pest attacks the crop in its early stages of growth with peak activity during March-June. Under moderate climatic conditions, it occurs throughout the year with peak activity in summer months. It can co-occur with other borers like pink borer, green borer, stalk borer, top borer and root borer leading to erroneous diagnosis. Shoot borer larva enters the plant laterally by making entry holes at the

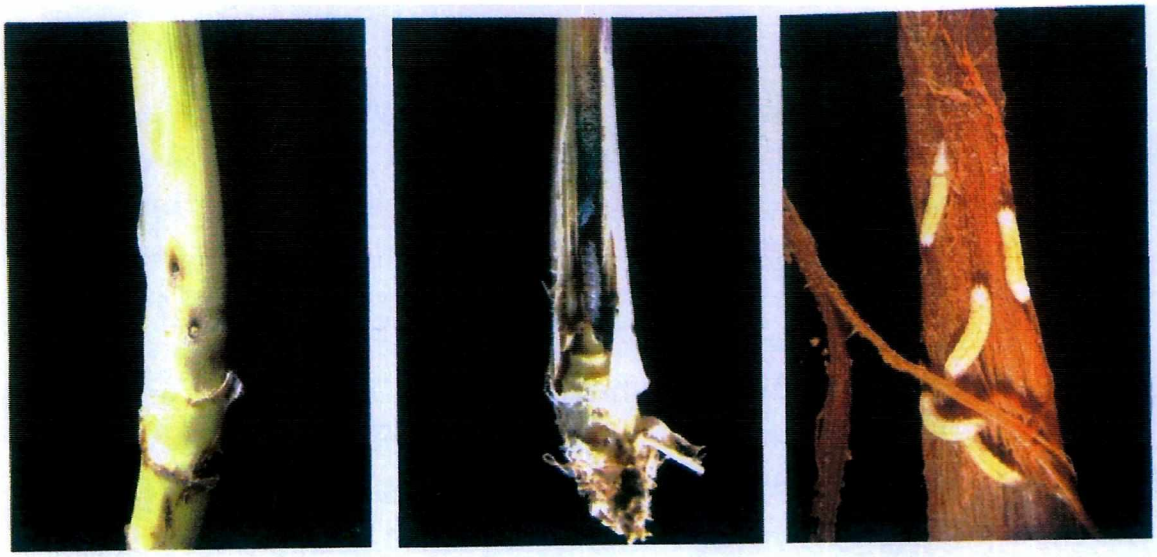


Fig. 1. Shoot borer damage in seedlings: bore holes made by larvae (left); larva feeding on meristem (middle); maggots in decomposed deadheart (right)

base of the stalk and bores downwards or upwards killing the growing point (Fig. 1). This would sever the central leaf spindle which dries up forming a deadheart (Fig. 2) that can be pulled out easily. The cut off portion inside the bored plant decays and the deadheart emits an offensive odor when pulled out. The larva feeds on the soft tissues and makes cavities extending to the setts. In some situations, the borer acts as an internode borer in the later stages of the crop. Borer infestation during the germination phase kills the mother shoots resulting in drying up of the entire clump creating gaps in the field. In the tillering phase, clumps do not get killed and their density remains same though individual tillers suffer mortality. Shoot borer attack often induces compensatory tillering if the mother shoot is not damaged in the affected clump. High tillering varieties suffer less damage than shy tillering varieties. The pest has a high economic threshold of 15-22% beyond which the crop can suffer gaps (Fig. 3) and reduction in millable canes.

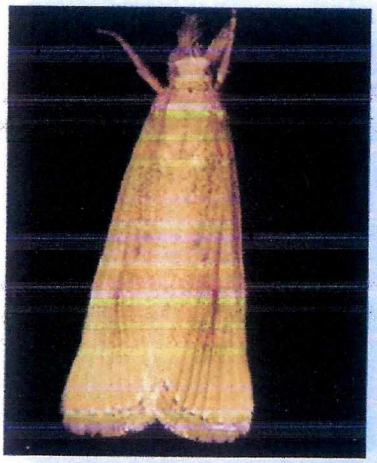
Fig. 2. Shoot borer deadhearts in the field

Bioecology

The light straw to brownish colored nocturnal adult moths lay eggs in clusters on the undersurface of middle portion of the first three leaves (Fig. 4). After hatching in 4-6 days,

Fig. 3. Gaps in plant stand in the field due to shoot borer attack

the larva wanders for a few hours and reaches the base of the stem by crawling or hanging by silken thread. The larva enters the gap between the first leaf sheath and stem and feeds on the inner tissue of leaf sheath like a leaf miner for a few days. Later, the larva bores into the stalk and



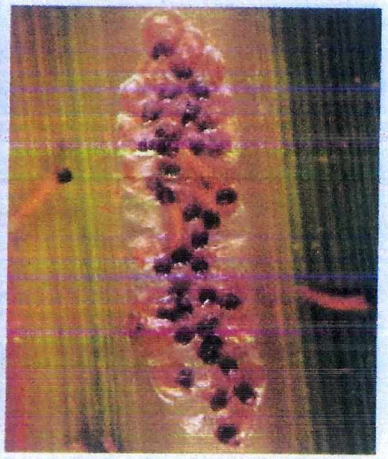
Adult

Fresh egg mass

Developing eggs

Pupa

Grownup larva



Neonate larvae

Fig. 4. Life stages of shoot borer

kills the growing point in 10-12 days. A single larva can disperse from plant to plant and damage more than one plant. Grownup larva is dirty white in color with dark brown head and five violet dorsal stripes running from second thoracic to eighth abdominal segments; the dorsal stripe is central and unpaired. Larva pupates within the plant after 5-6 instars; pupa has ridges on the fifth to seventh abdominal segments and pupal period lasts for about seven days. Shoot borer infestation is generally high during the pre-monsoon period, i.e. April-June when high temperatures and low to moderate humidity prevail. Borer activity decreases appreciably with the onset of south-west monsoon. The borer continues its attack in millable canes in Andhra Pradesh, Orissa, Rajasthan and Tamil Nadu where temperatures rise appreciably during the post-monsoon period.

Management practices

- Early planting (December-January) should be followed in endemic areas to avoid synchrony between the susceptible crop stage and peak borer activity period (April-June).
- Two to three rounds of light earthing-up and trash mulching operations should be given during the early stages of the crop growth. While earthing-up covers the base of the plant and denies entry point of larvae, trash mulching conserves soil moisture which is inimical to the borer. Trash mulching operation may be avoided in areas prone to termite attack since trash attracts them as a source of food.
- Wherever possible, frequent light irrigations, which would have the same inimical effect on the borer as earthing-up and trash mulching due to increased humidity, should be practiced instead of heavy irrigations at long intervals. Besides, the enhanced water supply may encourage the growth of secondary shoots.
- In the subtropics, intercropping with spices like coriander, onion and garlic, potato and green gram, depending on the season of planting, reduces shoot borer incidence (Fig. 5). In the tropics, pulses like green gram, black gram and soybean or coriander reduce the borer incidence when grown as intercrops. Similarly, pulses and *dhaincha* grown as green manure crop and incorporated into the soil reduce shoot borer incidence. Wheat and maize intercrops should be avoided as they enhance shoot borer attack; wheat also increases pink borer and armyworm incidence.

Fig. 5. Intercrop to reduce shoot borer incidence in sugarcane

- Setting up of sex pheromone traps (Fig. 6) two weeks after planting @ 25/ha with one lure change after 30 days to reduce moth population. The height of the trap should be adjusted to canopy level. Water level and kerosene/diesel/detergent topping in the trap should be checked every week. The traps should be kept in the crop canopy equidistant from one another and not outside the border rows facing fallow land. The method should be practiced on a community basis for reliable long-term results.

Fig. 6. Sex pheromones for trapping shoot borer moths: trap setup (left) and moths collected in pheromone trap (right)

- *The* activity of the *egg parasitoid Trichogramma chilonis* may be limited by summer temperatures during the pest's activity period. Need-based sequential releases of heat-tolerant strain of the parasitoid @ 50,000 (≈2.5cc of parasitized *Corcyra cephalonica*

eggs) / ha at 10 days interval beginning 30 days after planting during April-June would be useful.

- *Sturmiopsis inferens* (Fig. 7) is a regular parasitoid with moderate levels of parasitism which can occasionally reach 20%; granulosis virus is more active than the parasitoid on the borer. Together, these two natural enemies can cause up to 40% mortality of the borer in some months. Judicious use of insecticides, i.e. only after the pest level reaches ETL, conserves the parasitoid and facilitates natural biological control. The parasitoid can be released inoculatively in habitats that show its absence in larval samples.

Fig. 7. Adult of Sturmiopsis inferens

- Insecticidal spray with chlorpyriphos 20 EC @ 1 kg a.i./ha should be resorted to when the incidence level reaches the general ETL of 15%. This dosage amounts to 5 liters/ha or 2 liters/ac of the formulation which, at a dilution and application rate of 50ml/10 lit of water for 100 m row length, requires an approximate spray fluid of 1000 liters/ha or 400 liters/acre. The insecticide should be applied with a knapsack sprayer directing the spray fluid on leaf whorls and around the collar region of the plant. Lindane 20 EC, though effective at the same dosage, can be combined only with termite control in view of restrictions on its use, except for field control of termites.

4.1.2. Internode borer

Nature and extent of damage

The internode borer is a major pest of sugarcane in peninsular India with distribution in Tamil Nadu, Andhra Pradesh, Karnataka, Maharashtra, Bihar, Uttar Pradesh and Haryana. The borer begins its activity soon after internode formation and the damage continues until harvest. The neonate larva feeds on the ligular region and inner side of leaf sheath by scraping the epidermis for seven to eight days. Young larva also bores into the spindle region or the topmost formative internodes below the meristem egesting out fresh frass from the bore hole while scooping the tender surface of the shoot below the leaf sheath (Fig. 8). Two types of damage

modes can be distinguished due to the borer attack. Deadheart mode of damage (Fig. 9), which was rarely observed earlier, has now become a more common feature supposedly in the popular variety Co 86032. This is due to the modified larval behavior of feeding on the meristem by entering through the spindle region. But unlike in shoot borer damage, the deadheart when pulled out does not give any offensive smell. Meristem feeding and deadheart formation result in bunchy-top formation (Fig. 10). Often the side-shoots are also attacked by the borer (Fig. 11). In the bore hole damage mode, the larva after entering the formative internodes, generally tunnels upwards up to meristem but rarely feeds downwards (Fig. 12). The larva tunnels the inner tissues of the internode and pushes the frass to the exterior. The frass can be seen as a wet or dry mass hanging from the bore hole which can serve as an indicator of borer attack as well as the duration of attack. With the growth of the cane, the damaged internode hardens and poses difficulties with crushing. The infested internodes show diminished length and girth as compared to the healthy internodes (Fig. 12) or canes. Borer attack reduces weight of millable canes and plot yields. The infested canes suffer significant deterioration in juice quality when the borer damage extends to three or more internodes per cane or more than 10% of the total length of the cane.

Fig. 8. Frass extruding from bore hole (left) and young internode borer larva scooping formative internode surface (right)

Fig. 9. Deadheart caused by internode borer

Fig. 10. Bunchy top due to internode borer attack

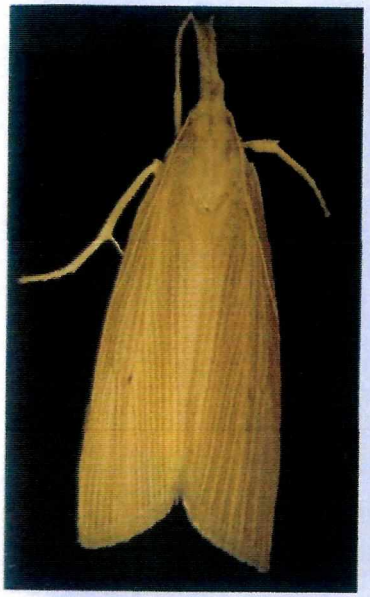
Fig. 11. Internode borer damage in side-shoot

Fig. 12. Internode borer damage (from left to right): tunneling by larvae; fresh frass protruding out of bore hole; decayed frass; reduced internode length and girth

Bioecology

Under tropical conditions, the borer remains active throughout the year and hence all stages of the pest can be observed at any time. Moths are straw colored with a light dark spot on each of the forewings; males are smaller and darker in color than females. Female moths lay eggs in clusters of 2-3 parallel rows on both surfaces of the green leaves, dorsally on the midrib and ventrally parallel to the midrib (Fig. 13). A single moth

lays up to 414 eggs. The incubation period is five to six days. The larva moults six to seven times with a duration of 37-54 days. The grown up larva has violet spots in four longitudinal stripes dorsally. The larva in the pre-pupal stage comes out of the tunnel and selects a semidry leaf-sheath, spins a silken cocoon and pupates inside. Freshly formed pupa is light brown in color becoming dark brown after six to seven days. The pupa has a row of rough projections on fifth to seventh abdominal segments. Adults emerge in 7-10 days. Heavy buildup of the borer occurs during July-December after the commencement of internode formation. Lodging, high dose of nitrogen, water logged condition and presence of large number of water shoots favor pest buildup.



Adult

Fresh egg mass

Developing eggs

Pupa

Grownup larva

Neonate larva

Fig. 13. Life stages of internode borer

Management practices

- The popular variety Co 86032 is not resistant or tolerant to the borer. The borer also produces deadheart and bunchy top symptoms in this variety due to meristem feeding. Since the borer erupts in a sporadic manner often devastating individual farms, cultivation of this variety may be avoided temporarily in such problem farms or areas. It may be grown in conjunction with other varieties, spatially and temporally, in hot spots for a couple of seasons.
- Adjusting the time of planting is of no consequence and not feasible because of the long activity period of the borer in the monsoon and post-monsoon period.
- Removal of water shoots at eighth or ninth month age of the crop would prevent perpetuation of the borer.
- Internode borer pupates outside the cane stalk in leaf trash. Periodical detrashing, preferably at fifth and seventh months, denies pupation sites or opportunities and reduces pupal survival. Also, in detrashed crop, dispersing larvae remain exposed and become vulnerable to predation. Detrashing, coupled with wide row spacing, keeps the crop clean and enables application of insecticide in endemic farms.
- Intercrops like coriander, *palak*, *methi*, soybean and green gram reduce internode borer. However, maize, jowar and okra intercrops may be avoided as they increase the borer incidence.
- Setting up sex pheromone traps @ 25 per hectare (Fig. 14) beginning fourth or fifth month age of the crop with three to four lure changes at 30-45 day intervals reduces moth population. The traps should be fixed at the level of top internodes and their height should be raised with the growth of the crop. The traps may be fixed to adjacent canes or separate stakes in windy region. Dead moths should be removed, and water level and kerosene/diesel/detergent topping should be checked every week. The traps should be kept in the crop canopy equidistant from one another and not outside the border rows facing fallow land. The method should be practiced on a community basis for reliable long-term results.
- Release of *Trichogramma chilonis* has been recommended for internode borer control for a long time. Recent studies indicated that weekly releases of 5 cc/ha during 5-11 months age of the crop can help reduce incidence and intensity of the borer.

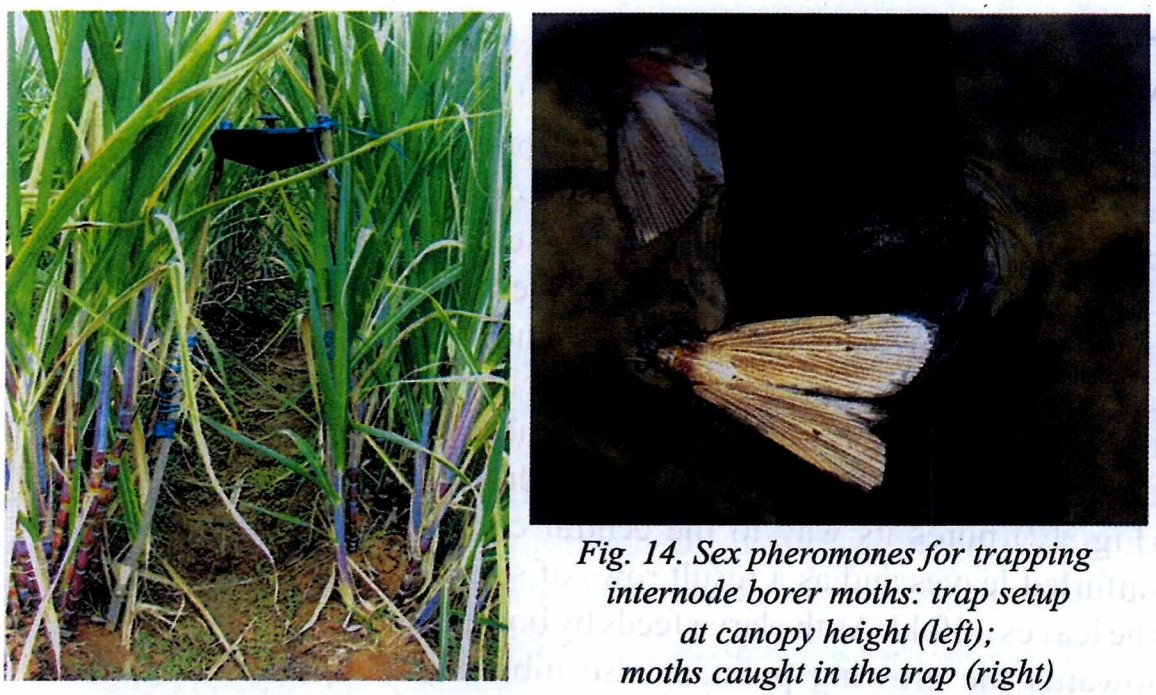


Fig. 14. Sex pheromones for trapping internode borer moths: trap setup at canopy height (left); moths caught in the trap (right)

- The braconid larval parasitoid *Cotesia flavipes* (Fig. 15), which shows up to 8% field parasitism levels in the borer, is a predominant natural regulating factor. The parasitoid can be mass multiplied in the laboratory on internode borer or sorghum borer *Chilo partellus* and released as inoculative dosages in areas where larval sampling and laboratory examination indicate its absence or low activity.
- Insecticides are generally not effective and application is not feasible except in early crop growth stages, i.e. fourth or fifth month or in detrashed and well maintained crop raised in wide row system of planting. Early application of systemic insecticides on top internodes, especially when the incidence is in the range of 15% would be useful.

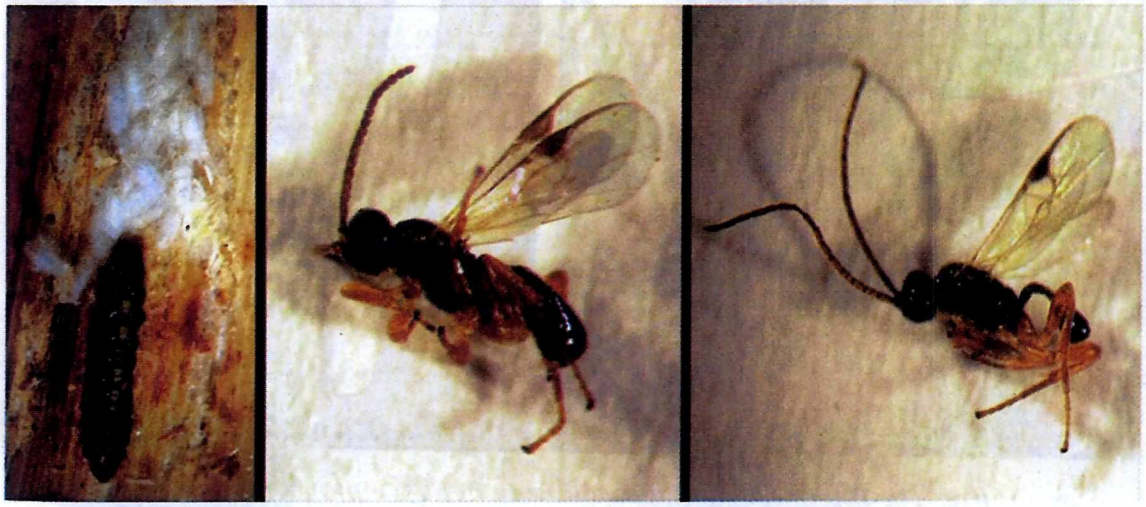


Fig. 15. Cotesia flavipes*: cocoon mass and host cadaver in leaf sheath (left); parasitoid female (middle) and male (right)*

4.1.3. Top borer

Nature and extent of damage

Top borer occurs as a major and regular pest in the subtropical region but as a minor and occasional pest in the tropics. Capable of attacking the crop at all stages of growth, top borer characteristically produces leaf mines, shot holes on opened leaf, atrophied central shoot, stunting of cane and sprouting of axial buds leading to bunchy top formation (Fig. 16). The unique early symptom of attack is tunneling by the first instar larva into the midrib causing a white streak that subsequently turns reddish brown and becomes visible on the ventral surface of the midrib. The larva (Fig. 17) bores its way to the central core of the spindle through the unfurled leaves and as a result rows of shot-holes become visible when the leaves unfold. As the larva feeds by boring into the narrow central core towards the growing point, it also nibbles the inner half of the leaf immediately surrounding the feeding region. This leaf dries up, becomes

Fig. 16. Top borer damage: multiple field symptoms (top left); midrib mines and shot holes on leaves (top right); deadheart and bunchy top in old attack (bottom left); apical shoot growth in bunchy top (bottom right)

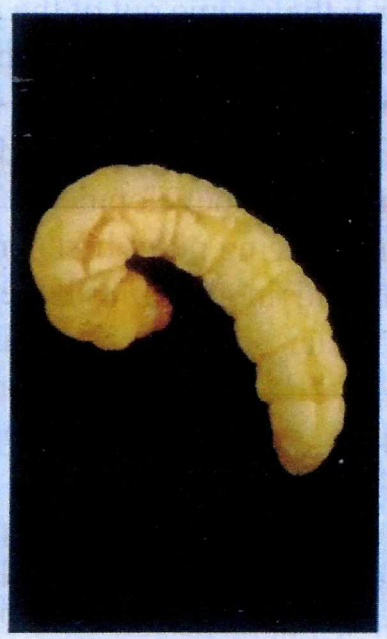
atrophied and turns dark brown forming the deadheart when the fourth instar larva cuts the growing point. The deadheart can not be pulled out easily because the leaf forming the deadheart is never severed off transversely in the course of feeding by the larva. In the tillering phase of the crop, the attacked shoots die leading to the formation of side tillers. In the grand growth phase, the crop growth is arrested and the crown with the deadheart completely dries and may be blown off leaving only a stump. In grownup canes, deadheart formation induces sprouting of the lateral buds giving a 'bunchy top' appearance. Occasionally, top borer infestation induces aerial root formation. Top borer attack on weak and old shoots may result in 100% mortality. At 55% infestation the yield loss could be 18.5 tonnes/ha. Loss in sugar recovery varies from 0.2 to 4.1 units.

Female

Moth with black spot

Egg mass

Pupae



Grownup larva

Naked egg mass

Neonate larvae

Fig.17. Life stages of top borer

Bioecology

Fig. 18. Larval tunnel of top borer through meristem and top internodes

Adult moth is silvery white in color with or without one black spot on each of the forewings (Fig. 17). The female has a tuft of crimson red, orange or buff colored anal hair. Eggs are laid in clusters of two to four overlapping rows covered with buff colored hair mostly on the underside of the basal or middle portion of second and third laminae. After an incubation period of 6-13 days, newly hatched larvae crawl actively on leaves, suspend themselves by silken threads and get dispersed to adjacent plants by wind. After three to four hours they bore into the midribs of leaves through the lower epidermis. The larvae prefer the most tender visible midrib mostly that of the '-1' leaf, which is rolled with only the lower epidermis exposed. Rarely, the entry holes are seen in the upper epidermis of midribs. More than one larva bores in to the midrib of a leaf and they may tunnel parallel to each other or one behind the other. After mining for 24 to 48 h they come out of the midrib only through the upper epidermis and enter into the interior of the spindle as first instar larvae. In this region, while some continue to tunnel through the soft midribs, others reach the central core of the spindle which is the essential site of feeding for their further development. The larva reaching the central core nearest to the growing point first survives while those away from the growing point and in the midrib perish. The legs become atrophied after the first instar and hence the larva can not disperse to adjacent plants. The larva feeds above the growing point up to the fourth instar after which it cuts across the growing point, causes deadheart and enters the top internodes either tunneling down in the centre or moving superficially towards the rind (Fig. 18). After spending 15 - 45 days in four instars, the full grown larva cuts an exit hole (Fig. 19) for the moth that would emerge after a pupal period of 6-21 days. Under tropical conditions, the pest multiplies continuously throughout the year with no brood pattern and no serious flare-ups of abundance. Under subtropical

conditions, the pest remains active from February to October passing through five broods and undergoes larval hibernation in winter. Failure of rains in July affects the number and size of egg masses and dry weather adversely affects hatchability. Abiotic factors are important in the second brood whereas biotic factors play a prominent role in the subsequent broods.

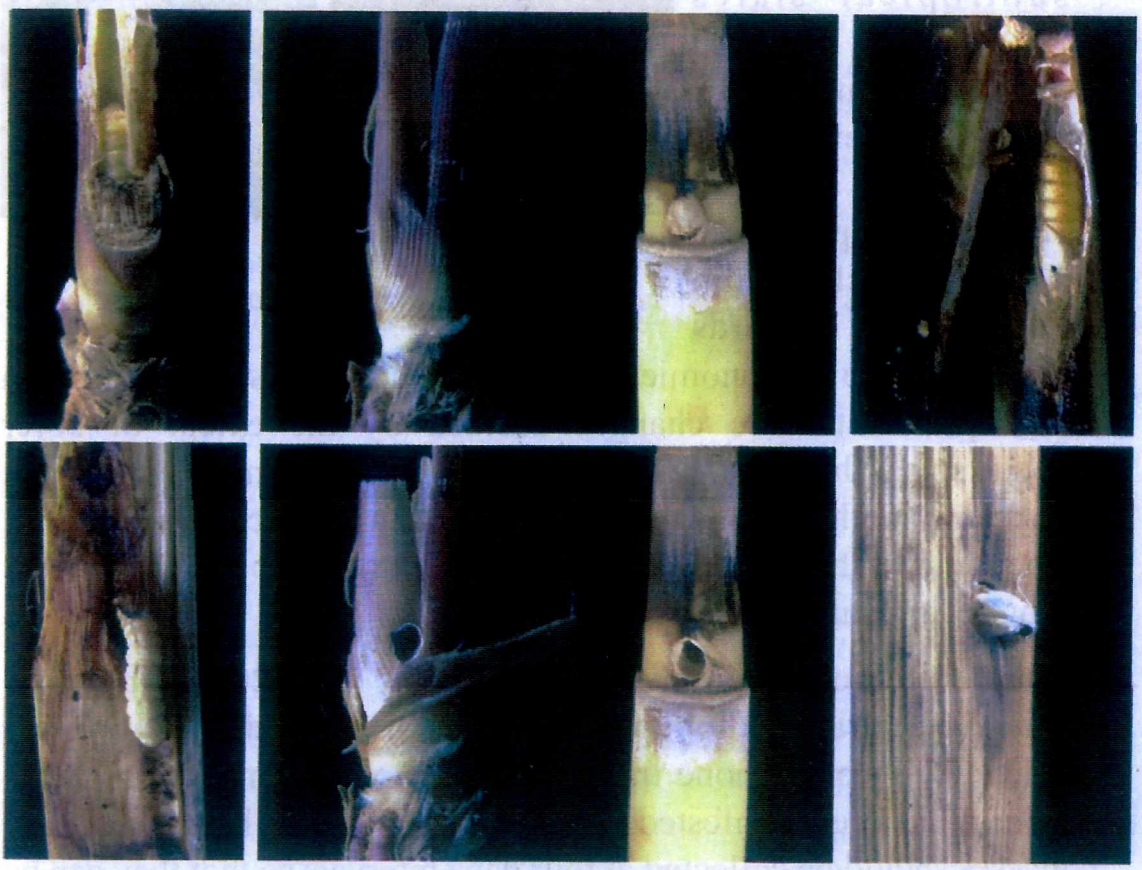


Fig. 19. Life history of top borer: larva in spindle (top left) and top internodal tunnel (bottom left); moth exit hole covered with epidermis (top middle) and open (bottom middle); pupa in silken case (top right) and emerging adult (bottom right)

Management practices

- Cane planted during July-August shows higher level of the borer in Tamil Nadu. Planting time may be altered wherever the borer is severe during these months.
- In subtropical conditions autumn planting is to be followed as it escapes the borer attack in the ensuing winter months.
- Intercropping with spices like coriander, onion, garlic, fenugreek, and fennel, and other crops such as wheat, potato and mustard reduces top borer incidence. In spring-planted sugarcane, intercrop with sunflower reduces incidence of second brood.

- Setting up of sex pheromone traps @ 50 numbers / ha for the first two broods and operated up to 30 days for each brood in subtropical states reduces moth population and brings down the severity of subsequent broods. However, trap catches appear to decline from third brood onwards making its use uneconomical. In tropical India, traps can be set up in hot spots with lure changes decided by the extent of borer occurrence. The traps should be kept in the crop canopy equidistant from one another and not outside the border rows facing fallow land. The method should be practiced on a community basis for reliable long-term results.

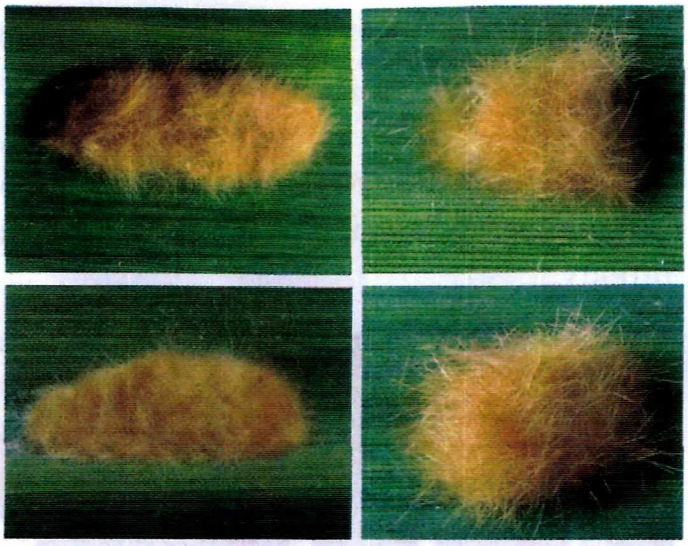


Fig. 20. Forms of top borer egg masses for hand collection

- Hand collection of prominent egg masses (Fig. 20) of the borer should be carried out for up to one month from the day of first moth collection in pheromone traps or the day of first moth emergence from a sample of infested cane tops kept in the laboratory. Egg masses should be collected at four days intervals so that they can be destroyed before the larvae hatch on the fifth day of oviposition. Alternatively, egg masses collected may be held in 60 mesh nylon bags in the field to facilitate selective emergence of egg parasitoids.

- *Isotima javensis* is an efficient natural parasitoid in the field (Fig. 21). For release in problem areas, the parasitoid may be multiplied on a small scale by exposing cane tops harboring the larvae to the parasitoid in polyvinyl cages. The parasitoid may also be redistributed from parasitoid-rich areas to parasitoid-poor or parasitoid-free areas.

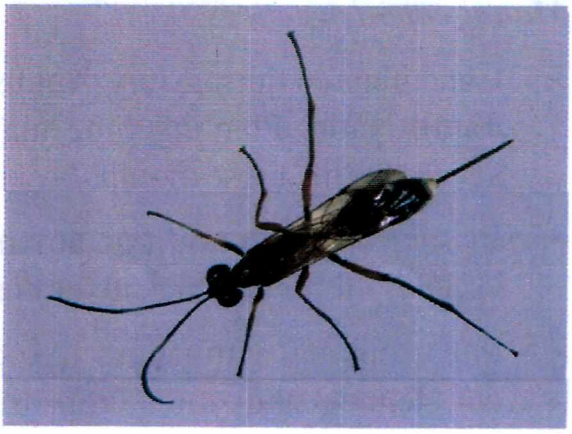


Fig. 21. Top borer parasitoid
Isotima javensis

- The egg parasitoid *Trichogramma japonicum* released five times at 2.5 cc/ha during second and third broods was found to reduce damage by half. Since multiplication techniques for egg parasitoids are available, it may be multiplied and used in problem areas.
- In severe cases of infestation, carbofuran 3G at 1 kg a.i./ha or phorate 10G at 3 kg a.i./ha may be applied in the root zone, covered with soil followed by irrigation against third brood in the third week of June.

4.1.4. Stalk borer

Nature and extent of damage

One of the most destructive pests of sugarcane in subtropical India, the stalk borer is a major pest in Uttar Pradesh, Haryana, Punjab and Bihar. Soon after hatching, the larvae move on the upper surface of the leaf for about 15 minutes but later move downward and take shelter inside the top leaf sheaths (+4 to +8) or in the central whorl. They feed by scraping the inner surface of these leaf sheaths for about a week where they complete two instars. Usually two to six larvae mine in one leaf sheath due to which the leaf sheath decays and subsequently the entire leaf dries. As a result of feeding by the newly hatched larvae, leaves show distinct longitudinal orange yellow streaks extending from tip to base on both sides of the midrib towards leaf margins. It is the third instar larva which bores into the shoot and internodes of the canes. In the early stages of crop growth, i.e. from March to June, the infested shoot produces a deadheart very similar to that caused by early shoot borer. The grownup cane shows no visual symptoms of infestation unless the leaf sheaths are removed when the bore holes may be seen clearly on the internodes (Fig. 22). An infested cane may harbor 3-15 larvae at a time and the damaged internodes show

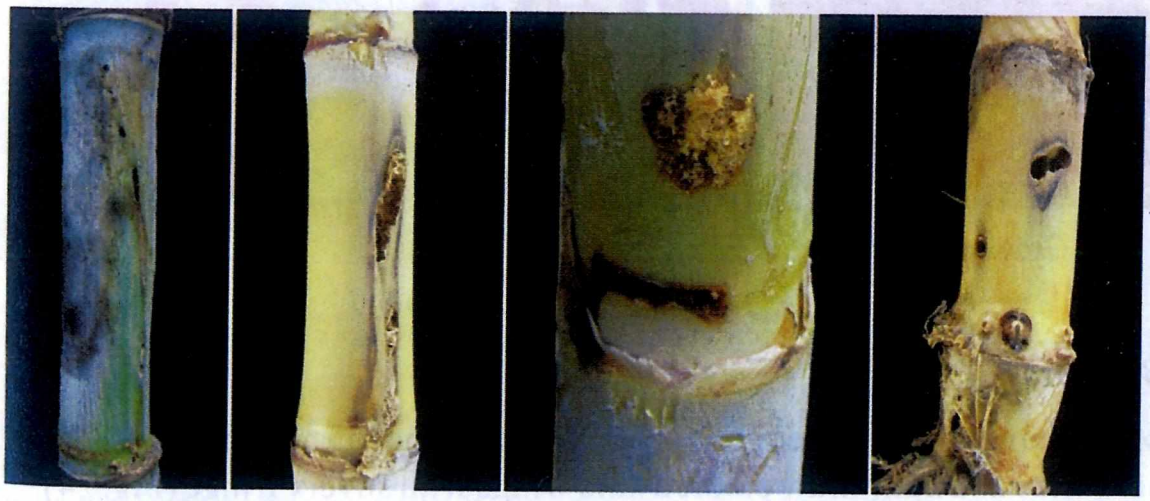


Fig. 22. Bore hole symptoms of stalk borer on sugarcane internodes

Fig. 23. Internodal damage due to tunneling of stalk borer larvae

symptoms of reddening (Fig. 23) which sometimes emit a rancid odor. Often in mature canes, three well marked regions of borer infestation, *viz.* the lower, middle and top portions may be discerned during August-December indicating the three broods of the pest occurring at different stages of plant growth. However, in epidemic conditions, larvae may be found in all the internodes of the infested cane during November-January. Canes which are severely damaged during July-August may dry up from November onwards. The borer causes losses of 16-29% and 1.7-3.7 units, respectively in cane and sugar yields in the subtropics.

Grownup larva *Pupa* *Adult*

Fig. 24. Life stages of stalk borer

Bioecology

Moths have straw colored forewings with a number of golden spots on the periphery and light straw colored hind wings with silvery fringe (Fig. 24). The eggs are laid in masses on the underside of the leaves arranged in two to five parallel rows. The incubation period ranges from 4-10 days. The

newly hatched larva is creamy white in color which normally passes through five instars but in summer and winter there can be as many as eight instars. The fully grown larva has five violet stripes along the length of the body. After a normal larval period of 16-51 days, pupation takes place inside the tunnel formed by the larva. Pupal period ranges from 6-10 days during March-October and 20-24 days in January. The borer completes five generations in Haryana, five to six in Uttar Pradesh and seven in Bihar.

Management practices

- Detrashing autumn planted crop during September-October will expose the infested internodes to the activity of natural enemies. This will enhance the effectiveness of insecticides if applied.
- Removal of water and late shoots at 15 days intervals during winter.
- Release of *Trichogramma chilonis* at 2.5 cc/ha at 10-15 days interval from July is reported to be useful in reducing the infestation level.
- The tachinid parasitoid *Sturmiopsis inferens* naturally parasitizes stalk borer up to 43%. Mass multiplication and field releases at low doses of 15 gravid females/ha have been found to control stalk borer in a subtropical sugar factory area. It would be useful to mass multiply the parasitoid for inoculative or augmentative releases.
- The braconid parasitoid *Cotesia flavipes* causes up to 14% natural parasitism of the borer. In field studies, the parasitoid at 2000 females/ha released five times reportedly reduced stalk borer infestation by 70%. This can be mass multiplied using available techniques and released for the control of the borer.
- Detrashing followed by application of systemic insecticides twice during August and September with one month interval would be useful.

4.1.5. Root borer

Nature and extent of damage

A serious pest in the subtropical sugarcane belt, root borer entered parts of tropical India about two decades back but subsided five years later. It attacks the underground stalk portion of cane and the intensity of damage varies with the stage of the crop. In the early stages, i.e. during May-June, deadhearts are formed which cannot be easily pulled out nor do they emit offensive smell as in the case of shoot borer. Often one or two leaves adjacent to the central whorl also dry-up. In grownup canes the damage

Fig. 25. Root borer infested cane showing yellowing of leaves

symptom is visible in the form of yellowing of leaves (Fig. 25). The canes need to be uprooted to detect the damage (Fig. 26) and the presence of larva (Fig. 27). While attack by the first brood affects tiller production, second to fourth broods reduce cane length and weight in the decreasing order of magnitude with the brood number. Yield loss and sucrose reduction have been observed due to borer attack.

Bioecology

Moths have straw colored forewings and whitish hind wings (Fig. 28). Female lays eggs singly on the upper and lower

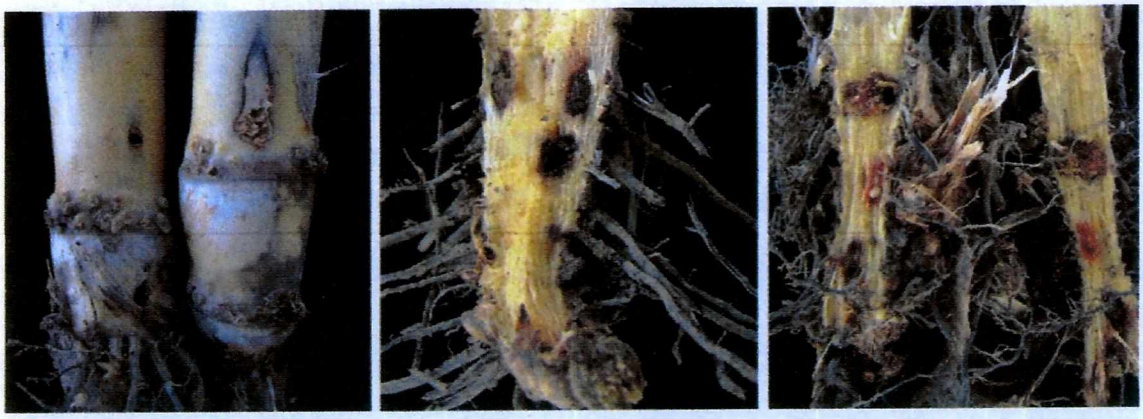


Fig. 26. External and internal symptoms of root borer damage in lower internodes

surfaces of leaves along the midrib. After an incubation period of 5-8 days, the first instar larva crawls to the base of the stem and enters it by making a single hole at or just below the ground level. The larva feeds in an irregular semi-circular pattern and may leave the bored stem and enter into another underground stem of the same clump or adjoining shoots. Larval period varies from 23 to 43 days in summer and longer during rainy season and winter. Larvae

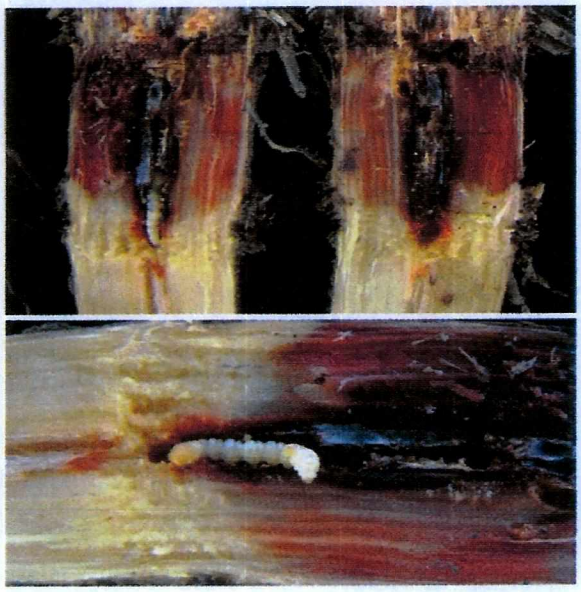


Fig. 27. Root borer infested internodes (above) and larva in tunnel (below)

Fig. 28. Life stages of root borer: eggs on leaf (top); enlarged egg, larva, pupa and adult (bottom row from left to right)

hibernate during October-February. The full grown white colored larva cuts an opening at the exterior end prior to pupation and constructs a silky pupal tube up to the surface of soil for easy emergence of the adult. Occasionally, pupation occurs in the silken tube outside the cane. Pupal period lasts for 7-11 days during summer and rainy seasons and 8-14 days during winter. Life cycle is completed in 30-73 days depending on the season and region. The borer is active at high temperatures and moderate humidity levels. Generally ratoon is more prone to its attack. Unirrigated fields and sandy or sandy loam soils harbor high borer incidence.

Management practices

- Mechanical destruction of affected shoots along with borer larvae in the pre-monsoon period reduces pest inoculum.
- Deep harvesting of canes that are to be ratooned should be adopted to expose larvae or pupae.
- In endemic areas, avoidance of ratoons minimizes proliferation of the pest. In such areas, digging and destroying stubbles after harvest reduces carryover of the pest to the next crop or season.
- In cases of severe infestation, fields should be ploughed up and affected stubbles with larvae should be collected and destroyed.

- In spring/summer planted sugarcane, green gram grown as intercrop followed by its incorporation reduces early incidence of the borer.
- Collection and destruction of moths using light traps also minimizes perpetuation of the borer.
- Release of *Trichogramma chilonis* @ 50,000/ha at 15 days intervals from July to October offers partial protection.

4.1.6. Gurdaspur borer

Nature and extent of damage

It is an important pest of sugarcane in Punjab, Haryana and western U.P. It is also reported from Sriganganagar in Rajasthan and some parts of Himachal Pradesh. The pest exhibits both gregarious and solitary phases. After hatching, larvae wander about for a few hours in search of a suitable site and enter the cane gregariously through a single hole. The entrance hole is always made on a sheathless internode and never below the third internode from the top. They feed gregariously in galleries in a spiral manner making minute punctures on the rind from within. Externally the tunnel appears as a dark spiral made up of a series of punctures (Fig. 29). As many as 35 larvae may feed gregariously in one cane. After feeding two thirds of internode in a spiral manner, the larvae bore deeper and feed upward by making a straight tunnel. Third instar larvae start dispersing to other canes singly or in groups of two to three and in the later stages one caterpillar is found infesting the internodes in each plant. Leaves wither

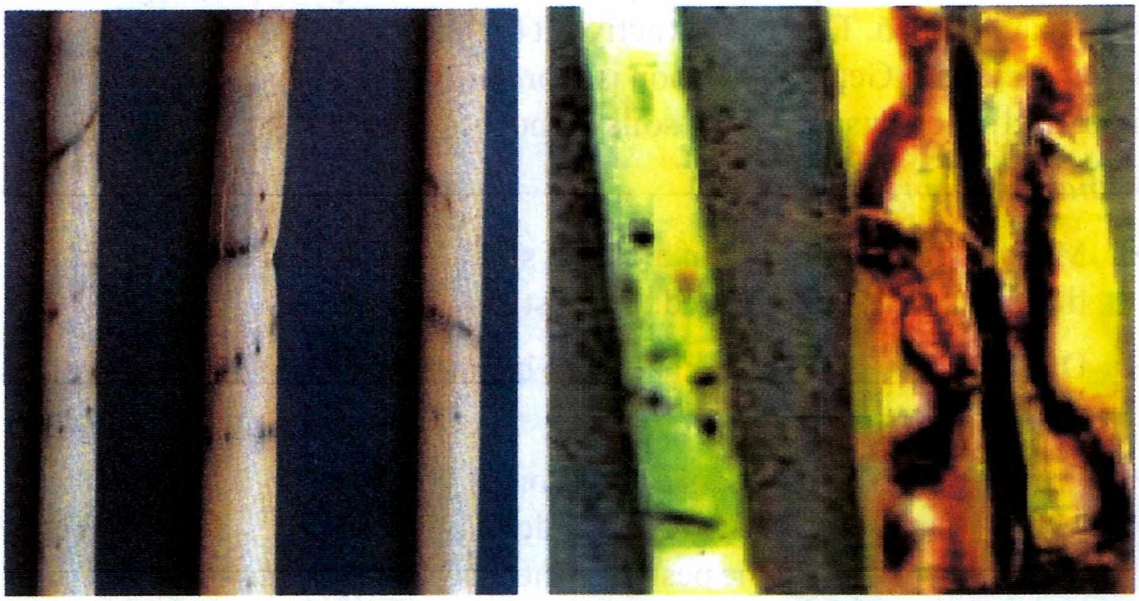


Fig. 29. Gurdaspur borer damage in sugarcane: larval feeding punctures (left); larval feeding tunnel (right) (Photo Courtesy: B. Singaravelu)

due to larval feeding just below the rind but as the infestation advances and the central tunnel is formed, the entire whorl of leaves turns yellow and dries up. As a result of the attack, canes fail to grow, damaged internodes become weak and infested stalks break off easily. Nodal buds in the remaining portions of canes are stimulated and side shoots are formed. The pest causes 15-25% damage normally but can inflict as high as 40-50% damage in years of severe attack with reported losses of 38-100% in cane weight and 29% in sucrose.

Bioecology

The forewings of the moth are pale grey brown in color with several blackish spots along the outer margins; hind wings are white in color. Adult moths lay creamy white eggs in clusters on the upper surface of leaf in and along the grooves of midrib near the leaf sheath. Mature larvae possess four violet stripes, the lateral being comparatively thicker. Before pupation, larvae form a pupal cell in the cane. The pupae are yellowish brown in color with reddish brown stripes and numerous microscopic spines on abdominal segments. The egg, larval and pupal stages last for 4-9, 48-64 and 6-13 days, respectively. After the completion of two broods during June-September, more than 80% larval population comprising full grown third brood larvae moves downwards to the below-ground portion of the cane by November for hibernation. The pest flourishes well under moderate temperature and high humidity conditions. Early monsoon, heavy rains and water logging also favor its multiplication.

Management practices

- Affected canes with five to six top internodes harboring borer larvae in the gregarious phase should be cut and removed regularly. The operation should be carried out on a campaign basis from second fortnight of July to the end of September.
- Stubbles harboring hibernating larvae, easily identified by the presence of round tunnel holes at the cut ends, should be uprooted and burnt to kill the larvae.
- Ratooning of heavily infested crop should be avoided to prevent perpetuation of the pest.

4.1.7. Plassey borer

Nature and extent of damage

The borer derives its name from its occurrence in an epidemic form at Plassey (West Bengal) in 1956. It is an important pest in some parts of West Bengal, Bihar and Assam. The incidence of the borer can be easily recognized by the presence of dried crown of infested sugarcane (Fig. 30). Borer attack occurs in two distinct forms. Primary infestation is caused by as many as 156 newly hatched larvae aggregating in the top three to five internodes. Due to such gregarious feeding, fresh red colored frass is seen projecting out of the bore holes and the top leaves of the canes ultimately dry up. Affected internodes break off easily and nodes adjacent to the infested internode develop sett roots which completely envelop the stalk; sprouting of nodal buds also occurs. In the case of secondary infestation, the grownup larvae disperse to either the lower healthy portion of the canes showing primary attack or the neighboring canes. Larvae feed by tunneling the internodes. One larva may bore into one to five internodes in a cane but cane tops do not dry up in this form of damage. Losses are more due to primary than secondary infestation and may vary in the range of 8.2 - 12.6% and 10.7 - 48.6% for yield and sucrose, respectively.

Bioecology

Moths are cinnamon brown with terminal series of black spots broken externally by small silvery white points. Hind wings whitish except for a few light brown scales in the costal area of male moths. Egg masses are deposited on the underside of top one to three leaves in two to four tiers. Occasionally, eggs are also laid on leaf sheath and stalk. Larvae from one egg mass hatch synchronously in seven days and penetrate into one of the tender internodes. After 10 days of primary infestation, the larvae disperse to adjoining canes each one boring into a separate internode. There is a well marked polymorphism and larvae are of four different types. However, a typical larva possesses four broad pinkish stripes present sub-dorsally and laterally in pairs. The egg, larval and pupal stages last for 7, 26-46 and 6-11 days, respectively. The pest remains active from end of February to middle of November. All stages of this pest are simultaneously met with from April to October showing overlapping generations. However, distinct broods are also reported in different places during June- October. Larvae hibernate from mid November to February. The fourth and fifth broods overlap during February-June.

Fig. 30. Plassey borer damage (clock-wise from top left): infested cane with dried crown, internode with bore holes; multiple larval feeding in internodes; sett roots in infested nodes (Plate Courtesy: B. Singaravelu)

Rainfall appears to favor its multiplication. The incidence is high in heavy soils and under waterlogged or flooded conditions.

Management practices

- Collection of moths in light traps to minimize pest proliferation.
- Collection and destruction of egg masses and cane tops showing primary infestation.
- The braconid parasitoid *Cotesia flavipes* causes up to more than 35% mortality. This can be mass multiplied with available techniques and released inoculatively or augmentatively for the control of the borer.
- High natural egg parasitism of *Trichogramma sp.* (30-71%) was observed on the borer. Avoiding indiscriminate use of insecticides conserves the parasitoid and allows them to bring about natural control of the borer.

4.2. Sucking pests

4.2.1. Foliage feeders

4.2.1.1. Pyrilla

Nature and extent of damage

Pyrilla is a serious pest of sugarcane in many parts of the country, often reaching epidemic levels in the subtropics. Adults and nymphs (Fig. 31) suck phloem sap from leaves and excrete honeydew on the foliage leading to sooty mould development. Such direct and indirect damage affects sugar yield and quality. Up to 28% of potential yield loss was recorded; poor growth of seed setts and difficulties in milling cane from affected plants were also reported. Consequent to pyrilla attack, there is a reduction in sucrose content and purity in juice ranging from 2.0-34.2% and 5-12 units, respectively. The syrup obtained from severely infested canes does not set well and results in poor quality jaggery.

Fig. 31. Congregations of pyrilla adults (left) and nymphs (right) on leaves

Bioecology

Adult *Pyrilla perpusilla* is a pale tawny-yellow soft bodied insect with the head prominently drawn forward. Wing span ranges 16-18 mm and 19-21 mm for males and females, respectively. The adult life span varies from 14 to 200 days and females live for a slightly longer period than males. The female has a pre-copulation period of about 11 days. Copulation takes place during the day and is completed within two hours. Generally the female takes 45-60 min for a single oviposition after a pre-oviposition period of 3-47 days, depending on the season and climatic conditions. Two to 25 days can elapse between two successive ovipositions. Females lay white to greenish yellow eggs which are 0.9-1.0 mm long and 0.45-0.64 mm wide. Eggs are laid during the day on the abaxial and adaxial surface of the leaves along the midrib (Fig. 32). They are deposited in four to five rows and are covered with a waxy filamentous

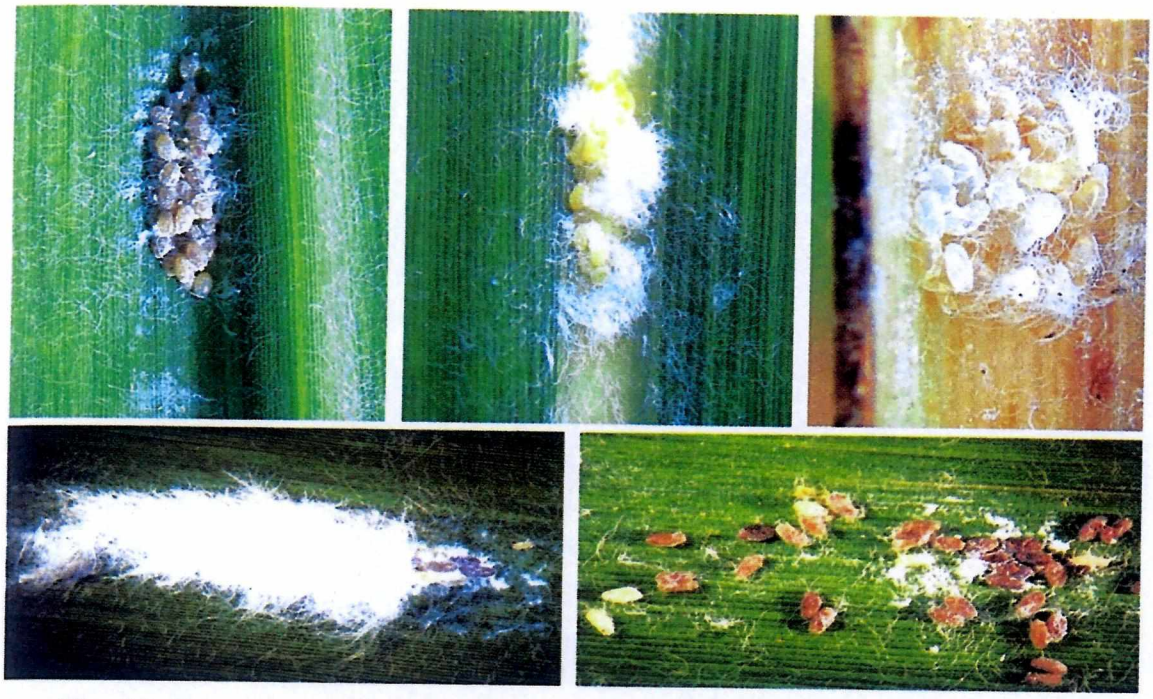


Fig. 32. Egg masses of pyrilla on abaxial (top left) and adaxial (top middle) leaf surface, and inside of leaf sheath (top right); egg mass with waxy filaments (bottom left) and exposed eggs (bottom right)

material secreted by the female. During the winter, eggs are laid between the stalk and the dried leaf sheath which apparently gives protection from adverse climatic conditions. The female usually uses a lower, shady, concealed site for oviposition. About 20-50 eggs are laid at a time with a life time fecundity of 37-880. The incubation period varies with season and ranges from 6-30 days. Newly emerged nymphs are 0.8-1.0 mm long and milky white in color and pass through five instars to reach maturity, each occupying 7-14 days with a maximum total nymphal period of 134 days although some workers recorded six nymphal instars in north India. Each nymphal instar bears characteristic anal filaments which are slightly longer than the body (Fig. 33). The ideal temperature for nymphal development was found to be 30°C with a RH of 80%.

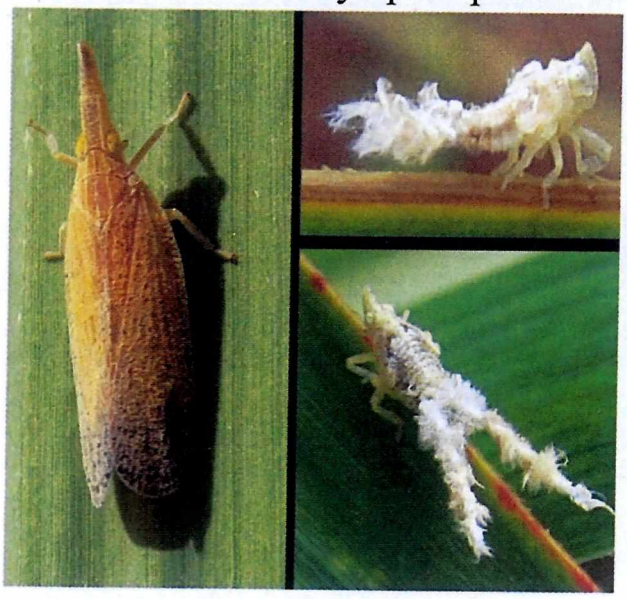


Fig. 33. Pyrilla adult (left) and nymphs (right)

Under subtropical conditions, overwintering nymphs develop into adults on the sprouts of ratoon crops during the second

fortnight of March. Egg laying begins after the first week of April and continues up to the middle of May. Mortality of nymphs is usually very high during the hot dry weather and the surviving nymphs develop into adults by the first week of July. First and second broods are well defined whereas subsequent broods overlap; all stages of the pest occur up to December. The pest completes 4-5 generations in different parts of the country. Copious irrigation during hot months and high foliar density are conducive for the buildup of pyrilla.

Management practices

A more destructive pest of subtropical India, it seldom occurs as a regular pest in tropical parts. Almost always present in small numbers in most fields, there were very few instances of the pest reaching damaging levels in isolated fields in Tamil Nadu. Surprisingly, serious recurrence of the pest in the same fields or the same area in the subsequent seasons was seldom observed. Yet, it is necessary to have a contingent management package for emergencies. Many of the following control measures recommended for subtropics could be selectively applied under tropical conditions too.

- Cane trash should be completely removed from the field after harvesting to be utilized as compost or burnt. This operation should be carried out until the middle of March to destroy unhatched egg masses and overwintering nymphs.
- Detrashing of leaves from August onwards reduces pyrilla populations, besides maintaining hygiene and enabling plant protection operations.
- Removal and destruction of the white colored puffy pyrilla egg masses (Fig. 32) or egg-bearing sugarcane leaves themselves at regular intervals minimizes buildup of populations. Alternatively, the egg masses may be kept in old cloth bags and suspended at different places in the field to facilitate selective emergence of adult egg parasitoids while trapping neonate nymphs.
- Spraying of malathion 50 EC at 0.1% or dimethoate 30 EC at 0.1% or acephate 75% SP at 0.15% in detrashed crop to combat emergency buildup of the pest.
- Long-term control of pyrilla and avoidance of aerial spraying of insecticides have been possible through the use of the ecto-parasitiod *Epiricania melanoleuca* (Fig. 34). The larvae of this moth are

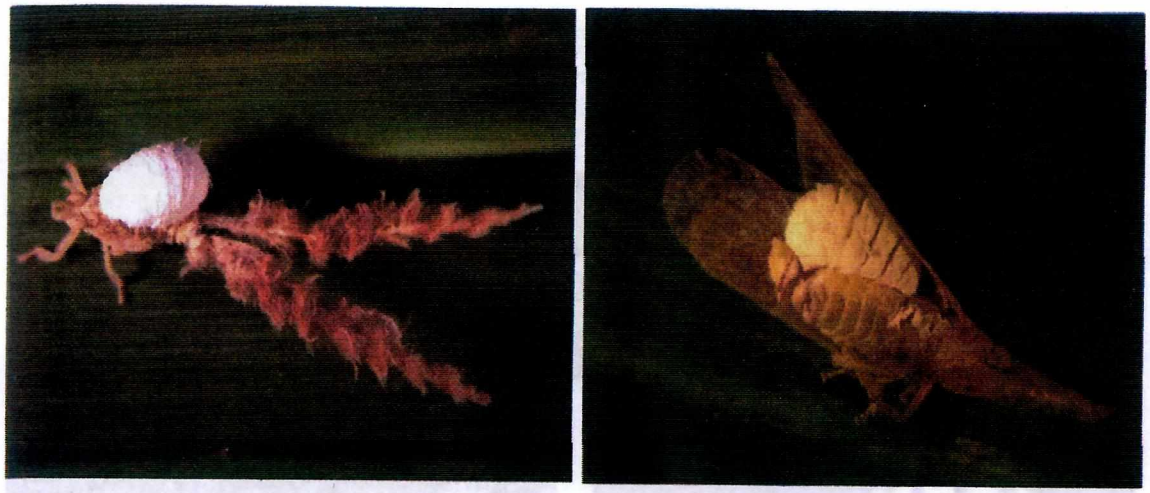


Fig. 34. Pyrilla nymph (left) and adult (right) carrying grownup larva of Epiricania melanoleuca

parasitic on first instar to adults of pyrilla (Fig. 35). High multiplication rate, short life cycle, active larvae, multiplication under wide range of agro-climatic conditions, resistance of cocoons to insecticides and fair degree of host specificity are the advantages with the parasitoid. The parasitoid is mass cultured on pyrilla nymphs and adults maintained on sugarcane leaf bits in the laboratory. Egg masses or cocoons of the parasitoid obtained from laboratory rearings or those collected from sugarcane fields (Fig. 36) can be colonized in target sugarcane fields at a dosage of 10,000 cocoons or 10,00,000 eggs per hectare. Leaf bits containing egg masses or cocoons are stapled on the under surface of the leaves in the center of infested field (100 m^2) if the parasitoid inoculum is small. If a large consignment is available, it is distributed uniformly in the field.

Fig. 35. Epiricania *larva parasitizing pyrilla adult*

- Selective use of pesticides restricted to border rows coupled with re-distribution and colonization of *Epiricania* during pre-monsoon to post-monsoon period should be adopted.

Fig. 36. Epiricania *stages: cocoons on leaf (top row); grownup larva and cocoon (middle row); female laying eggs near empty cocoon (bottom row)*

4.2.1.2. Woolly aphid

The woolly aphid, a pest restricted to north eastern India since the late 50's, appeared in an epidemic form in peninsular India in Sangli (Maharashtra) and Belgaum (Karnataka) in 2002 and later spread rapidly in the sugarcane growing areas of Maharashtra, Karnataka, Tamil Nadu and Andhra Pradesh. The aphid thrived on the crop in an epidemic form

for four to five years during which extensive coordinated investigations were conducted on the biology, ecology and management using a variety of control methods. Augmentative biological control with a few predators and introduction and colonization of a key parasitoid ultimately led to the aphid being kept under check in the subsequent years.

Nature and extent of damage

Fig. 37. Woolly aphid infested sugarcane

As in the case of any other aphid, woolly aphid desaps the plants colonizing the underside of leaves (Fig. 37). The attack generally begins in the middle leaves and extends to upper leaves. Within a leaf, colonies appear in the middle portion and extend to both ends. As the aphids grow and reach later instars, their body is covered with white waxy filaments giving the appearance of a white waxy coating to the infested leaves. A crop that has been attacked for about two months can be identified from a distance by the presence of white patches of plants contrasting with the green canopy background. The wax filaments that detach from the body of thousands of aphids drop down and cover the ground with a powdery coating giving it a white appearance (Fig. 38) which easily catches the attention of one's eye upon entering the field. The large volumes of honeydew excreted by the innumerable aphids settle on the upper surface of leaves located directly below the infested leaves. These leaves with the deposits not only gleam against bright light but also attract a variety of insects

Fig. 38. Woolly aphid wax deposited on the ground

such as bees, wasps and flies, though regular attendance by symbiotic ants is seldom noticed. Sap sucking activity of huge colonies of nymphs and apterous adults causes stunted growth. Although well-nourished plants normally do not show any extreme symptoms due to aphid infestation, gradual yellowing and drying of leaves and plants is possible under severe attack of poorly maintained crop. The indirect damage includes the development of sooty mould on the honeydew deposits (Fig. 39) which interferes with photosynthesis; infested cane tops are believed to affect the health of cattle when fed to them.

The pest generally begins colonizing five-month or older crop though younger crop is also known to support aphid attack in an epidemic situation. The pest remains almost until harvest and causes serious direct and indirect damage affecting both cane yield and quality, besides reducing fodder value. In north-eastern India, cane growth parameters at

Fig. 39. Sooty mould growth on honeydew deposited on upper leaf surface in woolly aphid infested plants

less than 100% infestation were affected to various levels leading to a significant reduction in cane weight (16.6%) and sucrose content (53.25%). In Maharashtra, reduction of 25-36 tonnes/ha in yield and 1.20-3.43% in sugar recovery were observed in three popular varieties (Co 86032, Co 8014 and CoC 671). In Tamil Nadu, aphid attack in fifth month did not affect incremental cane growth; attack in the sixth month

Fig. 40. Late stages of wingless woolly aphid with wax covering

Fig. 41. Winged adults of woolly aphid with nymphs

affected cane growth initially which, however, recovered in the later stages. Higher brix and sucrose% in infested canes suggested possible concentration of solids due to sap feeding by the aphid. Aphid attack did not show definite impact on jaggery.

Bioecology

Under tropical conditions, the aphid invariably reproduces asexually (parthenogenesis) by giving birth to young ones (vivipary) that are composed of females only. The aphid normally produces wingless (apterous) forms (Fig. 40) but towards the end of the season and under competition for food and space, winged (alates) females are produced. These are black in color with two pairs of transparent wings, clear wing venation and no waxy secretions on the body. Winged females generally initiate the attack in a new crop by producing pale greenish nymphs (Fig. 41). With a short life span of 7-9 days, alates produce 8-43 young ones which develop into wingless forms. Apterous adults live for 11-23 days giving birth to 34-62 pale yellowish nymphs (Fig. 42) whose developmental period is 6-22 days. These apterous forms multiply profusely producing large colonies of thousands of individuals on the undersurface of leaves protected from direct sunlight. While winged forms are responsible for plot-to-plot or long distance dispersal, the active first instar nymphs disperse to adjacent leaves or plants in the contiguous canopy in the morning hours. Another form of dispersal is through congregations of young nymphs on the leaf tip which are blown off by wind in a process called ballooning. The first and second instar nymphs are naked, i.e. without the white woolly filaments; dorsal side of the body of the third and fourth instar nymphs produces waxy filaments.

Fig. 42. Nymphs of varying age in woolly aphid colony

Fig. 43. Wingless adults of woolly aphid with young nymphs

The last instar nymphs and wingless adult females are densely covered with thick, white cotton like secretion on the dorsum (Fig. 43). The aphids have a pair of characteristic frontal horns (Fig. 44) and the tubular cornicles are reduced to pore like structures. Under mild tropical conditions of peninsular India where the pest occurred in epidemic form, the aphid could potentially multiply throughout the year including summer. However, June-October appeared to be the most preferred season in many studies, provided the suitable 5 - 6 month old crop is available in June for initiation of aphid colonies.

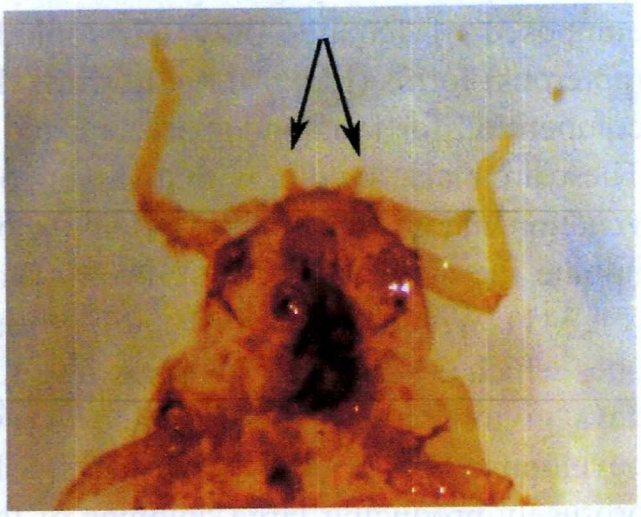


Fig. 44. Frontal horns of woolly aphid

Natural enemies

Among the predators (Fig. 45), *Micromus* sp. is important in some geographical regions. *Eupeodes* sp. occurs in the early stages but is replaced by other predators. The major predator *Dipha aphidivora*, which constructs galleries on either side of the midrib (Fig. 46), builds up populations along with the aphid and by the end of October or early November it generally overtakes the aphid populations and decimates them completely. The introduced and colonized parasitoid *Encarsia*

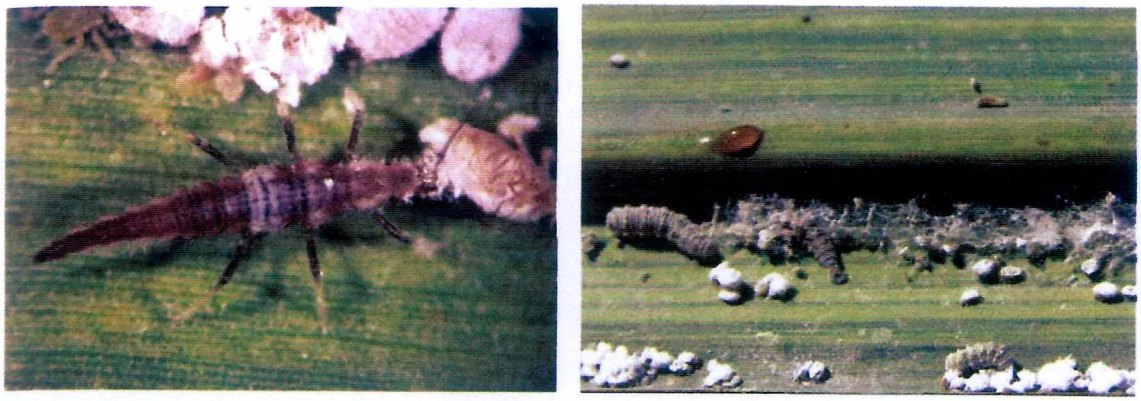


Fig. 45. Larvae of predators Micromus *(left) and* Eupeodes *(right) feeding on woolly aphid*

flavoscutellum (Fig. 47) co-occurs with the host and reduces host populations to zero within two months.

Management practices

i. Preventative management

Although formulated in the initial months of invasion of the epidemic years, preventative management would be relevant in the event of its recurrence in the future.

- Complete avoidance of transport of seed material or green tops as fodder from affected areas to minimize the risk of introduction into a new area.
- Destruction of affected leaves in the early stages of infestation and priority for harvest of affected cane to prevent spread of the pest in recently invaded areas.
- Detrashing enhances accessibility for monitoring and application of insecticides.
- Avoidance of excessive and late application of nitrogen, and excess irrigation to minimize severity of attack.

Fig. 46. Dipha aphidivora *galleries*

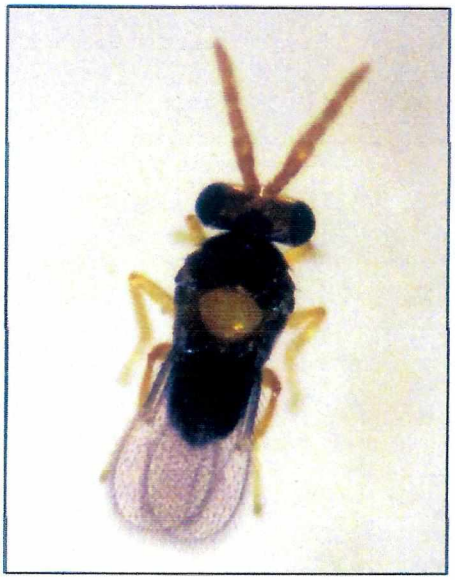


Fig. 47. Adult of Encarsia flavoscutellum

- Wider spacing and paired row planting, and wrapping and propping operations render the crop canopy more amenable to monitoring and chemical control operations.
- Temporary replacement of the popular cultivars, several of which including Co 86032 are susceptible to the aphid, with resistant varieties like CoSnk 0344, CoSnk 0361 and CoSnk 03754 or CoVC 2003-165 to avoid proliferation of the aphid. The popular varieties can be brought back into cultivation after the aphid populations are stabilized by the use of natural enemies.

ii. Curative management

The following prophylactic itinerary can be followed to manage the pest in both the invading and established phases.

- Intensive weekly monitoring of the field is essential due to the high multiplication rates and dispersal ability of the aphid.
- First colonies noticed should be destroyed by spraying insecticides such as acephate 75SP and dimethoate 30EC at 2g or 2ml per liter of water as spot application. Besides the infested patch, unattacked plants within 2 m radius of infested plants should also be treated with insecticide to control the inapparent colonies.
- At high aphid densities, a few patches in the field should be designated as refugia to conserve predators; these should be colonized with additional numbers of natural enemies and kept insecticide-free.
- Treated fields should be monitored and spot application of insecticides continued if predators have not established.

iii. Biological control

Among the natural enemies, the predator *Dipha aphidivora* arrived along with the aphid. The parasitoid *Encarsia flavoscutellum* was introduced from Assam and soon established. Biological control using these natural enemies can be practiced as follows.

- Redistribution of *Dipha* larvae and cocoons (Fig. 48) from established fields to fields without them.
- Mass multiplication of *Dipha* by tray rearing method and field release at dosages up to 1,000 cocoons per ha. Leaf bits bearing the cocoons can be inserted in leaf axils of standing cane from which

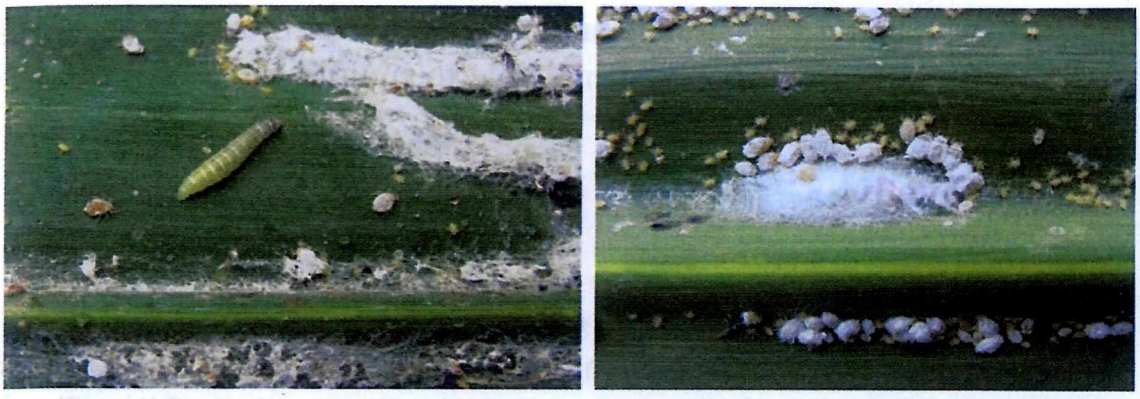


Fig. 48. Larvae, galleries (left) and cocoon (right) of Dipha aphidivora

Fig. 49. Field release of Dipha *by inserting cocoon-bearing leaf bits in leaf axils (left); eggs laid among aphid colonies on leaf (right)*

adults emerge and oviposit among the established aphid colonies (Fig. 49).

- *Micromus igorotus* can be mass multiplied and released wherever it is predominant.
- The introduced parasitoid *Encarsia flavoscutellum* established in aphid infested areas of Tamil Nadu in one year. The parasitoid gave a more rapid control than *Dipha*. It is important to conserve the parasitoid and allow it to regulate aphid populations. As the parasitized aphids can be recognized by the presence of emergence passages in the waxy coating, which appear like tiny pin holes (Fig. 50), it is possible to

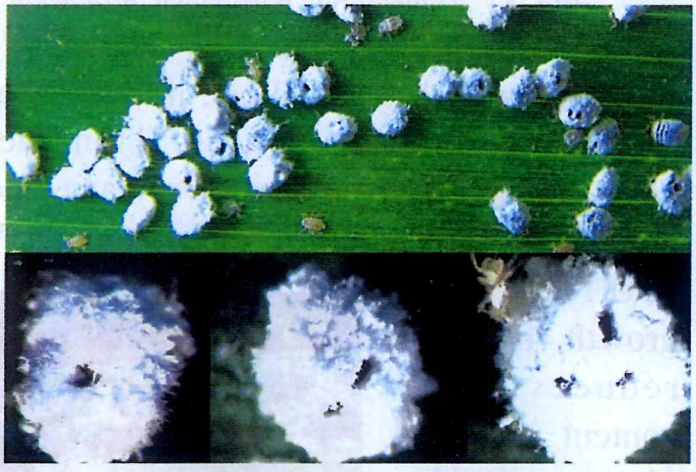


Fig. 50. Emergence pin-holes of Encarsia flavoscutellum *adults on aphids (top); single and multiple holes on individual aphids (bottom)*

redistribute the parasitoid to newly establishing colonies with young nymphs. The parasitoid is amenable to multiplication in shadenet house.

4.2.1.3. Whitefly

Nature and extent of damage

Whiteflies damage sugarcane by extracting large quantities of phloem sap from leaves which can result in greater than 50% yield reduction. The whitefly *Aleurolobus barodensis* occurs in Andhra Pradesh, Bihar, Tamil Nadu, Haryana, Punjab, Gujarat and Maharashtra. Large colonies of *Aleurolobus barodensis* nymphs suck the sap from the undersurface of

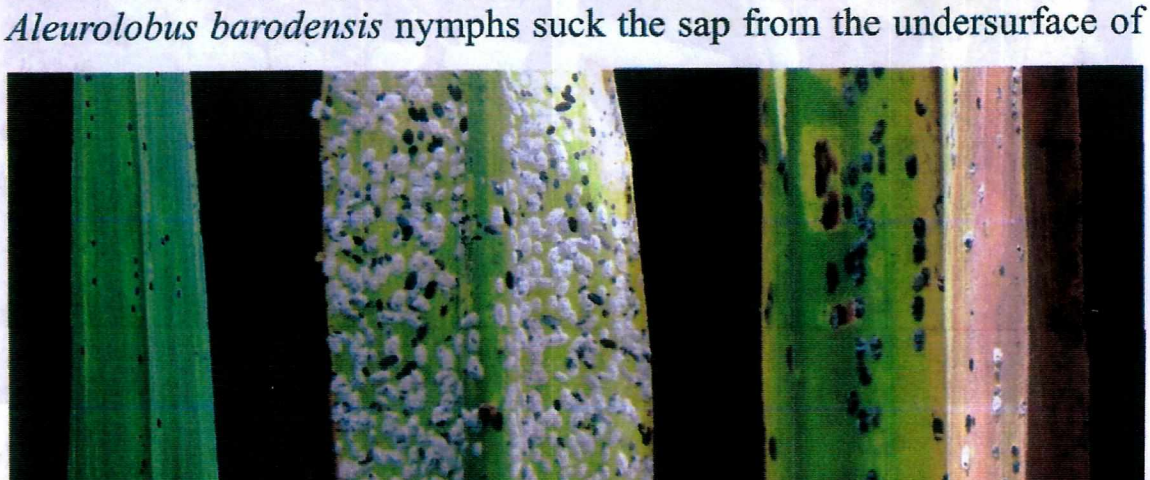


Fig. 51. Aleurolobus barodensis *attack stages: colony initiation (left), severe colonization (middle) and leaf discoloration (right)*

the leaves which turn yellow; in severe cases of infestation the leaves show pinkish discoloration (Fig. 51) and the infested leaves gradually dry up. Honeydew deposited on lower leaves encourages sooty mould growth which adversely affects photosynthesis. Whitefly infestation not only retards plant growth but also reduces sugar content in canes. *Neomaskellia bergii* is sporadic in occurrence and the colonies are restricted to small areas on leaves (Fig. 52).

Fig. 52. Colonies of Neomaskellia bergii *on leaf*

Biology of Aleurolobus barodensis

The emergence of *Aleurolobus barodensis* commences with the formation of a 'T' shaped split in the dorsum of the puparium (Fig. 53). Adults have pale yellow body with dirty white wings; females are larger and less active than males with a longevity of 24-48 h. The conical eggs with a rounded base and supporting peduncle are laid in 2-15 mm long linear rows. Fresh egg is creamy yellow in color but changes to light brownish grey and finally turns black in about 90 min. Egg period lasts for 8-10 days but may prolong to 39 days in winter. The neonate nymph is tiny, pale yellow in color with three pairs of legs and a pair each of compound eyes and ocelli. The color of newly hatched nymph gradually changes to shiny black after it settles on the leaf surface. Secretion of white wax appears in the form of a pair of white rounded specks on either side of the mid-dorsal line of the nymph. Freshly moulted second instar nymph is slightly larger than the first instar, flat with a slightly convex dorsum. It is creamy yellow in color which subsequently changes to

Eggs-different stages

Young nymph

Grownup nymph

Adult

Adult emergence split

Puparium

Fig. 53. Life stages of Aleurolobus barodensis

black. Later, the body is covered by whitish grey waxy coat. Third instar resembles the second instar nymph but is bigger in size. The body is dorso-ventrally compressed with a prominent dorsal convexity and distinct abdominal segmentation. In freshly moulted nymphs, the eyes appear as dark specks on either side of the cephalic region. Active growth and development occur in fourth instar. Outward appearance of this stationary phase resembles pupal stages of other insects. The waxy coat covering the nymphal body is white in color changing to ash color in a few days. Small spines are present along the margins of the body. Female nymphs are larger and broader with less convexity than the males which are thin and slender with prominent convexity on the dorsum. The durations of the first, second, third and fourth instars vary from 2-4, 4-5, 3-5 and 10-15 days, respectively. Total life cycle is completed in 25-47 days but is prolonged to 119-130 days in winter. There are nine generations in a year.

***Biology of* Neomaskellia bergii**

The sluggish adults have long and thick forewings with prominent black transverse patches in both sexes (Fig. 54). The abdomen of female is broad with a short ovipositor. Eggs are laid in concentric, opposite semicircles and are attached to the leaf surface by a peduncle. Eggs are shiny pale yellow but turn dusky yellow in 48h; apices turn brown and acquire a chocolate color during the egg period of 2-3 days. First and second instar nymphs are pale brown whereas the third instar is elliptical with distinct transverse striations on the slightly convex dorsum; the three instars last 5-7 days. The fourth instar or pupal stage is thick, translucent and dark brown with a prominent cretaceous fringe on the margin; the stage lasts 7-10 days. The total life cycle is completed in 15-25 days in different seasons.

Ecology of whiteflies

Drought during summer and dry spells during monsoon profoundly influence whitefly buildup. In semi-dry alkaline patches, heavy incidence of the pest is observed due to physiological stress. Generally, crops subject to water-logging, especially in low lying areas of eastern Uttar Pradesh, Bihar, Tamil Nadu, Gujarat and Haryana, are heavily infested by whitefly. Water-logging leads to physiological starvation of the crop and is characterized by symptoms of nitrogen deficiency which promotes pest buildup. Similarly, leaching of nitrogen due to heavy rains also promotes infestation levels. High levels of humidity generally favor its multiplication. In general, higher whitefly incidence is observed in

neglected crops and unmanured ratoons as compared to manured ratoons. Varieties which have long and broad leaves are highly susceptible to the pest.

Ovipositing females

Female with eggs

Semi-circular egg mass

Puparia

Newly moulted nymph

Nymphal stages

Fig. 54. Life stages of Neomaskellia bergii

Management practices

- Since the pest proliferates under water stress, proper water management of crop to avoid extremes of dry conditions or water-logging should be followed. This should be coupled with nitrogen management, especially in ratoon crop, for minimizing the pest.
- Detrashing and destruction of leaves bearing whitefly puparia before the emergence of the adults which can be determined by the presence of 'T' shaped split in the dorsum of the puparium.
- In the initial stages, attack of whitefly would be limited to border rows or areas. Hence insecticide sprays with malathion 50 EC at 0.1% or dimethoate 30 EC at 0.1% or acephate 75% SP at 0.15% can be restricted to border areas.

- Redistribution of the nymphal-puparial parasitoid *Amitus minervae* from high-activity fields to parasitoid-free fields holds the key to successful biological control. The parasitoid attacks first to fourth instar nymphs and emerges as adult from puparia by making three to seven characteristic round exit holes on the dorsal side of individual puparium (Fig. 55). In contrast, whitefly adult makes a 'T' shaped emergence vent at the posterior end of the dorsal side of the puparium which would be absent in parasitized puparia. In infested fields, parasitoid emergence holes appear about a week after the emergence of whitefly adults from unparasitized puparia. When constant monitoring indicates emergence of whitefly adults, it should be further monitored for the first appearance of parasitoid emergence holes. To confirm parasitoid emergence, 20 cm sample leaf bits with fully developed puparia of whitefly can be held in suitable containers with provision to retain leaf turgidity and observed for a few days. Once parasitoid presence is confirmed, leaves infested with whitefly puparia can be collected from such source fields, transported to target fields and distributed by placing them in leaf axils of standing cane for parasitoid emergence and establishment.

Fig. 55. Emergence holes of Amitus minervae *on* Aleurolobus barodensis

4.2.1.4. Black bug

Nature and extent of damage

Of the three species of black bugs infesting sugarcane, *Cavelerius sweeti* is the most predominant pest of ratoons in north India. While *Dimorphopterus gibbus* is of sporadic occurrence, *Spilostethus macilentus* is an occasional pest. The nymphs and adults of *Cavelerius sweeti* are found in the leaf whorls and under the sheathing bases of leaves. The leaves of affected plants turn pale yellow with brown patches.

Fig. 56. Black bug adult in leaf axil (left) and with nymph in leaf sheath (right)

In severe infestation, they become riddled with holes, owing to several bugs puncturing the same spot. The tips and margins of the leaves dry up gradually and the entire plant may wither. The growth of the plant is arrested and the quality of juice is adversely affected. Both nymphs and adults suck the sap resulting in stunting of the ratoon crop.

Bioecology

Adult *Cavelerius sweeti is* black in color with legs and antennae being ochraceous (Fig. 56). The longevity of males and females is 112 and 118 days in summer and 210 and 242 days in winter, respectively. Fresh eggs are cigar shaped, smooth and creamy white turning vinaceous brown later. The egg period ranges 9-17 days during May-September and 85-159 days during October-April. First instar head yellow, ochraceous; compound eyes red; antennae four segmented, the fourth being the largest. Fourth segment of the body is amber colored with white spots, fifth and sixth segments reddish brown and last three segments black. Second instar head reddish brown, posteriorly suffused with black; compound eyes scarlet red; pronotum blackish, meso and metanotum suffused with white. Third instar head reddish brown, suffused with black; pronotum dark brown, posteriorly suffused with reddish brown. Mesonotum brown, anterior margin of both pronotum and mesonotum suffused with white; wing pads evident. The durations of first, second and

third instar nymphs are 8-15, 3-17 and 4-14 days, respectively. Black bug incidence is heavy in ratoon fields where trash is retained for a long time. Mild weather and large numbers of overwintering individuals are responsible for the outbreak of the pest during the pre-monsoon period. The loss due to bug damage is severe in unirrigated fields.

Management practices

- Burning trash and crop residues after harvest, removing sprouts from stubbles by the end of April and irrigating the fields reduce black bug infestation.
- Application of acephate 75SP or dimethoate 30EC or malathion 50 EC at 2g or 2ml per lit directed towards the leaf whorls to target all stages.

4.2.2. Cane colonizers

4.2.2.1. Scale insect

Nature and extent of damage

Of the several species of scale insects that attack sugarcane, the armored scale insect *Melanaspis glomerata* is economically important. The symptoms of attack in the field become evident only when heavy populations of the pest cover the entire cane, the encrustation giving a greyish black appearance (Fig. 57). When large colonies of different stages desap the cane, the crop loses general vigor, shrivels up and exhibits stunted growth with reduction in internodal length. Consequently, cane yield, percentage of juice extraction, juice quality and jaggery production suffer reduction. Use of infested

Fig. 57. Encrustation of Melanaspis glomerata *on sugarcane internodes*

setts for planting hampers germination to a level of 11.3 - 33.3% in different varieties. The perceptible decrease in cane height and girth reduces cane yield to the extent of 33% depending on variety and soil type.

Bioecology

Adult female lays 270-400 elongate, narrow and ovoid eggs which are rounded at the anterior and posterior ends. They are light yellow in color and gradually turn to pinkish red as the embryonic development advances. After a very short egg period of 4-12 h, the nymphs or crawlers hatch within the body of the mother and escape through the genital aperture (Fig. 58). The first three instars show no morphological differences between males and females. Female passes through five instars with no difference between the fifth instar and the adult except for the size and outer scale. The scale encrustation is thick, round, grey to light black in color and convex with white waxy coating on the outer surface. The adult female is oval in shape and yellow in color. The male insect passes through four nymphal instars and a pupal stage before reaching the adult stage. Reproduction is generally by fertilization and occasionally by parthenogenesis. The life cycle of female varies from 39-49 days in summer and 50-57 days in winter. Male insect completes its development in a shorter period of 18-22 days. In the field, all stages of the insect are generally observed throughout the year indicating that the generations overlap. High temperature and high humidity prevailing during July-September favor population buildup. Well spread but non-beating rains coupled with high humidity from September onwards promote the growth of scale populations. Rainwater and high velocity winds disperse crawlers to new areas.

Fig. 58. Crawlers and nymphs of Melanaspis glomerata *on leaf sheath and internodes*

Management practices

- Avoidance of movement of susceptible varieties from infested areas for seed purpose ensures prevention of spread of the insect to new areas and delays establishment.
- Selection of healthy seed from pest free areas and uninfested fields is important since infested setts affect germination. It is also significant when seed material is being lifted to an area where scale was not recorded earlier. Also, in areas where the pest has remained low for a long time, use of healthy seed prevents its reentry or reestablishment.
- Prevention of waterlogging reduces humidity and helps minimize scale populations.
- Soaking setts in malathion 0.1% for 15 minutes is important when seed material is lifted to new or pest-free areas.
- Detrashing of crop two or three times beginning with internode formation would expose the colonizing sites as well as the crawlers that move upwards to settle underneath the tightly clasping leaf sheath.
- Wide-row spacing, wrapping and propping, and detrashing help maintain crop hygiene and facilitate insecticide application in endemic areas.
- The pest harbors a variety of predatory coccinellids (Fig. 59) and parasitoids. Indiscriminate use of insecticides should be avoided if their activity is observed in the field.
- Since ratoons show greater infestation levels than plant crop, avoiding ratoons in high intensity areas for two to three years would prevent rapid multiplication and perpetuation of the pest.

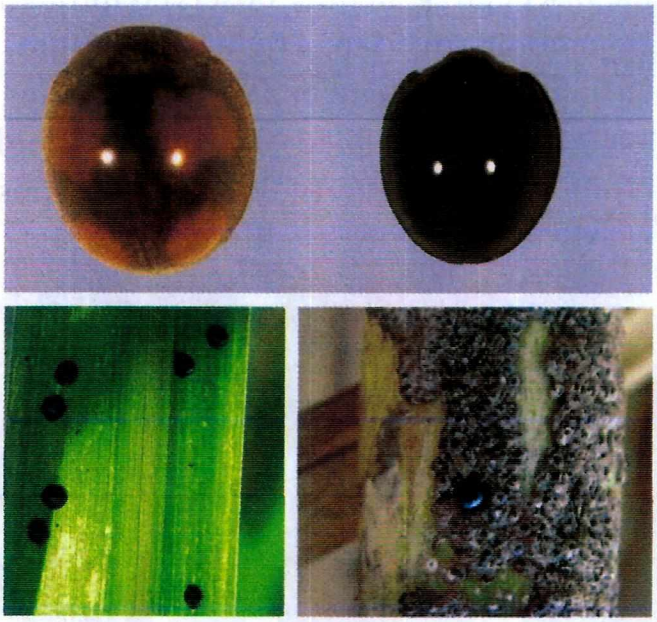


Fig. 59. Salce insect predators Pharoscymnus horni *(top left) and* Chilocorus *sp. (top right);* Chilocorus *congregation on leaf (bottom left) and a beetle feeding on scales (bottom right)*

- If ratooning is inevitable, stubble shaving should be carried out followed by stubble drenching with malathion or dimethoate or chlorpyriphos at 0.1% to prevent carryover of the pest.
- Application of malathion 50 EC at 0.1% or dimethoate 30 EC at 0.1% or acephate 75% SP at 0.15%; detrashing before spray application would enhance the effectiveness of insecticide.

4.2.2.2. Mealybug

Nature and extent of damage

The mealybugs derive their name from the whitish, powdery/filamentous mealy coating on their body. They are ubiquitous in all sugarcane growing tracts of the world but seldom assume major pest status. Of the six species of mealybugs that occur in India, adults of five species, including the common pink mealybug (Fig. 60), are soft bodied with well developed legs whereas the adults of *Antonina graminis* are enclosed in a hard, brown colored shell like structure and are apodous. The adult males are delicate, alate insects and are not observed as commonly as the relatively large and apterous females. Depending on the species, severe

Fig. 60. Pink mealybug females on node and internode (top left), and nymphs on node (top right); females on underground stem (bottom left), at the base of sprouted aerial bud (bottom middle) and tended by ants (bottom right)

infestation results in stunting of canes and yellowing of leaves. Loss of sap may even kill the young shoots or may result in a marked setback in cane growth, ultimately leading to the total drying of the crop. As a result of infestation, the stem gets covered with sticky honeydew which serves as a medium for the development of black sooty mould around the insect colonies. In severely infested canes, sucrose content decreases by 24.1% and brix by 16.2%.

Bioecology

Three species of mealybug are commonly encountered in the field and glasshouse. The pink mealybug *Saccharicoccus sacchari* is the most commonly occurring species throughout the sugarcane growing areas of the country (Fig. 60). Their infestation starts as discrete colonies just below the node on the side opposite the bud, later spreading to the internodes as well. Germinating aerial buds also harbor the mealybug. Colonies on the underground portion of the cane are not uncommon. The adult females are distinctly pink in color, with a round or dumb-bell shaped, clearly segmented body. The body of adult female is soft and legs are moderately long and not hairy. The black ant *Camponotus* sp. often attends the mealybug. The yellow mealybug *Kiritshenkella sacchari* (Fig. 61) commonly infests the nodal regions but it is also known to colonize leaf-sheaths, internodes, underground portions of stalk and roots

Fig. 61. Yellow mealybug colony on cane (left); adults on internode (top left) and inside of leaf sheath (top right); adult on inner leaf sheath (bottom)

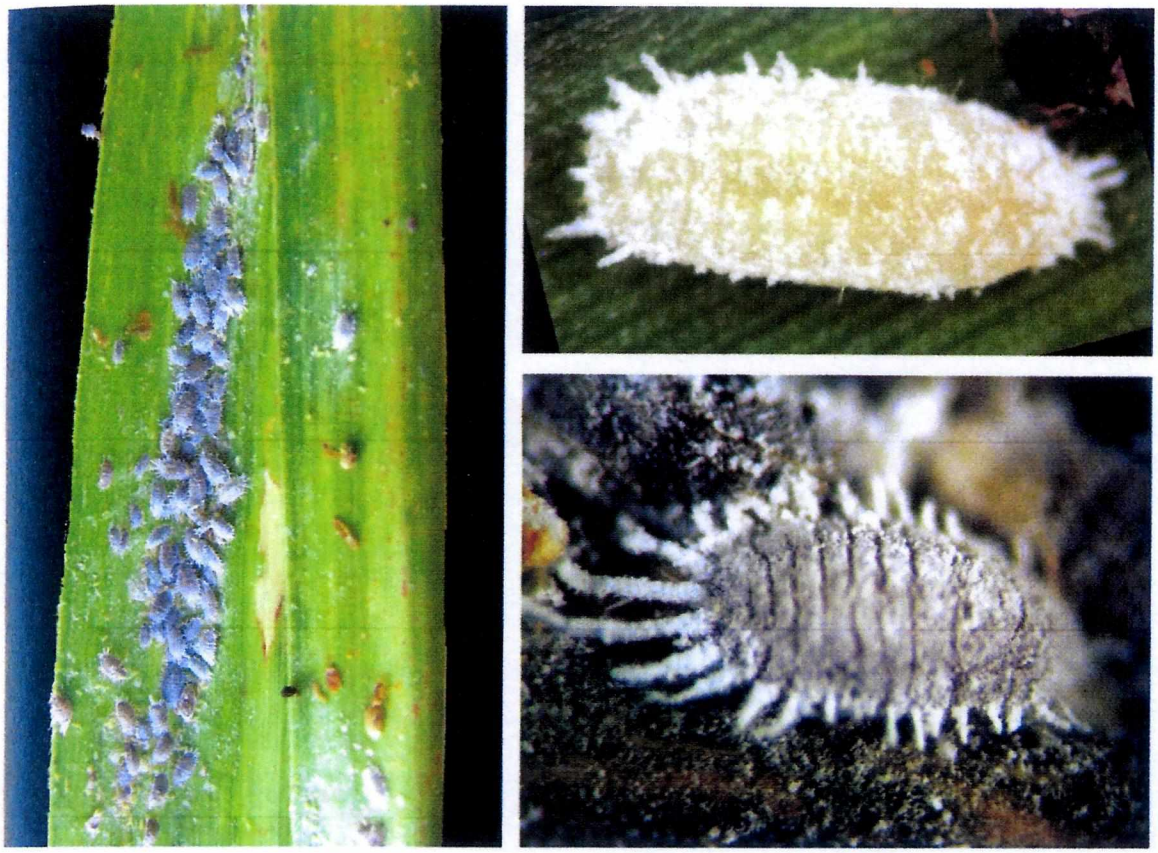


Fig. 62. Dysmicoccus carens *colony on leaf (left); nymph (top right) and adult female (bottom right)*

as well. Adult females are flattened and covered by a white mealy secretion. Gregarious in habit like the pink mealy bug, they are pale yellowish or light pink in color. *Dysmicoccus carens* generally infests the leaves in a severe form in potted plants under glasshouse conditions (Fig. 62). The adult females are elongate, oval and small sized (3mm long) with a waxy white secretion covering the body. There are short waxy filaments along the margins of the body. Legs are long and slender. Drought appears to be a major factor that influences mealybug populations. Rainfall dislodges populations and encourages entomopathogenic fungi. They are often found in large numbers on stunted canes. Varieties with loose clasping leaf sheaths harbor higher levels of mealybug populations than those with tight clasping leaf sheaths.

Management practices

- Planting uninfested setts with leaf sheaths removed reduces perpetuation of mealybugs to new areas as well as new plantings.
- In grownup crop showing considerable incidence of mealybugs, detrashing is essential to expose the colonies to abiotic (high temperature and sunlight) and biotic (natural enemies) stresses.

Detrashing is the single most effective practice that can easily disturb and dislodge fully developed females. This practice is incidentally useful against other sucking pests like scale insect which too grow under the shelter of leaf sheaths.

- Avoidance of overdose of nitrogen and repeated ratoons in areas prone to the pest should be ensured. Ratoons can act as the inoculum for the next season crop since the mealybugs can multiply in the underground portions of the plant.
- Management of water stress and general health of the crop is important to reduce mealybug incidence.
- In cases of severe infestation, insecticides such as acephate 75SP, dimethoate 30EC or malathion 50 EC at 2g or 2ml per lit should be sprayed after detrashing. Insecticide should be directed towards lower and freshly exposed internodes that harbor colonies.
- Indiscriminate use of insecticides should be avoided if activity of predators is observed in the field.

4.3. Subterranean pests

4.3.1. Termite

Nature and extent of damage

The mound forming *Odontotermes obesus* and the non-mound forming *Microtermes obesi* are important among the 13 species of termites known to attack sugarcane from germination until harvest. Termite infestation occurs soon after planting when germinating setts and young shoots are affected. Newly planted setts suffer the most serious damage as termites enter through their cut ends or through the buds and feed on soft tissues replacing them with soil. The infested stools or shoots dry up soon after germination and these can be pulled out easily (Fig. 63). Such shoots show no compensatory tillering. Occasionally 40-60% of the eye buds are destroyed leading to poor germination, gaps in the field and subsequent yield loss. In the ratoons, infestation occurs through the cut ends of the stubbles. In tillers, termites feed on the inner tissues of underground portion of the stem filling them with soil (Fig. 64). In millable canes, termites feed on the inner tissues leaving the rind intact and the cavity thus formed is filled with moist soil containing galleries. Severely affected canes show yellowing and drying of outer leaves first followed by the inner leaves. Heavily damaged canes collapse under their own weight

Fig. 63. Drying of young plant (left) and clumps (right) due to termite attack

unless wrapped and propped. About 2.5% loss in yield and 4.5% loss in sugar output have been reported due to termite attack.

Bioecology

Termites are social insects with well developed yet diverse colony structure characteristic of mound forming and non-mound forming or subterranean species (Fig. 65). The caste structure usually comprises one queen and one king, and numerous workers and soldiers. Colony establishment begins with swarming of winged reproductive adults after the first summer rains. Males and females mate during the nuptial flight, shed the wings and search for a suitable site for founding a colony. The first batch of eggs laid by the female hatches into workers which take care of expansion activities of the nest. Subsequently, soldiers are produced which protect the colony and foraging workers. Queen termite grows unusually large, up to 3-4 inches in length and about an inch in diameter, and becomes an egg-laying machine depositing thousands of eggs every day for several years. Workers forage for food and, hence, are responsible for crop damage almost round the year. Since workers cover long distances inside their protective earthen tubular walkways, colonies need to be located some distance away from the site of crop damage for mechanical destruction. Termite activity is observed in both loamy and heavy soils; areas of low rainfall or with poor irrigation potential are known to be more prone to its damage.

Fig. 64. Termite feeding and mud filling in setts (top row), lower internodes of young canes (middle row) and millable canes (bottom row)

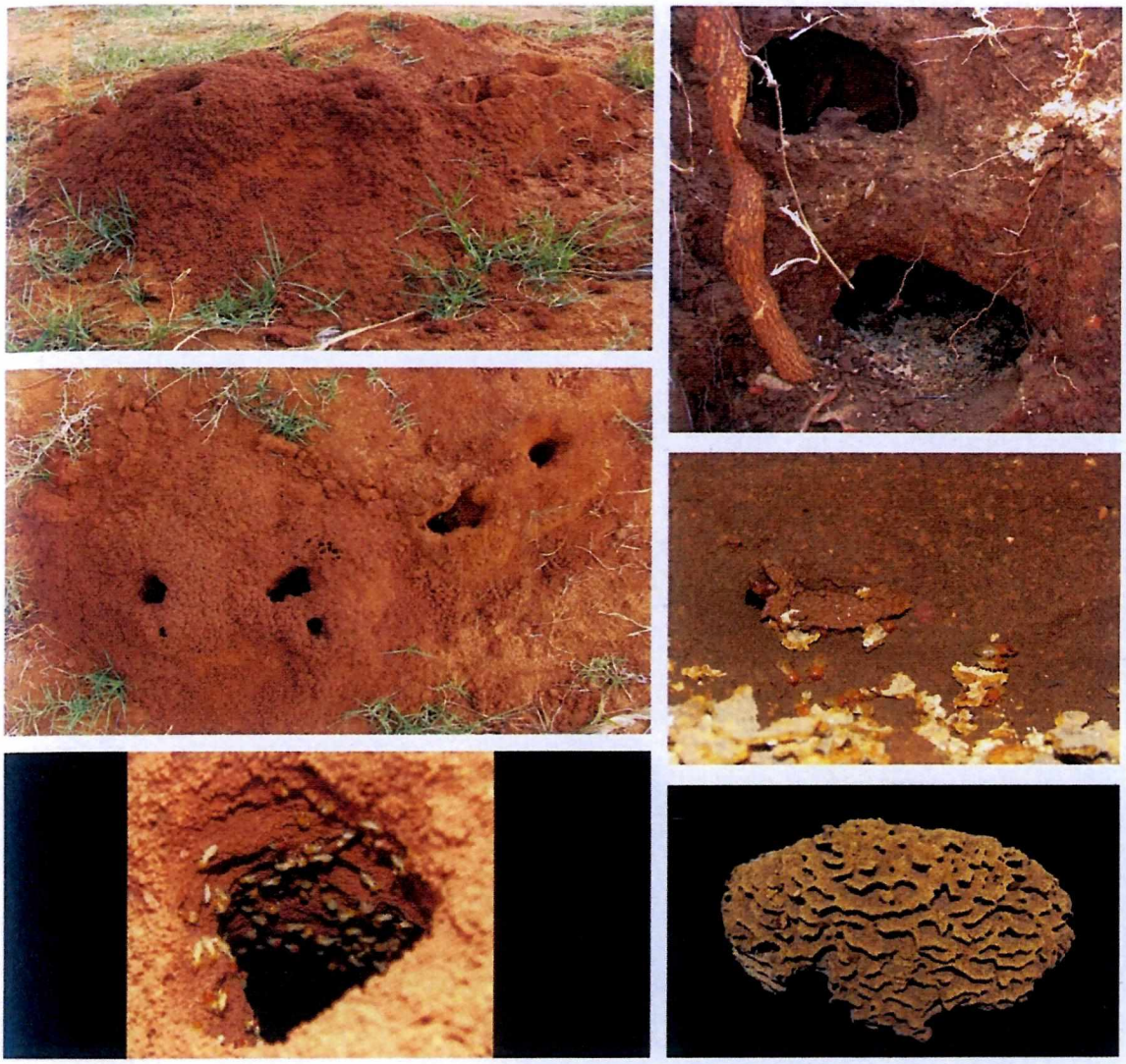


Fig. 65. Mound building termites (left): fresh mud plastering on mound (top), chimney openings (middle) and workers in chimney (bottom). Subterranean termites (right): chambers (top), workers sealing an opening (middle) and fungus comb (bottom)

Management practices

i. Mechanical and cultural measures

- Location and destruction of termite colonies in those species that build conspicuous mounds by breaking open the nest and removing the queen termite. Although secondary reproductives often replace the destroyed queen, the time delay ensures reduction in overall colony buildup.
- Ploughing or disturbing high field bunds would expose and destroy colonies of subterranean termites.
- Clearing and burning of crop residues and other debris in the crop ecosystem deprive the subterranean termites of food and reduce the activity of foraging workers.

Fig. 66. White grub damage to roots, setts and stem (top row); holes scooped on underground cane portion (bottom row)

recent past apparently due to expansion of sugarcane area, monoculture of the crop and minimal varietal diversity. Adults of *Holotrichia serrata* feed on foliage of host trees like neem (*Azadirachta indica*), *Ailanthus* sp., acacia (*Acacia arabica*), *Prosopis* sp., *Zyziphus* sp., etc. Young larvae feed on organic matter whereas late larval stages feed on main roots of sugarcane and subsequently damage the underground portions of stalks by scooping holes (Fig. 66). Following injury, spindle wilts and leaves turn yellow; such clumps gradually dry up and these can be easily pulled out. Affected canes collapse, dry up and become unfit for crushing or planting. Although the damage generally occurs in patches, often leaving gaps, in severe cases of attack the entire field may be devastated. In such fields, affected clumps often harbor 7-10 grownup grubs in the root region. Such severe symptoms of damage by older grubs generally

Fig. 67. White grub damage in sugarcane crop: late stage grub in root zone (top left); dried clump (bottom left) and canes in a row (right)

manifest only late in the season, i.e. September-October, resulting in complete loss of crop (Fig. 67) since curative chemical control is ineffective against late stage grubs. In subtropical India, *Holotrichia consanguinea* has a life cycle similar to that of *H. serrata* but shorter in duration. In subtropical *Heteronychus sublaevis*, adults damage the underground portion of stem during April-May while peak infestation is observed in August. The pest overwinters in adult and grub stages in earthen cells from October to February. Pupation occurs in March and adult emergence takes place in the following April. Adults feed on underground portion of stem leading to drying of plants in a week after which the beetles move to other shoots.

Bioecology

Beetles emerge at dusk after first rains during April-June and congregate on preferred host trees like neem and *Ailanthus* where they mate, feed on the leaves and return to soil before day-break (Fig. 68). Eggs are laid in the soil in sugarcane fields, fallow lands or grassy bunds along water channels. First instar grubs hatching after 10-12 days feed on roots of grasses or organic matter initially and switch to sugarcane roots. After a short one month period in each of the first two instars, third instar grubs feed voraciously on sugarcane roots for three to four months. Pupation takes place in earthen cells from September and the adults emerging in

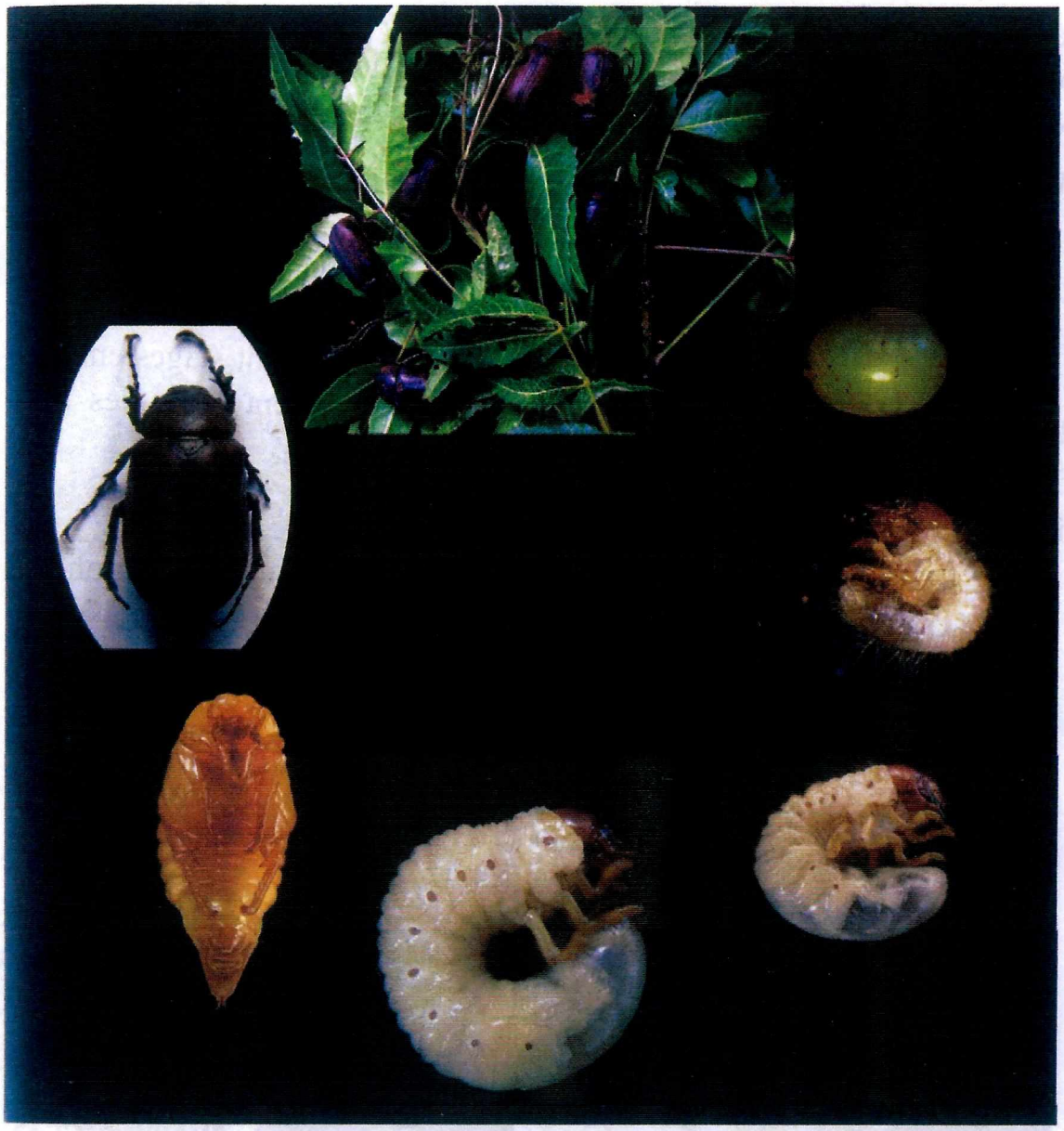


Fig. 68. Life cycle of Holotrichia serrata *(clock-wise from top): adult congregations on neem branches, egg, three larval instars, pupa and adult*

10-14 days remain in the soil until early summer showers in the following year stimulate them to emerge out of the soil. *Holotrichia serrata* thrives in moist sandy soil as well as black cotton and clayey soils. Grubs can withstand drought conditions by remaining dormant inside earthen cells for over three months in different instars. High moisture is detrimental to the grub and heavy rains and waterlogged conditions force the grubs to come to soil surface. Although deforestation is considered responsible for its extensive spread, factors such as monocultures, reliance on a single variety like Co 86032, prevalence of adult host trees and dispersal ability of adults probably contributed to its spread from hills to plains in some sugarcane tracts of Tamil Nadu. Continuous planting of crop almost throughout the year to meet the requirements of sugar industry and

jaggery production not only ensures availability of crop of all ages to the pest but also subjects young crop to increased damage probability often leading to 80-100% yield losses in severe cases of attack.

Management practices

Insidious damage, late appearance of symptoms and tolerance of the most damaging third instar larvae to insecticides minimize reliance on prophylactic or curative chemical control. However, the annual life cycle of the pest with specific activity period for the different stages enables planning and implementation of various management strategies in a sequential manner.

i. Mechanical control

- Large scale mechanical collection of beetles congregating on the most preferred neem trees during mass emergence (Fig. 69), starting from the night of first showers and continued for a week, reduces beetle population in the habitat progressively over a few years. Since

Fig. 69. Mechanical collection of beetles: congregations on neem (top left); dislodging with hooked pole (top right); collection from the ground (bottom left); hand picking from branches (bottom right)

the beetles are not actively attracted to light, branches with congregations should be shaken vigorously with a hooked pole to dislodge the beetles which would then be attracted to light sources such as jeep or tractor head lamps. Alternatively, kerosene vapor (Petromax) lamps may be placed near the trees to attract the dislodged beetles. The beetles that hit the light source and drop down should be collected in double layered synthetic cement or fertilizer bags and secured tightly after treating with dichlorvos to kill them; alternatively, the beetles may also be killed by drowning them in drums filled with soap water.

- The collection of beetles should be continued for a week particularly on beetle-intense trees that attract them in hundreds. There is a need to identify such preferred trees every season and commence collection early in the night before the beetles settle on the foliage.
- Mechanical collection yields better results when carried out on a community basis with the active participation of both sugarcane and non-sugarcane farmers. Incentives may be offered for the beetles collected to promote the method. The campaign may require monitoring summer showers, gradation of trees on the basis of relative spatial and temporal attraction to beetles, formation of collection groups and procurement of collection kits.
- Mechanical collection can be extended to easily detectable third instar grubs in infested fields that show the first symptoms of yellowing or drying of clumps late in the season.

ii. Cultural control

- Repeated deep ploughing at land preparation in February, i.e. well before summer showers, particularly in farms with neem trees nearby or fields around beetle-intense trees, exposes quiescent adults to desiccation and vertebrate predation.
- Ploughing and flooding for 24-48 h of similar fields in February, when planting is taken up during the pest activity period (June-September), would be useful in minimizing grub populations of different stages.
- Puddling and rotation with paddy can have a similar longer-lasting negative effect on grub populations. Rotation with the non-preferred sunflower is also advisable to break the continuous availability of sugarcane.

iii. Biological control

- The white muscardine fungus *Beauveria brongniartii* (Fig. 70) formulated with carrier materials such as press mud, lignite or talc may be applied at 2.5 x 10^{12} spores / ha during June July coinciding with emergence and oviposition activity of beetles to target young grubs. The formulation may be mixed with suitable quantity of farm yard manure or well cured press mud and distributed in the furrows followed by irrigation. Repeated application for 4-5 years may be needed to build up inoculum of the fungus in the soil to enable it to act as a self-perpetuating mortality factor. Pesticides commonly used in sugarcane adversely affect the fungi in culture media but they are less likely to be as toxic in the field. Asynchronous application would prevent such incompatibility problems.

Fig. 70. White muscardine caused by Beauveria brongniartii *in white grub: healthy grub (left), infected grub with pink discoloration (middle) and grub with sporulated fungus (right)*

iv. Chemical control

- Small neem trees may be sprayed with carbaryl or chlorpyriphos immediately after the first summer rain to kill the adult beetles which congregate on these trees for feeding. Alternatively, big branches of the neem trees sprayed with the insecticides may be planted in the fields to attract and kill the adult beetles.
- When planting is taken up during May-June in endemic areas with a recorded history of white grub occurrence, 50 kg of 2% methyl parathion dust mixed with farmyard manure or press mud may be ploughed into the soil to target first instar grubs. In early planted crop, the same insecticides may be mixed with 100 kg of farmyard manure or press mud and applied in the furrows during June-July to attract and kill the first instar grubs.

- Since targeting third stage grubs in standing cane decreases the success of chemical control and renders it uneconomical, it is important to monitor the crop from June onwards for detecting early symptoms of leaf yellowing or young grubs near the root zone for deciding on the adoption of chemical control. Application of quinalphos 5G at 2.5 kg a.i./ha (50 kg formulation/ha) may offer some protection. New insecticides such as chlothianidin 50% WDG @0.05 kg a.i./ha are showing promise against subtropical white grubs.

4.4. Non-insect pests

4.4.1. Rat

Nature and extent of damage

The predominant rat species that inflict damage to sugarcane are *Bandicota bengalensis*, *Rattus meltada*, *Tatera indica* and *Mus musculus*. They begin to damage the canes around 90 days after planting and the damage increases with the age of the crop. Their activity in the field is indicated by the presence of burrows with mounds of dug out loose granular soil (Fig. 71). Damage is mainly caused due to gnawing of the rind in the lower internodes of canes and disturbance to the roots during digging of burrows, particularly by the highly fossorial *Bandicota bengalensis*. As a result of gnawing of roots and loosening of soil during burrowing, canes may lodge when irrigated or due to wind if not properly wrapped and propped. Lodged canes and ratoon crops are generally known to suffer greater damage. Rats have been known to partially damage 8.6% - 12.1% canes with most of the damage restricted to lower internodes. These canes weigh about 31.5% less than healthy canes and also contain about 24.5% less sugar content.

Bioecology

Cane fields harbor higher rat populations compared to other crops because they provide an undisturbed habitat for their burrowing, feeding and breeding activities, a protective cover from avian predators and an abundant amount of high energy food for most of the year. In addition to the resident population of rats, frequent waves of immigration from surrounding fields caused by disturbance due to ploughing, harvesting and flooding with irrigation or rainfall often enhance rodent population in cane fields.

Fig. 71. Rodent damage in sugarcane: Bandicota bengalensis *and burrow openings in bunds (top row); burrow near a young clump and standing cane (middle row); clump drying and gnawing of lower internodes (bottom row) (*Bandicota *Photo Courtesy: B. Singaravelu)*

Management practices

The available management options can be grouped into two basic approaches: 'non-lethal or preventative' and 'lethal or reductional'. The non-lethal or preventative measures involve environmental, cultural and biological methods, which produce a gradual and more lasting effect. The cost- and labor-intensive lethal approach, particularly the use of rodenticides and trapping, provides solution to the problem in the event of an outbreak.

i. Environmental and cultural methods

- Manual or mechanical removal of wild vegetation or weeds on crop field boundaries discourages establishment of rats in the habitat by denying suitable breeding grounds/habitat and alternative food.
- Reduction in bund thickness and height discourages bandicoot rats since they prefer tall thick bunds and earthen embankments of water channels for burrowing.
- Deep tillage and ploughing of vacant land around fields destroy rat burrows.
- Rotation of paddy with crops like sunflower may break the food cycle and reduce immigration to sugarcane which is frequently subjected to waves of rodent immigration related to agricultural operations in paddy
- Adoption of wrapping and propping of the standing crop, judicious irrigation and use of non-lodging varieties indirectly help to prevent rat damage. Varieties with a thick barrel, hard rind, high fiber and non-lodging habit reduce damage.

ii. Mechanical methods

- Bandicoot rats can be driven out of burrows by ploughing the fields during the period between crops, flooding of burrows with irrigation water or smoking the burrows by burning cow dung cake or paddy straw.
- Trapping rats in fields and premises involves the use of two basic types of traps, namely the snap or kill trap and the live trap. Tanjore bow trap, wooden snap trap, arrow trap and break-back spring loaded snap trap with wooden or jawed iron base can be used for killing rats. Pitfall or pot trap, foldable iron sheet boxes with a spring loaded shutter and wonder traps of different sizes and shapes can be used for live trapping.

iii. Chemical methods

- The effectiveness of rodenticides depends upon the selection of an appropriate compound, its formulation, and the method and timing of application. Closing or smoking the burrows a day before treatment helps to locate the active burrows in the field.
- The acute rodenticide zinc phosphide is used as a single-dose poison. A cereal bait mixture of broken wheat grain, sugar powder and groundnut oil (96:2:2) consisting of 2% zinc phosphide is recommended. To prevent bait aversion, pre-baiting live burrows without zinc phosphide should be practiced for two days. Bait aversion can also be reduced by changing the cereal base and its texture, and leaving sufficient time gap between two consecutive treatments. On the third day, 10 grams of the zinc phosphide bait is placed in the live burrows for controlling the pest. Baiting should be continued for two to three days for effective control.
- Fumigation of burrows with aluminium phosphide targeted against resident populations is generally effective in damp soils and its use needs care. A single tablet is dropped into each active burrow, a small quantity of water is added, especially if the soil is dry, and the burrow sealed with wet mud. Toxicity hazards, cost of application and low efficacy against species like *B. bengalensis* limit its use.
- The chronic anticoagulant warfarin 0.025% is less toxic to non-target organisms but needs prolonged baiting. The second generation single dose anticoagulant bromadiolone 0.005% bait is less toxic to non-target species and simple to use. The bait cakes can be placed near or inside the active burrows and treatment should be continued until results are apparent. Bromadiolone baits would be more suitable than aluminium phosphide for the control of immigrant populations. Deployment of a sequential combination of aluminium phosphide tablets and bromadiolone cakes is desirable.

iv. Biological control

- Although several vertebrates predate on rats, it is neither advisable nor practicable to deploy them by augmentative methods. Since barn owls are known to be good predators of rats, it is possible to encourage them by placing suitable perches at the canopy height in the field.

4.4.2. Mite

Mites are distinguished from insects by the sac like body divided into two regions, absence of antennae and presence of four pairs of legs in the adults. Mites are generally considered to be minor pests, though occasionally they explode to very high populations in large areas. Yellow mite *Oligonychus sacchari* and the blister or sheath mite *Aceria sacchari* are the common species of sugarcane mites that occasionally reach pest status.

Nature and extent of damage

In *Oligonychus sacchari*, colonies or webs are formed on the underside of leaves in 6-8 rows, more or less parallel to the midrib (Fig. 72). The mite scrapes the epidermis and sucks the sap remaining inside the web producing white mottled patches which can be seen on the upper surface of the leaves. The webs are thin and semitransparent in the beginning and become whitish and opaque subsequently. The webs are uniform in size (2 mm long), oval in shape and number 50-100 per leaf normally but can reach 1300-1500. The webs do not coalesce but the leaves dry up later. Webs are blown off the surface leaving behind only whitish patches.

Aceria sacchari feeds on the inner side of the leaf-sheath forming a circular erineum, i.e. gall with a shallow depression in the center (Fig. 73). The 9-12 mm dia. blister is light green at first but slowly turns rusty red due to laceration of the tissues which get hardened afterwards.

Fig. 72. Yellow mite infested plants (left); yellow specks on dorsal side of leaf (middle); colonies in parallel rows on ventral side of leaf (right)

Fig. 73. Erinea of Aceria sacchari *on infested leaf sheath (top left); outside and inside view of fresh erineum (top right); old erinea on outer side (bottom left); corky old erinea on inner side (bottom right)*

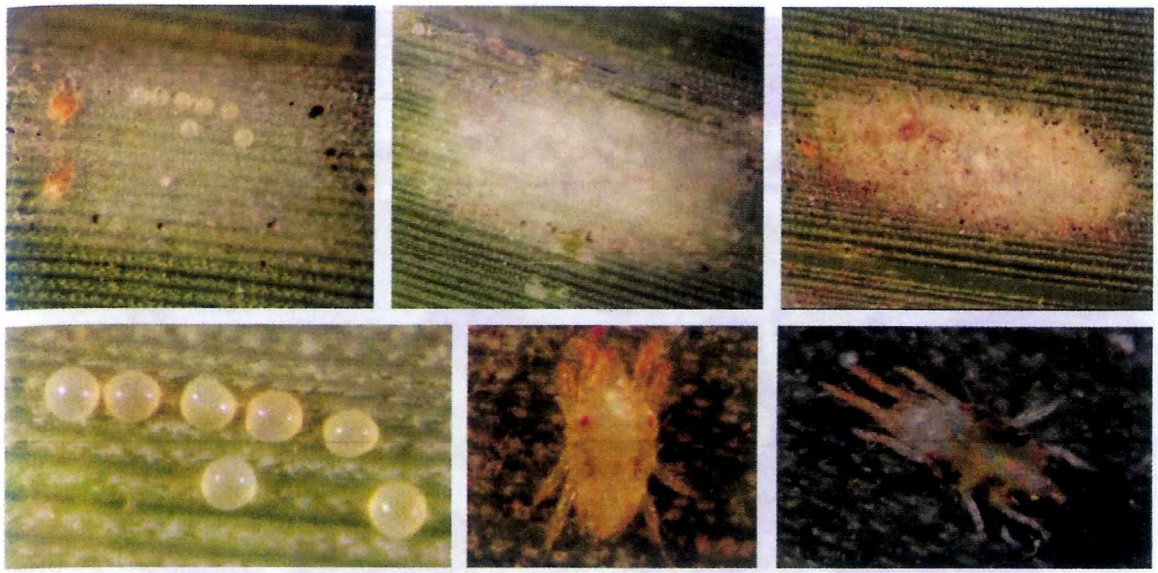


Fig. 74. Stages of Oligonychus sacchari*: transparent, translucent and opaque webs with eggs and/or immature stages inside (top left to right); eggs inside the web and nymphal stages (bottom left to right)*

In later stages, the outer side of the leaf-sheath exhibits swollen scars. The epidermal cells in the outer layer of the inner side of the leaf-sheath become largely flattened and destroyed.

Bioecology

Eggs of *Oligonychus sacchari* are laid singly or in short rows inside the webs with each web containing 6-15 eggs (Fig. 74). Nymphs remain within the web for sometime but later move out and spin new webs and moult therein. The egg and nymphal durations range 3-5 and 8-11 days, respectively at 26.3 - 28.7^{0}C. *Oligonychus sacchari* is generally observed throughout the year in the tropics though greater activity is common during December-April. Moderate temperature and moderate to high relative humidity favor the pest. In subtropical India, it is more active from mid-June to end of October; low temperatures of winter are unfavorable.

The life cycle of *Aceria sacchari* is completed in 15 days at 21.8-28.9^{0}C. The transparent eggs are deposited singly or in small clusters of 5-7 in the spongy tissues on the infer surface of the leaf-sheath. The adult female is slender, elongate, minute, creamy white in color and worm-like with annulated abdomen (Fig. 75). Males are not found in natural populations. The mite is active during June-September in the subtropical states of Punjab and Uttar Pradesh. Moderate temperatures and moderate to high relative humidity favor the buildup of the mite. Ratoon crop is sometimes more seriously affected than plant crop.

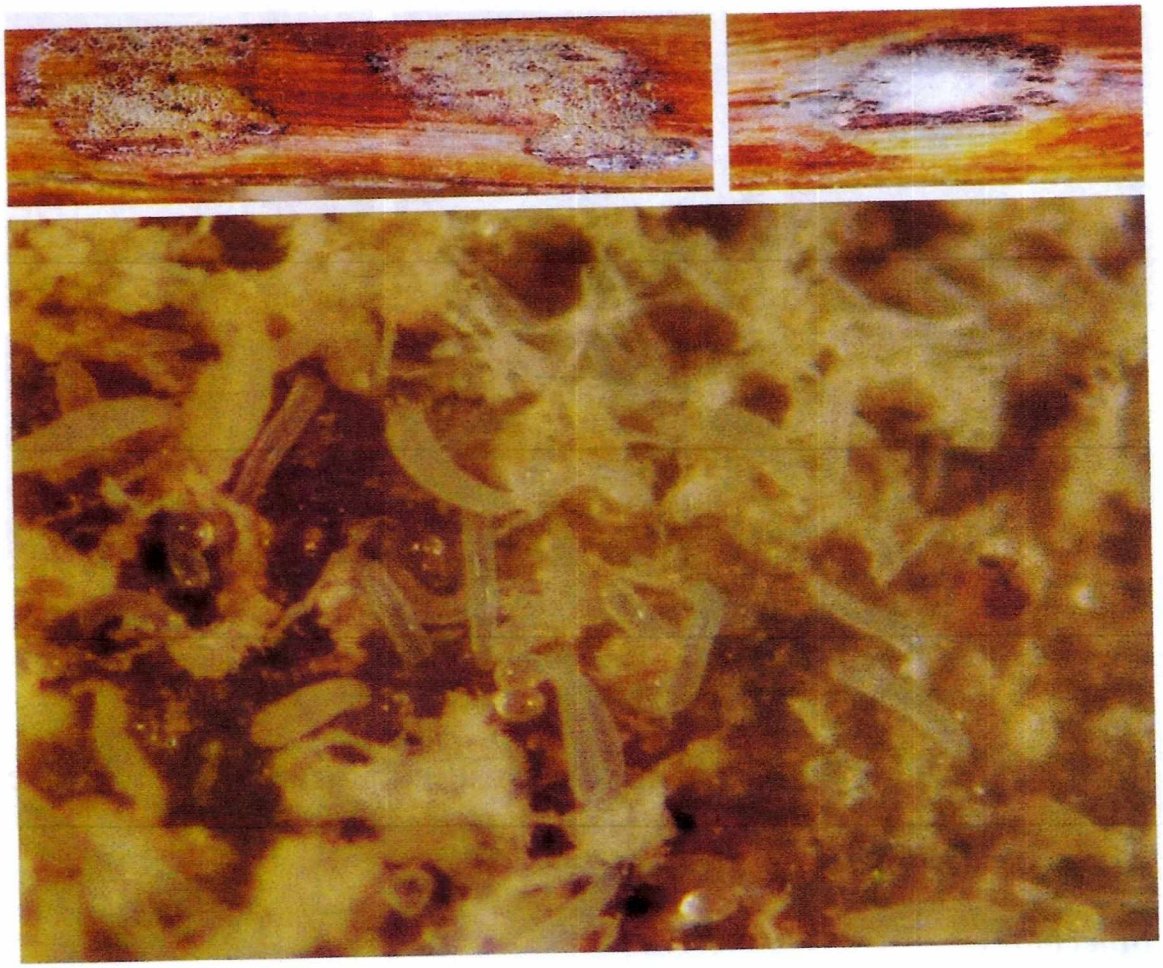


Fig. 75. Aceria sacchari *erinea on inner side of leaf sheath (top) and worm-like females in the erineum (bottom)*

Management practices

- Removal of wild relatives of sugarcane such as *Saccharum spontaneum* and monocot weeds which serve as alternative hosts to prevent proliferation and spread of *Oligonychus sacchari*.
- Removal and destruction of infested leaves in early stages prevents further buildup.
- The pest is known to occur sporadically in certain pockets of sugarcane. However, in case of regular occurrence, monitoring and early detection of attack can be followed with spot application of malathion, dimethoate, quinalphos or dicofol at 0.05% as foliar spray. The spray application may have to be repeated after 20 days to kill the nymphs emerging from the eggs as the insecticides do not have ovicidal action. As old colonies or webs are not destroyed by sprays, acaricidal efficacy should be assessed based on the mortality of mites in the existing colonies or absence of new colonies on hitherto uninfested leaves.

5. Summary

Sugarcane represents a stable crop system, particularly in tropical India where climatic conditions are less extreme than in the subtropical region. The mild climate of the tropics facilitates temporal and spatial continuity of the crop, pest proliferation and natural enemy survival leading to a balance or equilibrium between pests and natural enemies. Several native pests maintain themselves well below the damaging levels and occasionally reach economic injury levels. Invasive pests occasionally cause epidemics, apparently aided by human intervention. The key to management of pests lies in restoring the status quo by not resorting to the insecticide umbrella that is characteristic of crops like cotton. In the subtropics, pests tend to exploit the limited post-winter period after emerging from diapause and thus display greater severity. Successful management of these pests requires regular monitoring and early implementation of a variety of tactics in isolation or combination as outlined in the previous section under individual pests.

Native pests often reach injury levels when a single or a small number of popular varieties is cultivated for a prolonged period. Since varieties are rarely evolved for insect pest resistance, popular varieties, even if incidentally tolerant to some pests at the time of release, become susceptible to field populations in course of time. Pests often change behavior or expand geographical range under mono-variety regimes. It is advisable to adopt a multiple-variety regime in space and time for a short period to allow the pest populations to stabilize. Routine cultural practices such as earthing-up minimize activity of certain pests. However, cultural practices like detrashing, trash-mulching and wrapping/propping may be constrained by labor shortage. Irrigation management can be an effective tactic to manage early shoot borer or termites. These practices, including the use of pest-free sett material, can be integrated into crop management wherever feasible to give the associated advantages of pest control.

The seemingly impracticable or uneconomical mechanical control has long-term advantages if practiced on a community scale. Collection and destruction of quiescent or hidden stages of pests in the soil or crop residues over successive generations would reduce pest populations in a given habitat. Any aerial or subterranean pest stage that generally occurs in congregations is the best target for such approach. White grub pupae or adults in the soil, adult beetle congregations on foliage of neem or other host trees, queens from mound-building termites, detectable egg masses

of top borer and pyrilla, early-stage larval aggregations of Gurdaspur and Plassey borers, leaves infested by sucking pests like woolly aphid in the very early stages, etc. are some examples.

A stable crop system like sugarcane with minimal insecticide usage is amenable to both natural and applied biological control. Several parasitoids, predators and pathogens acting as natural biocontrol agents cause considerable levels of pest mortality. The pyrilla parasitoid *Epiricania melanoleuca* and woolly aphid parasitoid *Encarsia flavoscutellum* are outstanding examples of natural biological control for a native and invasive pest, respectively. In applied biological control, the egg parasitoid *Trichogramma chilonis* has been historically the most widely used parasitoid against several borers. Simple production technology adopted by small entrepreneurs, besides the sugar industry, to specifically cater to sugarcane farmers led to its easy availability. Of late, there have been attempts to mass multiply more difficult-to-rear parasitoids such as *Sturmiopsis inferens* and *Cotesia flavipes* by selected sugar factories to combat borers. Entomopathogenic fungi like *Beauveria brongniartii* are being mass multiplied and used for long-term white grub control. Yet another biological product used for the control of borers is sex pheromone lures to trap moths with an intent to reduce populations over space and time. Enhancement of crop diversity in the form of intercropping not only reduces pest abundance but also increases natural enemy activity thereby indirectly effecting natural biological control.

Chemical control, the last weapon in the arsenal of sugarcane growers, is usually possible in the first half of the crop cycle. Under the limitations of the hostile canopy, it can best be used in combination with biological control. Insecticides can be used to bring down rapidly multiplying populations of sucking pests to be followed by the establishment of applied biological control agents. Selective use through spot application minimizes pesticide load and conserves biological control agents. Adoption of wide row spacing, detrashing, and wrapping and propping facilitates insecticidal application even in the second half of the crop cycle. Overall, integrated use of available control tools with short- and long-term planning in a situation-specific manner ensures management of pest populations below damage levels in the second most important commercial crop of the country. In this context, sugar industry can play a greater role by promoting biological control through establishment of mass multiplication units and production of sex pheromones on a large scale to bring about environment-friendly pest management in sugarcane.

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7. Keys for symptom-based identification of major pests

The following keys based on symptoms of damage serve as a quick field guide to identify the causative major sugarcane pests in the shoot and cane stages of the crop. The details of each pest and the management practices to be followed, elaborated in the preceding sections, are given as page reference. The details are also summarized in a tabular form in the succeeding pages.

I. Shoot stage:

Key No.	Symptoms	Go to Key No.
1	Deadheart formed of central shoot which shows wilting or drying symptoms	2
-	Deadheart absent, whole plant shows yellowing or drying symptoms	5
2	Deadhearts can be pulled out easily	3
-	Deadhearts can not be pulled out easily	4
3	Several feeding punctures near the base of shoot; inner part of deadheart emits offensive odour due to rotting	Early shoot borer (Page 5)
-	Biting holes and several larvae in the leaf-sheath which rots and leaf dries; leaves show longitudinal orange yellow streaks	Stalk borer (Page 21)
4	Atrophied deadheart accompanied by midrib mining and parallel rows of shot holes on the emerging leaves	Top borer (Page 16)
-	One or two open leaves dry along with deadheart that gives no foul odor; a single fine hole at the base of shoot	Root borer (Page 23)
5	Entire shoot dries up and can be pulled out easily; setts hollow inside and generally filled with soil; termites present if attack is fresh; attack any time of the year	Termite (Page 54)
-	Yellowing and drying of shoots which can be pulled easily and roots eaten away; late stage grubs present; attack and symptoms only during August-September	White grub (Page 58)

II. Cane stage:

Key No.	Symptoms	Go to Key No.
1	Plants lose anchorage; foliage showing yellowing or drying; cane with no symptoms or pest stages	2
-	Plants do not lose anchorage despite foliage showing yellowing or drying symptoms; cane shows stunted growth	4
2	Soil examination may reveal pest stages besides typical damage symptoms	3
-	Soil examination reveals heaps of soil at the base of clump but no pest stages; basal and a few upper internodes chewed; canes often lodge	Rat (Page 65)
3	Canes collapse if disturbed; below and above ground internodes filled with moist soil inside papery rind; active stages present if attack is fresh and attack anytime of the year	Termite (Page 54)
-	Crown can be pulled easily; roots eaten away and holes scooped in underground stem; larval stages present in soil and damage during August-September	White grub (Page 58)
4	Canes show fully or partly formed deadhearts of central shoot	5
-	Canes do not show deadhearts	6
5	Crown with completely dried atrophied deadheart often blown off leaving only a stump; midrib mines and shot holes on leaves; typical bunchy-top due to sprouting of lateral buds	Top borer (Page 16)
-	Central shoot shows full-fledged deadheart; top internode shows bore hole filled with fresh or dry frass; bunchy-top due to axial bud germination	Internode borer (Page 10)
6	Bore holes in above-ground internodes either visible or concealed by leaf sheaths	7
-	No bore holes on the above-ground internodes	10

II. Cane stage (Cont'd)

Key No.	Symptoms	Go to Key No.
7	Solitary, rarely gregarious in the later stage, attack by all stages of larvae	8
-	Gregarious feeding by young larvae and solitary feeding by grown-up larvae	9
8	Bore holes on internodes visible when leaf sheaths are removed; tunnels in internodes with more than one larva; bore holes at three levels indicate broods	Stalk borer (Page 21)
-	Bore hole with fresh frass visible in the top internodes; usually one larva in internode or cane; short and thin internodes with bore holes indicating old attack	Internode borer (Page 10)
9	Dark spiral of minute puncture holes on the rind made by gregarious (35 nos.) young larvae; leaves dry up; side shoots are formed	Gurdaspur borer (Page 26)
-	Fresh red frass projects out of bore holes of gregarious (150 nos.) young larvae; top leaves dry up; affected internodes break-off; sett roots cover internode	Plassey borer (Page 28)
10	Leaves with no insect colonies on either surface	11
-	Leaves with distinctly visible insect colonies mostly on the undersurface	16
11	No insects in leaf whorls or under the sheathing bases of leaves	12
-	Insect congregations in leaf whorls and under the sheathing bases of leaves; leaves with brown patches or feeding punctures	Black bug (Page 46)
12	Symptoms of damage or insect stages present on the cane, nodal region or leaf sheath	13
-	No stages on above-ground parts despite yellowing of leaves; bore holes on underground stem and feeding tunnel and larva inside	Root borer (Page 23)

II. Cane stage (Cont'd)

Key No.	Symptoms	Go to Key No.
13	No visible symptoms of damage on leaf sheaths	14
-	Circular galls or blisters appear on the outside of leaf sheath as swollen scars which harden as leaf matures	Blister mite (Page 69)
14	No encrustation on internodes; soft insect stages on the nodes or inside the leaf sheath	15
-	Encrustation of small gregarious papery scale like insects on internodes; shriveled canes in late stages	Scale insect (Page 48)
15	Pink round or dumb-bell shaped soft insects with small young ones on nodes; internodes, aerial buds and roots also harbor stages; black ants often attend them	Pink mealybug (Page 51)
-	Soft yellow round and slightly flattened insects covered by mealy secretion on nodes, leaf-sheaths, internodes, underground stalk and roots	Yellow mealybug (Page 51)
16	Sooty mould growth mostly on upper surface of leaves	17
-	No sooty mould growth on leaves; numerous small white colonies in linear parallel rows running from the base to the tip of leaf	Yellow mite (Page 69)
17	Leaves with apparently static insect stages which do not move upon mild shaking of leaves	18
-	Agile insects that move actively or jump off the leaves when approached or leaves are disturbed; immature insects with two long posterior filaments	Pyrilla (Page 30)
18	Hundreds of closely packed white wax covered mobile insects generally in contiguous colonies; white patchy appearance of crop from a distance	Woolly aphid (Page 34)
-	Dense but loosely placed black or wax covered grey static insects spread all over the leaf; often pink discoloration of heavily infested leaves	Whitefly (Page 42)

8. Ready reckoner of pests, symptoms and management

Pest	Distribution	Symptoms	Management
I. Borers			
Early shoot borer	Widely distributed in all sugarcane growing areas of the country.	A pest of early crop stage with peak activity during March-June. Larva enters the plant from the base and bores downwards or upwards killing the growing point. The deadheart thus formed can be pulled out easily and it emits an offensive odor. Infestation during germination phase kills the mother shoots resulting in drying up of the entire clump creating gaps in the field. In later stages, tillers, but not clumps, suffer mortality.	Early planting, earthing-up, trash-mulching, frequent irrigations, intercropping with region-specific crops, use of sex pheromone traps and drenching application of chlorpyriphos.
Internode borer	A major pest in peninsular India with distribution in Tamil Nadu,Andhra Pradesh, Karnataka,Maharashtra, Bihar, Uttar Pradesh and Haryana.	The activity of the borer begins with internode formation and continues until harvest. Larval feeding on the meristem causes deadheart and bunchy-top. Larva tunneling in the formative internodes pushes out frass which can be seen as a wet or dry mass hanging from the bore hole. The damaged internode becomes short, thin and hard reducing yield and quality.	Detrashing at fifth and seventh months, removal of water shoots at eighth or ninth month, intercropping with pulses and spices, setting up sex pheromone traps and release of parasitoids.

Pest	Distribution	Symptoms	Management
I. Borers			
Top borer	Top borer occurs as a major and regular pest in the subtropical region but as a minor and occasional pest in the tropics.	In the early crop stage, top borer produces leaf mines and shot holes on opened leaf, atrophied central shoot and stunting of cane. The deadheart can not be pulled out easily. In tillering phase, central shoots die leading to the formation of side tillers. In grownup canes, deadheart formation induces bunchy top. Occasionally, aerial roots are produced.	Autumn planting, intercropping with spices, setting up of sex pheromone traps @ 50 numbers/ha for the first two broods, hand collection and destruction of egg masses in the field in each brood, carbofuran 3G at 1 kg a.i./ha or phorate 10G at 3 kg a.i./ha aplication in the root zone against third brood.
Stalk borer	The borer is a major pest in Uttar Pradesh, Haryana, Punjab and Bihar.	Newly hatched larvae feed by scraping the inner surface of top leaf sheaths leading to their decay and drying of leaves. Leaves show distinct longitudinal orange yellow streaks from tip to base. Third instar larva bores into the shoot producing deadheart in the early crop stage. Bore holes made by grown-up larvae will become visible on the internodes when the leaf sheaths are removed. An infested cane may harbor 3-15 larvae at a time.	Detrashing autumn planted crop during September-October, and removal of water and late shoots at 15 days intervals during winter; release of the egg parasitoid *Trichogramma chilonis* and the larval parasitoids *Sturmiopsis inferens* and *Cotesia flavipes*.

Pest	Distribution	Symptoms	Management
I. Borers			
Root borer	A serious pest in the subtropical sugarcane belt, root borer entered parts of tropical India about two decades back but subsided five years later.	Root borer attacks the underground stalk portion of cane causing deadhearts in the early stages (May-June) which cannot be pulled out easily. Often one or two leaves adjacent to the central whorl also dry-up. Larval attack in grown-up canes causes yellowing of leaves. The first brood affects tiller production whereas second to fourth broods reduce cane length and weight leading to yield loss and sucrose reduction.	Destruction of affected shoots with borer larvae, deep harvesting of canes that are to be ratooned, digging and destroying stubbles after harvest, avoidance of ratoons in endemic areas, incorporation of green gram intercrop in spring/summer planted sugarcane, and collection and destruction of moths using light traps.
Gurdaspur borer	An important pest of sugarcane in Punjab, Haryana and western U.P., it is also reported from Sriganganagar in Rajasthan and some parts of Himachal Pradesh.	Newly hatched larvae enter the cane gregariously and feed in galleries in a spiral manner making minute punctures on the rind from within which externally appear as a dark spiral. Third instar larvae disperse to other canes and feed on internodes individually. Leaves wither due to larval feeding below the rind and the whorl of leaves turns yellow and dries up. Canes fail to grow, damaged internodes become weak, infested stalks break off and side shoots are formed.	Removal and destruction of affected canes with five to six top internodes harboring borer larvae in gregarious phase on a campaign basis during July-September. Stubbles harboring hibernating larvae should be uprooted and burnt to kill the larvae. Ratooning of heavily infested crop should be avoided.

Pest	Distribution	Symptoms	Management
I. Borers			
Plassey borer	It is an important pest of sugarcane in some parts of West Bengal, Bihar and Assam.	Gregarious feeding by newly hatched larvae in the top three to five internodes results in fresh red colored frass projecting out of the bore holes and the top leaves of the canes ultimately dry up. Affected internodes break off easily and nodes adjacent to the infested internode produce sett roots and bud sprouting. The grownup larvae disperse and feed by tunneling the internodes. One larva may bore into one to five internodes but cane tops do not dry up.	Collection of moths in light traps, collection and destruction of egg masses and cane tops showing gregarious primary infestation, mass multiplication and release of the predominant parasitoid *Cotesia flavipes*.
II. Sucking pests			
Pyrilla	Pyrilla is a serious pest of sugarcane in many parts of the country, sometimes at epidemic levels especially in the subtropics.	Large congregations of adults and nymphs suck sap from leaves and excrete honeydew on foliage leading to sooty mould development. Such direct and indirect damage affects sugar yield and quality. Puffy egg masses are seen on both surfaces of leaves and in dry leaf sheaths. Under heavy infestation, numerous cocoons of the ectoparasitoid *Epiricania melanoleuca* are seen on the leaf surface.	Removal of cane trash after harvest, detrashing, and removal and destruction of egg masses or egg-bearing leaves reduce pyrilla numbers. Redistribution of field populations and laboratory multiplication and release of *Epiricania melanoleuca*.

Pest	Distribution	Symptoms	Management
II. Sucking pests			
Woolly aphid	A pest of north eastern India since the late 50's, it invaded peninsular Indian States of Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh, and pockets of Kerala, Uttar Pradesh and Bihar in 2003-04.	The pest generally colonizes crop of five months and above age. Characteristic white patches of infested plants visible from a distance, wax powdery coating on the ground, honeydew settling on the upper surface of lower leaves and black sooty mould on honeydew deposits are the symptoms. Colonies of pale yellow to green young aphids are difficult to locate but mature aphids covered with white waxy filaments are more easily visible on the leaf surface.	Restricted movement of canes or green tops, destruction of affected leaves, detrashing, wider spacing, paired row planting, and wrapping and propping; regular monitoring, maintenance of refugia to conserve predators and spot application of acephate or dimethoateare; conservation, redistribution, mass multiplication and release of *Encarsia flavoscutellum* and *Dipha aphidivora*.
Whitefly	*Aleurolobus barodensis* occurs in Andhra Pradesh,Bihar, Tamil Nadu, Haryana, Punjab, Gujarat and Maharashtra.	Large colonies of nymphs suck sap from the undersurface of leaves which turn yellow and pinkish in severe cases as in the case of *Aleurolobus barodensis*; infested leaves gradually dry up. Honeydew excretion promotes sooty mould on lower leaves. Plant growth is retarded and sugar content reduced. *Neomaskellia bergii* colonies are restricted to small areas on leaves often attended by ants.	Proper water and nitrogen management, detrashing and destruction of leaves before adult emergence; selective spraying of affected border rows; redistribution of the nymphal-puparial parasitoid *Amitus minervae* from active fields to deficit fields.

Pest	Distribution	Symptoms	Management
II. Sucking pests			
Black bug	*Cavelerius sweeti* is a pest of ratoons in subtropical India.	Nymphs and adults are found in the leaf whorls and under the sheathing bases of leaves. The leaves of affected plants turn pale yellow with brown patches and become riddled with holes in severe infestation. Leaf tips and margins dry up and the entire plant may wither. Plant growth is arrested and juice quality affected.	Burning trash and crop residues after harvest, removing sprouts from stubbles by the end of April and irrigating the fields, and application of acephate, dimethoate or malathion in leaf whorls to target all stages.
Scale insect	The armored scale insect *Melanaspis glomerata* is economically important in both tropical and subtropical India.	Heavy populations cover the entire cane and the encrustation gives a greyish black appearance. Due to desapping crop loses vigor, shrivels up, exhibits stunted growth with reduction in internodal length; yield and quality suffer. Use of infested setts for planting hampers germination.	Selection of healthy seed, prevention of water-logging, malathion sett treatment, detrashing, wrapping and propping, avoiding ratoons, stubble shaving and judicious spray or drenching with insecticides.
Mealybug	The pink and yellow mealybugs are prevalent in both tropical and subtropical India.	Pink round or dumb-bell shaped adults and small nymphs are found on the nodes when leaf sheaths are removed. Colonies are seen on germinating aerial buds and underground cane portions. The yellow mealybug infests the nodal regions but also colonizes leaf-sheaths, internodes, underground stalk and roots.	Planting healthy setts without leaf sheaths, detrashing, avoidance of overdose of nitrogen and repeated ratoons, management of water stress, application of acephate, dimethoate or malathion after detrashing.

Pest	Distribution	Symptoms	Management
III. Subterranean pests			
Termite	Several species of mound building or subterranean termites have wide distribution in the country.	Termites attack newly planted setts and ratoons through cut ends or buds and feed on soft tissues. Stools or shoots dry up which can be pulled out easily. Poor germination and gaps result in yield loss. Termites feed on the inner tissues of underground portions of tillers and millable canes leaving the rind intact and filling the cavity with moist soil. Affected canes turn yellow and dry. Damaged canes collapse under their own weight.	Destruction of queen in mounds, ploughing field bunds, burning crop residues, avoidance of trash mulching in endemic areas; treatment of mounds with aluminium phosphide tablets, lindane or chlorpyriphos; sett treatment with imidachloprid, drenching planted setts or standing crop with imidachloprid or chlorpyriphos.
White grub	*Holotrichia serrata* is predominant in the tropics; *Holotrichia consanguinea* and *Heteronychus sublaevis* are more common in the subtropics.	Late larval stages of *Holotrichia* spp. feed on roots and underground portions of stalks by scooping holes. Spindle wilts and leaves turn yellow; clumps gradually dry up which can be easily pulled out. Affected canes collapse, dry up and become unfit for crushing or planting. Damage in patches leaves gaps but in severe cases the entire field may be devastated. Clumps often harbor 7-10 grownup grubs in the root region. Adults of *Heteronychus sublaevis* damage the underground portion of stem leading to drying.	Mechanical collection of beetles on neem trees after first rains, collection of third instar grubs in fields showing yellowing or drying of clumps; repeated deep ploughing and flooding for 24-48h in February, rotation with paddy or sunflower; regular use of the fungus *Beauveria brongniartii*; spraying small neem trees to kill beetles, insecticides against first instar grubs.

Pest	Distribution	Symptoms	Management
IV. Non-insect pests			
Rat	Among the predominant rat species of sugarcane, *Bandicota bengalensis* occurs in both tropics and subtropics.	Rat damage to sugarcane begins around 90 days after planting. The activity is indicated by the presence of burrows with mounds of loose granular dug out soil. The rind of lower internodes shows gnawing or chewed out symptoms. Lodging of canes, weakened by gnawing of roots and loosening of soil during burrowing, is a common symptom.	Removal of wild vegetation, reduction in bund thickness and height, deep tillage and flooding, rotation of paddy with crops like sunflower, wrapping and propping; trapping rats using snap or kill traps and live traps; use of zinc phosphide, aluminium phosphide and bromadiolone; placing perches at canopy height to encourage barn owl predators.
Mite	Yellow and blister mites are found in both tropical and subtropical India.	Oval colonies or webs (2 mm long) of yellow mite numbering up to 1300-1500 per leaf are seen on the underside of leaves in 6-8 parallel rows. The scraping of epidermis from inside the web produces white mottled patches on the upper leaf surface. The blister mite damage occurs on leaf sheaths in the form of circular erineum or gall with a depression in the center. The light green blister turns rusty red, hardens and the outer side of leaf-sheath exhibits swollen scars.	Removal of wild sugarcane and monocot weeds, removal and destruction of infested leaves in early stages, monitoring and early detection, spot application of acaricides.