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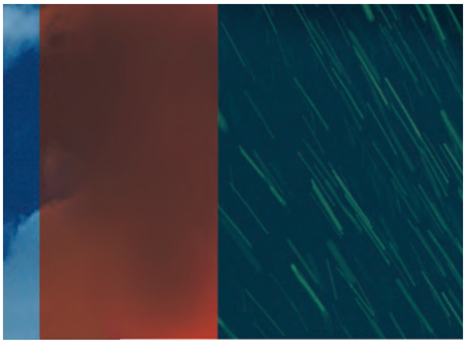

PEST MANAGEMENT

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PESTS are significant constraints on the efficient and economical production of sugarcane in Australia. Insect and other animal pests cost the Australian sugar industry more than $20 million each year in lost production and control costs.

INTEGRATED PEST MANAGEMENT

Integrated pest management, or IPM, combines a range of suitable control techniques in as compatible manner as possible to maintain pest populations below those causing economic damage. IPM is the concept of keeping entire pest populations, often over large areas, below levels likely to cause economic damage. Emphasis is placed on the use of a combination of methods aimed at providing cost-effective, but long-term, control with a minimum of harmful side effects. The IPM concept is a significant change from ideas of pest control by eradication, usually with pesticides on a field-by-field basis.

Attempts to develop IPM for the Australian sugarcane industry have three main thrusts. The first approach is the most efficient use of present controls, especially of registered pesticides.

The second approach is a search for benign substitutes for chemical pesticides, such as attractant traps, and biological control agents. However, such curative methods, although less intrusive, still avoid confronting the causes of damaging pest infestations. Most of the substitutes keep growers dependent on experts and suppliers of products, and they perpetuate the concept of eliminating pest enemies, rather than managing the crop to limit pest numbers below the economic threshold.

The third approach is to redesign farming systems, to reduce their attractiveness to pests, to ensure pests do not find the cropping system convenient for breeding, and to ensure that potential pests remain at levels below those that are likely to cause economic damage. These are often referred to as cultural controls. Such an IPM approach views excessive pest numbers and damage as indicators of poorly designed and poorly managed systems.

IPM systems depend on a good understanding of the pest species. Information on where the pest lives, what it does to the crop, how long it takes to develop, where and how it mates, and where it lays eggs is important in designing appropriate and effective strategies. Even apparently similar pests can have very different life histories.

For example, greyback canegrub has a 1-year life cycle, lays more than one batch of eggs, occurs in a wide range of soil types, and disperses widely as adults to feed on tree leaves before selecting fields in which to lay eggs. On the other hand, Childers canegrub has a 2-year life cycle, lays only one batch of eggs, occurs on clay soils only, and does not feed or disperse widely as an adult. Thus, strategies such as early harvesting and early planting might be used to concentrate greyback canegrubs in low-value fields or small areas, but are not appropriate against Childers canegrubs. Also, curative insecticides are widely used against Childers canegrubs because they can be applied just after harvest to control actively feeding third-stage grubs; however, third-stage greyback canegrubs occur when the crop is well grown and access to apply insecticides is difficult or impossible. Examples of IPM tactics are given in Table 1.

Development of IPM also depends on a good understanding of the ecology of the pest. How the pest relates to its environment, and what factors determine its abundance, e.g. abiotic factors such as weather or biotic factors such as natural enemies. Research into the ecology of greyback canegrub has opened up new avenues for control using

Table 1. Examples of IPM tactics.

Pest	IPM tactics
Greyback canegrub	Prepare for planting using minimum tillage to retain diseases of grubs. Choose resistant/tolerant varieties. Plant late and harvest the most valuable crops late to minimise egg laying. Use suSCon® Blue where effective or where soil conditions can be modified. Substitute BioCane™ where available. Target adults on cane leaves with an insecticide where this is permitted. Attract beetles to lights and kill them. Retain a green-cane trash-blanket in ratoons. Try trap crops to concentrate grubs.
Childers canegrub	Prepare for planting using minimum tillage to retain diseases of grubs. Choose resistant/tolerant varieties. Apply suSCon® Blue in the plant crop. Treat infested ratoons with a knockdown insecticide (Mocap® or Rugby®).
Sugarcane weevil borer	Plant resistant varieties. Minimise harvester losses. Use shredder-topper or mulch trash to make trash unsuitable for breeding. Apply Regent® when appropriate.
Rodents	Control weeds by fallow management, herbicides and green-cane trash-blanket. Mow headlands to reduce rodent movement and increase effectiveness of predators. Revegetate creek banks and harbourage areas with trees. Harvest fields adjacent to harbourage areas early to create a buffer zone. Use Racumin® or Ratoff® in years assessed as high risk and if allowed.

grub diseases, by mass-producing the disease organism, *Metarhizium anisopliae* (Metschnikoff) Sorokin, or by conserving diseases in soil, and trap cropping.

Research into new management strategies is being carried out in real farm situations. Without input from growers and extension staff, problems arise in integrating results into practical IPM programs, and in making growers aware of and confident of adopting possible alternative control strategies. Grower participation assists in the development of IPM strategies by focussing research on real problems, by including grower knowledge, and by validating strategies under realistic farm conditions. Grower participation assists the adoption process by increasing farmer ownership of the end results and by jump-starting extension.

IPM is not a recipe for pest control. It relies on understanding the concepts that govern populations of each pest and the losses they cause, and then using these concepts to develop management strategies and tactics suitable for large areas or individual farms or fields where this is possible. The components of IPM are not constant, and they will change as more research is carried out and as IPM strategies are tested, found wanting and refined.

CONTROL STRATEGIES

Four basic types of control strategies are used within the Australian sugar industry: pesticides; biological controls; cultural controls; and quarantines. Each has characteristics that make it useful in some situations, but not in others.

Pesticides

Pesticides have been the backbone of control of Australian sugarcane pests since the development of the organochlorines during the late 1940s. These insecticides provided cheap and effective control of canegrubs and soldier flies until they were withdrawn from use in the 1980s. BHC was replaced with a controlled-release formulation of organophosphate, but the cyclodienes, such as dieldrin, have no substitute. More recently, materials from other chemical groups have been tested. Pesticides from some of these groups are registered to control other pests of cane, e.g. the pyrethroids permethrin and bifenthrin are registered for use against armyworms and wireworms, respectively, the carbamate aldicarb is registered against nematodes, and the phenylpyrazole fipronil is registered against sugarcane weevil borer.

Pesticides work in different ways, depending on the chemical group. All of the insecticides registered for use on Australian sugarcane interfere in some way with nerve functions. Other insecticides may interfere with hormone regulation and the moulting process, with the respiration, or with the permeability of the gut wall of insects.

The organophosphates (e.g. chlorpyrifos) are ganglionic poisons causing blockages at the nerve-cell junctions. They bind to and inhibit the enzyme cholinesterase, which is needed to destroy the transmitter substance acetylcholine after the nerve is activated. In poisoned animals, the accumulation of acetylcholine first diminishes the reaction to stimuli, and the insect becomes hyperactive while its internal glands pour fluid into the alimentary canal. It then causes blockage of the nerve impulses, the legs are extended in paralysis, and the insect dies.

Carbamates (e.g. aldicarb, carbaryl) also act by inhibiting cholinesterase, but the chemical mechanism is different and the inhibition is more readily reversed than with organophosphate poisoning.

The pyrethroids (e.g. permethrin, bifenthrin) appear to exert their toxic action on the nerve fibres, causing intense electrical activity that blocks nerve impulses. They act at the same site on the voltage-dependent sodium channel as do insecticides such as DDT; nerves fail to repolarise immediately after an action, and repetitively discharge, throwing the muscles into tremors and finally locking them in paralysis.

Phenylpyrozoles (e.g. fipronil) appear to act by blocking the γ-aminobutyric acid-gated chloride channel in a manner similar to the cyclodienes. However, the exact binding site may be distinct from that of the cylcodienes.

The coumarin rodenticide coumatetralyl is an anticoagulant, which inhibits blood coagulation by blocking the formation of prothrombrin in the liver. It requires multiple feeding to produce lethal effects.

All pesticides are designed to kill. Precautions must be taken to avoid harming nontarget animals including humans. Two concepts are important. Toxicity of a pesticide is its ability to kill or injure. Toxicity is ranked on the basis of how much of the material is required to kill half of a group of test animals (usually rats) when fed to them in their diet; this is termed the oral LD_{50} and is given in units of milligrams per kilogram of body weight. Highly toxic materials have LD_{50}s less than 50 mg/kg and are rated on the poison schedules as S7; examples are aldicarb (in Temik®) with a value of 1 mg/kg and fenamiphos (in Nemacur®) with a value of 15 mg/kg. Materials such as chlorpyrifos (in suSCon® Blue, Lorsban® and Chlorfos®) ethoprophos (in Mocap®), and carbaryl with values of 50–500 mg/kg are moderately toxic and are rated as S6 poisons. Those with values of 500–5000 mg/kg are slightly toxic and are rated as S5 on the poison schedule. Most pesticides fall into the first two categories. The second concept is hazard, the chance that injury to nontarget animals will result from the use of the pesticide. It is influenced by how the material is used; use of materials in the way outlined on the label results in minimal hazard to nontarget animals even for very toxic materials. Hence, it is vital that the label directions should be read and followed.

Labels also give important information on the amount of pesticide to apply and how and where that pesticide should be applied. Label directions are formulated only after extensive trials have proven them to work. They are the only legal ways to apply the product. Correct placement is usually vital to achieving good results. For example, the active ingredient in the canegrub insecticide suSCon® Blue, chlorpyrifos, moves little in soil. This means the granules must be positioned where the grubs will contact them. For optimum control of grubs, the granules must be applied by a precision granule-applicator in a band 150–200 mm wide across the centre of the drill and covered with at least 50 mm of compacted soil. They should be covered by 150–200 mm of compacted soil once the row is filled in and hilled up. Depending on the depth of the planting furrow, granules may have to be applied at planting or at cutaway or drill fill-in to achieve this placement.

Although pesticides are widely used, they are not appropriate to all situations. It is not worthwhile applying a pesticide if the economic benefits of controlling the pest are not greater than the cost of the product plus the application costs. There are also instances of pesticides failing to work because they are degraded rapidly. This occurs in the Burdekin area when the chlorpyrifos content of suSCon® Blue granules reduces rapidly in the highly alkaline soils. Development of resistance to insecticides is also a threat, but no cases have yet been seen in the Australian industry.

There is not a limitless pool of insecticides available to the sugar industry. The market for any product tailored to the needs of the industry is small, so many companies will not invest in products specifically for control of cane pests. The long cropping cycle of sugarcane brings special problems of application and residual action and there are many pests, especially the soil-dwelling species, whose biology ensures that they will always be difficult to treat with insecticides. For these reasons, other types of controls must be sought.

Biological controls

Biological control usually refers to the use of predators, parasites or diseases to reduce numbers of the pest. Some biological control agents are very specific in their action, with a narrow host range and perhaps only attacking the target pest. Biological control may offer advantages that are not possible with other control measures. It can be permanent, especially where the biological control agent perpetuates itself in the field, and target species often find it difficult to develop resistance. Biological control can be safe, as the agents are usually not toxic or harmful to nontarget species. Biological control can also be very economical; for example, if the agent is established and self-perpetuating, there are no application costs.

Three different types of biological control have been used in the Australian sugar industry: introductions from overseas, and conservation and augmentation of natural enemies. Each of the three has characteristics that suit it to different situations.

The classic form of biological control is the introduction from overseas of a parasite or predator from the centre of origin of the pest. Most of the Australian pests of sugarcane are native species, so this procedure is difficult to implement. In the 1930s, BSES experimented with the introduction of parasitic flies and wasps that attack canegrubs in Indonesia and the Philippines, for control of native canegrubs. However, none of these established, because either native Australian canegrubs are poor hosts, or the Australian environment is unsuitable. In Australia, a parasitic fly introduced from Papua New Guinea provides some control of sugarcane weevil borer, also introduced from New Guinea; an example of classical biological control. As in this example, the technique works best where both the agent and the target are from overseas, but it can be used against native pests that have close relatives overseas. Present legislation limits introductions to those parasites or predators that attack a very narrow range of host species. This means that generalist predators usually cannot be introduced, so introduction of a generalist predatory species, like that icon and ecological disaster the cane toad, would not be allowed today.

An often-overlooked type of biological control is the conservation of native natural enemies. Native pests, for example canegrubs and soldier flies, have a range of parasites, predators and diseases that help regulate numbers in natural situations. In sugarcane crops, many of these natural enemies find it difficult to survive and flourish, so numbers of the pests increase. Usefulness of these natural enemies can sometimes be enhanced if the environment of the canefield is changed to make it more favourable for their survival. If pesticide applications are reduced, there will be less effect on parasites—this may be useful where armyworms are attacking early-harvested ratoons; by allowing parasites of armyworms to breed up, armyworm damage later in the season may be minimised. Reduced tillage during the fallow will help survival of natural enemies of pests such as canegrubs and soldier flies, that would be harmed by cultivation. Wasp parasites of canegrubs require nectar to give them fuel for flights through canefields; provision of such nectar sources may enhance wasp activity. If numbers of predators and parasites are to increase they need breeding sites; the provision of breeding boxes for owls allows the birds to breed in canefields and feed on canefield rats. All of these require slight changes to the way growers farm, but they are usually cheap, no products need to be bought, and they are environmentally sensitive.

Augmenting native natural enemies involves the mass rearing of the biological-control agent and then periodic releases of large numbers into canefields. Development of the fungus *Metarhizium anisopliae* as the bioinsecticide BioCane™ targeting canegrubs is the most obvious example of this type of control in the Australian sugar industry. However, like any insecticide, there are ongoing production and application costs that the grower must bear. Legislation also considers such a product the same as any chemical insecticide, so it must undergo rigorous field testing and environmental and health evaluation before it can be registered and marketed. The development of BioCane™ for control of greyback canegrub took 7 years from isolation of the strain of fungus to launch of the product.

Cultural controls

Cultural control aims to manipulate the environment to make it less favourable for the pest. Manipulation requires a thorough knowledge of the life history and habits of the pest and of its plant host. Vulnerable stages of the pest's life cycle must be identified and farming practices altered to prevent attack, kill the pest, or slow down its rate of reproduction. When these control measures are also desirable agronomic practices, they are usually readily adopted by farmers. They are often cheap to employ but require forward planning to implement successfully.

The most obvious example of a cultural control in sugarcane is the ploughout of infested crops. Insects such as canegrubs, soldier flies and earthpearls are often in higher numbers in older ratoons than earlier in the crop cycle. A ploughout will kill a proportion of the pests present, but the effect will often be greater when it is followed by a significant break from sugarcane, either as a fallow or as a rotation with an alternative crop on which the pest does not feed. What is done to the field during the break can be important — a cover crop may allow natural enemies to survive and minimum tillage will allow diseases of pests to survive, but growing a grass crop will allow soldier flies and earthpearls to survive better than growing a broad-leaved crop.

Management strategies for rodents in Australian sugarcane depend on cultural controls. Rodents only inhabit sugarcane fields after the crop provides sufficient cover, and numbers must build up again after each harvest by immigration from nearby grassy, non-crop refuges or unharvested crops. They require grass seeds as a protein source for breeding; extra protein will lead to a population explosion. The most effective strategy is to control weeds in canefields by fallow management, herbicide and trash blanketing, mow headlands to reduce the freedom of movement of rodents from harbourage areas, and revegetate creek banks and other harbourage areas that are not accessible by machinery, using trees that form a closed canopy and restrict weed and grass growth.

Resistance to pests in different cultivars (varieties) of sugarcane can also be an important cultural control. Recent work has shown that some cultivars are much more tolerant of earthpearls than are others. Cultivars with soft rinds or those that crack along the stem are much more susceptible to sugarcane weevil borer than hard and noncracking cultivars. There is also considerable interest in the use of genetic engineering to introduce genes for resistance from other plants.

Pests are only one factor, although a very important one, in the efficient production of sugarcane. Therefore, any recommended cultural control method must be properly integrated with proven agronomic and water-management practices. It is also important to remember that, as production systems change, cultural practices that were once effective in minimising the economic impact of pests may not be effective under the changed conditions. For example, while bare fallow could kill soldier flies, it is no longer appropriate because of increased concerns about soil erosion. This illustrates the necessity for cooperative work between all sectors of the industry.

Quarantines

The Australian sugarcane industry has traditionally maintained a strict quarantine system for the movement of cane into Australia from other countries and between the canegrowing regions within Australia.

Internal quarantines exist between all major areas within Australia. These are useful in minimising the spread of introduced pests, such as sugarcane weevil borer and ground pearls, as well as many sugarcane diseases.

No plant material is allowed into Australia without first going through strict quarantine channels. Until recently, because the trade in sugarcane products was largely restricted to processed sugar and molasses rather than plant material, there was a negligible quarantine risk. Recently, however, there has been increased interest in the trade of used sugarcane machinery, use of sugarcane in traditional cooking, and the importation of germplasm for breeding purposes. These factors combined with the increase in sugarcane production in Irian Jaya and Timor to the north of Australia and the Ord River District of northern Western Australia have increased concerns about the accidental introduction of sugarcane pests and diseases.

Overseas, more than 1280 species of insects and mites are known as pests of sugarcane; these have been detailed in a rigorous Pest Risk Analysis where all details of the pest are used to determine its potential for introduction, establishment and spread in Australia. In the area to the immediate north of Australia, there are over 450 species, of which 39 have high potentials for introduction. This group includes 11 planthoppers, 2 leafhoppers, 12 moth borers, 7 whitegrubs, 2 black beetles, 2 scale insects, 1 whitefly, 1 aphid and 1 weevil borer.

Planthoppers include eight species of *Perkinsiella*, all of which feed only on sugarcane. These are very similar to the now-established sugarcane planthopper or sidewinder, *P. saccharicida* Kirkaldy, which transmits Fiji Disease Virus in southern and central Queensland. Some of the eight are also vectors of Fiji Disease, but the vector status of other species is unknown. Only the biology of the widespread *P. vastatrix* (Breddin) is known and it is similar to that of *P. saccharicida*. Detection of these species in Australia would be difficult, as they closely resemble *P. saccharicida*.

The yellow planthopper, *Eumetopina flavipes* Muir, is found on sugarcane as close as the Torres Strait islands and Bamaga. Nymphs and adults live within the leaf funnel and are easily spread through planting of tops. The species causes some damage through direct feeding, yellowing and development of sooty mould, but its major importance lies as a vector of Ramu Stunt Disease. Cairns is an obvious point of introduction where chewing canes could be brought in from Papua New Guinea or the Torres Strait. Other planthoppers feed and disperse in a similar manner and may transmit viruses.

The maize leafhopper, *Cicadulina mbila* (Naude), occurs through eastern and southern Africa and as far east as Réunion and India. Its importance to sugarcane arises from its ability to transmit Maize Streak virus, of which Sugarcane Streak is one strain. The leafhopper lays its eggs along the midrib of leaves and a single insect of either sex can transmit the virus after feeding for a few days on infected plants. Infective adults stay so for life. Sugarcane Streak does not occur in Australia and its impact could be significant on the yields of susceptible cultivars; losses in the 1930s in South Africa were estimated at 7–10% of the crop.

The sugarcane leafhopper, *Pyrilla perpusilla* (Walker), occurs through most of southern and southeastern Asia, as close to Australia as Indonesia, and feeds on a wide range of grasses, some legumes and figs. Feeding by this insect can have a dramatic effect on yield, with sugar recovery less than 50% during epidemics.

Sugarcane stalks at any stage of growth are liable to attack by moth borers, which can be loosely classified into three types according to the part of the stalk they usually attack: shoot borers; top borers; and internode, stalk or stem borers. However, a species is not restricted to one specific part of the plant, damage being more dependent on the stage of cane available for attack.

Sugarcane shoot borer, *Tetramoera schistaceana* (Snellen), occurs in Mauritius, Réunion, Sri Lanka, China, Taiwan, Okinawa, Vietnam, Malaysia, the Philippines and Indonesia. Eggs are laid on the leaf sheaths or on the underside of leaves. Young larvae penetrate the young plants through the basal portion of the plant at or near the soil surface. Once inside the plant, larvae travel upward in a spiraling tunnel near the stem surface. On reaching the top of the plant, they bore downwards, usually killing the growing point and producing a dead heart, or, if the growing point is not killed, producing a distorted shoot enveloped in a dry leaf. Before pupation, the larva bores through the leaf sheath closest to the outer sheath and makes a cocoon, which blocks the opening. Larvae can migrate between shoots and total development takes about 3–4 weeks. On mature cane, larvae feed on the aerial buds and root band of the internode, both on the surface and from inside. Rarely do the feeding tracks extend to the next internode.

The top borers are distributed through southern and Southeast Asia, with *Scirpophaga excerptalis* (Walker) reaching Papua New Guinea. Eggs are laid in masses of up to 30 near the midrib on the underside of upper leaves and are covered with brown hairs and scales from the body of the female moth. Larvae hatch after 8–9 days and are dispersed by the wind on silken threads. They enter stalks from the spindle or through the midrib of the youngest leaf and bore down through the growing point. This leaves a dead heart and characteristic 'shot-holes' in new leaves. Death of the growing point causes heavy sideshoot development. Before pupation, each larva makes an exit hole below the growing point, covered with a thin film of tissue. Young cane is preferred, and with favorable conditions there can be 5–6 generations a year. Severe damage results in large reductions in cane yield, sugar yield and sugar purity. *S. excerptalis* also feeds on Johnson grass, which aids in its establishment and dispersal.

Stem borers such as larvae of *Chilo* spp. feed initially in the leaf spindle and disperse and bore into the stem or leaf sheaths as third-stage larvae. Boring reduces sugar content, and can cause stem breakage and dead hearts. Eggs are laid on the underside of the top few leaves or around the leaf sheath. Larvae pupate within the stem. In summer, life cycles take about 33–40 days and in subtropical areas there can be 6 generations per year. Most species feed on a variety of grasses, such as sugarcane, millets, rice and sorghum. Damage to crops can be high, with records of damage of up to 75% of canes and yield losses of 33%. Six species are known as pests of sugarcane through Southeast Asia and Papua New Guinea.

Three species of *Sesamia* damage sugarcane to the north of Australia. Some species occur on a wide variety of grasses, while others attack only sugarcane. Eggs of *S. grisescens* (Warren) are laid behind the leaf sheath, usually of the 4th–6th leaves from the top. After hatching, groups of up to 200 larvae feed on the inner surface of a leaf sheath for a few days before moving into the soft tissue 2–3 internodes up to the apical meristem. This produces a dead heart as the larvae hollow out the top internodes. At this time, usually the fourth stage, larvae disperse singly or in small groups to nearby cane plants to complete development; up to 50 adjacent stalks can be attacked. Before pupating, the fully grown larva cuts an exit hole in the stalk and retreats back into the bored stalk to pupate. There can be 6–7 generations per year, depending on climate and species, with generations highly synchronised. Infestation can lead to significant yield losses (18% sugar loss at Ramu in Papua New Guinea) and reduced sugar quality and extraction.

There is a wide diversity of melolonthine whitegrubs in the countries to the north of Australia, all of which are similar to native canegrubs and cause similar damage. This means that detection of an introduction could be difficult because of confusion with local species. However, the risk of introduction would be relatively low, as larvae would have to enter Australia in soil and the life of mated adults is usually short.

The black beetle, *Scapanes australis* (Boisduval), damages cane as adults and not as larvae. Adults have a long life, about 100 days, and feed by boring into the crowns and trunks of palms, the pseudostems of bananas, and the tops of sugarcane plants. Damage is often not excessive, but acts as a site of entry for secondary pests, such as weevils, and for diseases. Larvae feed on rotting logs or vegetation and take about 1 year to develop. They occur in Papua New Guinea and New Caledonia.

Pulvinaria scale, *Saccharipulvinaria iceryi* (Signoret), occurs through Southeast Asia on a wide range of grasses including sugarcane. Feeding reduces growth, with the premature death of leaves, and chlorosis gives a yellow edge to leaves. Plants will fail to ratoon and the stem can rot. If the infestation is severe, the plant will die. All individuals are females, with only the first-stage nymphs mobile. The scales feed on the underside of the leaf or sometimes on the leaf sheath near the junction with the leaf blade. The life cycle, from egg to initial egglaying, takes 35–60 days, depending on temperature, and adults continue laying eggs for a further 20 days. Each female can lay up to 1000 eggs.

Sugarcane scale, *Aulacaspis tegalensis* (Zehntner), is very similar to *A. madiunensis* (Zehntner), a scale already introduced to Australia, but is potentially more damaging. *A. tegalensis* is widespread through eastern Africa and Southeast Asia and is present on some Torres Strait islands. The scales usually feed on the stem underneath the older leaf sheaths where the internodes are fully elongated, but under crowded conditions they can colonise the leaves. The first-stage nymph is the most mobile and females take about 27 days to complete development in summer. There can be as many as 8 generations per year, and the scales multiply more under dry conditions. Leaves become discoloured and desiccated due to feeding, often with chlorotic blotches. Stems become desiccated and rots can enter because the wax layer is removed. Sugar yields can be reduced markedly and bud germination and sett growth can be poor. This species is easily transported on infested cane.

Sugarcane whitefly, *Aleurolobus barodensis* (Maskell), is widespread on sugarcane and its wild relatives in Pakistan, India, Thailand, Malaysia, Taiwan and Indonesia. Feeding causes yellowing and drying of the leaves, which reduces photosynthesis. Excreted honeydew increases the production of sooty moulds. In high infestations there is a reduction in cane yield and sugar quality. Eggs are laid in a single strip on the lower surface of leaves, usually in batches of 6–30. The total life cycle takes about 32 days, but adult females live for fewer than 2 days. Nymphs are not active and settle in one place to feed, but adults can be easily seen flying about when the plant is disturbed. Populations increase with crop maturity.

Sugarcane woolly aphid, *Ceratovacuna lanigera* (Zehntner), occurs on sugarcane and its wild relatives from India and Nepal, through Southeast Asia, north to Okinawa and Taiwan and south through Papua New Guinea to the Solomon Islands. Adults are all females, do not have sex and produce live young. The first stage is the most active stage, and will wander from the mother to find a suitable feeding site, usually on the underside of a leaf. Colonies of aphids are easily distinguished by the woolly layer of wax that covers them. The life span of an individual is about 34 days and females can produce up to 34 nymphs. Heavy feeding reduces photosynthetic activity and can reduce all yield parameters. This is further exacerbated by sooty mould growing on honeydew produced by the insect.

Red palm weevil or coconut weevil, *Rhynchophorus ferrugineus* (Olivier), occurs through Central and South America and from Pakistan through Southeast Asia to Papua New Guinea. It is primarily a pest of palms, but will bore into the roots and underground stems of sugarcane. Females lay up to 1000 eggs over 5–8 weeks — the total life cycle takes about 4 months. This species could be brought in on palms or sugarcane stalks, and spread within Australia would be facilitated through the movement of palms. It could also be confused with the naturalised sugarcane weevil borer, in both appearance and habits.

To deal with introductions of new pests, a Pest Incursion Management Plan has been formulated. This details the steps to be taken once a pest has been detected and covers both incursions into commercial cropping areas and into back-yard plots of sugarcane in non-commercial cropping situations such as the Torres Strait, Cape York Peninsula or urban areas. The plan has been developed after consultation with industry groups and should be revised with further developments in the sugar industry and with developments in the pest situation outside Australia. If a new pest is suspected, it should be reported immediately to the local BSES extension office or Cane Protection and Productivity Board. Plants should not be removed from the field and workers must be extremely careful not to spread infestations in cane, or on vehicles, machinery or clothing.

PESTS OF AUSTRALIAN CANE

Many species can damage sugarcane in Australia and many symptoms of damage to cane can be caused by more than one pest species, so it is important to accurately diagnose the species involved. The obvious symptoms of pest damage and the major pests responsible are given in Table 2. This list is not exhaustive, and pests other than those listed may be responsible for some symptoms. Also, many symptoms may be related to

Table 2. Symptoms of pest damage and the major pests responsible.

Symptom	Pests
Germination failure	Soldier flies, bud moth, wireworms, field crickets, mole crickets, wart eye, termites, weevils
Ratoon failure	Soldier flies, canegrubs, wireworms, cicadas, ground pearls, butt weevil, stenocorynus weevil
Dead hearts leading to dead shoots	Wireworms, black beetles, rhyparida, butt weevil, stenocorynus weevil, large moth borer, ratoon shoot borer, bud moth
Yellowing, poor growth and death in young cane	Canegrubs (spring-summer feeding species), nematodes, ground pearls, cicadas, symphylans, weevils, funnel ants
Yellowing and death of semi-mature or mature cane	Canegrubs (summer-autumn feeding species), sugarcane scale
Boring of large stalks	Weevil borer, large moth borer, termites
Large-animal chewing of shoots or stalks	Rodents (ground and climbing rat), feral pig, wallabies, fox, eastern swamphen, cockatoo
Chewing of large areas of leaf	Armyworms and loopers, locusts
Sooty mould	Planthoppers, mealybugs, aphids, sugarcane scale
Mottling or discoloration of leaves	Planthoppers, froghopper, linear bug, aphids

factors other than pests, such as diseases, soil water and nutrition, weather, soil compaction, and physical damage by implements and harvesters. Pests also transmit the causal organisms for some diseases, especially Fiji disease (planthoppers) and sugarcane mosaic (aphids).

Many of Australia's pests are native species that have adapted to feeding on sugarcane, e.g. canegrubs, soldier flies, rodents. There are few important introduced species, with sugarcane weevil borer, sugarcane planthopper and sugarcane mealybug the most notable. Australia is different from most other sugarcane-growing regions in that it has no serious caterpillar-stemborer problem.

Canegrubs

Canegrubs destroy the roots of sugarcane. This deprives the cane of soil moisture and soil nutrients, and, in the case of well-grown cane, of mechanical support. In general, leaves turn yellow and the cane can die. Severe attack will deprive the plant of all roots, and stools will die or be pulled out during harvest. This creates gaps in subsequent ratoons. The extent of damage and lodging depends on the number of grubs present, the variety of cane, the age of the crop, and the growing conditions. The time at which damage becomes noticeable depends on the life cycle of the species involved.

Damage by 1-year grubs usually occurs in well-grown cane. Deprived of roots, the cane will lodge, the leaves turn yellow and the plant will eventually die. However, the cane may still be worth harvesting, although the sugar content may be reduced.

Damage by 2-year grubs commences in central and northern districts when the young third-stage grubs come up from overwintering. The cane then is usually small and the soil dry. Such small cane can be killed, but often the loss of roots causes only wilting and yellowing. In December and January good rain often falls, and the grubs slow their feeding. The cane then recovers and resumes growth, leaving only reduced size and stooling as evidence of attack. In southern Queensland, the winter and early spring behaviour of some 2-year grubs is less well defined and roots may be fed on during winter, the attack becoming intensified in spring and early summer.

Cane beetles fly and lay eggs between September and January, depending on weather and the species. Cane is damaged when the grubs reach the third and last larval stage. In those species with a 1-year life cycle this occurs in late summer or early autumn, 2–4 months after the eggs are laid. Species with a 2-year life cycle spend about 10 months in the first two larval stages and reach third stage the spring following parental flight. Typical 1-year and 2-year life cycles are discussed more fully under greyback canegrub and French's and negatoria canegrubs, respectively.

Nineteen species of canegrubs, all native to Australia, are known to attack cane in eastern Australia. At least one species is present in each mill district, but up to nine may occur in any area with up to three in individual fields. The adults of all cane beetles are medium to large, light to dark brown beetles. Some are covered with white scales to varying extent, whereas others have a covering of fine hairs. Larvae are the stage usually submitted for identification. The most important character is the shape and arrangement of hairs on the under surface of the last abdominal segment in front of the anus. The group of hairs is called the raster, and comprises two central groups of hairs or palidia (palidium, singular) with a naked path between. The number and arrangement of these hairs or pali (palus, singular) are sufficiently different between most species to allow identification. Exceptions are the French's, negatoria and noxia canegrub group and the southern 1-year and Nambour canegrub group; members of each of these groups have very similar raster patterns, but can be distinguished using biochemical means. Local extension officers can help with identification of grubs and beetles.

Greyback canegrub

Greyback canegrub, *Dermolepida albohirtum* (Waterhouse), is the most damaging of Australian canegrubs. It occurs in all northern and central districts, but is less common around Mackay. Infestations commonly occur on loam soils along the Burdekin and Herbert River systems. A wide range of soil types, particularly the red volcanic loams, is infested from Tully to Mossman. Land that originally supported rainforest is prone to damage by greyback canegrubs.

Greyback canegrubs cause 1-year type damage between February and July. In the worst form of damage, plants deprived of supporting roots topple over and pull the stool from the ground. Lack of stubble prevents further ratooning. In less devastating instances, the crop remains upright but grows poorly and the foliage yellows.

The raster of greyback canegrubs has two almost straight palidia, each with a single row of 26 (range 20–28) short pali (Figure 1). Palidia curve slightly inward at both ends and have a naked path between. Head capsule widths for the three larval stages are 3.25 mm, 6.5 mm and 9 mm, respectively. Beetles are large (35 mm long) and coloured grey by a coating of body hairs. Beetles develop dark patches as hairs abrade away. The underside of the abdomen has a central bare, dark area.

Greyback canegrubs (Figure 2) have a 1-year life cycle. Adults emerge after rain between October and February. Beetles mate and feed on trees, particularly figs, wattles, palms, some eucalypts and bananas. Egglaying commences after 10–14 days with a clutch of about 28 oval, cream-coloured eggs 3–4 mm in diameter laid in a single chamber 220–450 mm deep in the soil. Beetles can lay up to three clutches of eggs, and eggs hatch after 2 weeks. First-stage grubs feed on organic matter and roots for 4 weeks. Second-stage grubs aggregate under cane stools and feed on roots for 5 weeks. Third-stage grubs feed voraciously on the roots and stool and grow rapidly in the first 2 months when they cause most damage. After 3–4 months, fully fed grubs burrow down and form chambers in which to pupate. Pupae form between July and October, and beetles develop within 1 month. Beetles remain in chambers until rainfall and suitable weather conditions stimulate them to emerge.

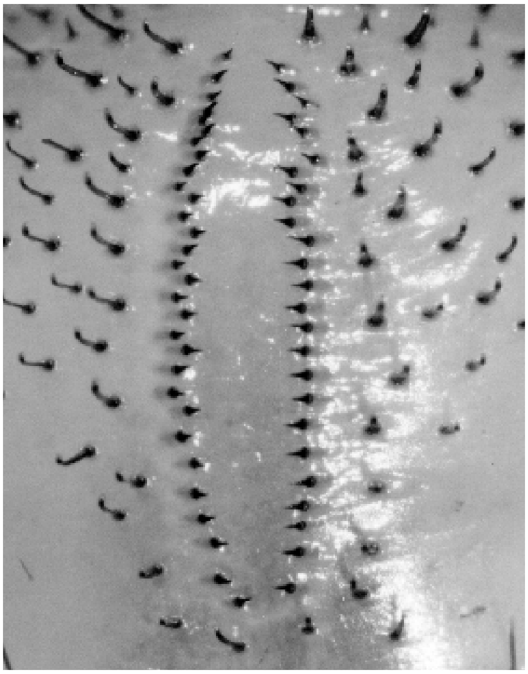

Figure 1. *Raster of greyback canegrub.*

Management of greyback canegrub is based on the following concepts. Beetles of both sexes are attracted to lights, so light traps can remove a proportion of the egg-laying population. Beetles are attracted to taller cane for egg-laying, so crops planted early or harvested early in one season will have higher numbers of grubs in the following season. Grubs are affected by diseases, such as the fungus *Metarhizium anisopliae* and the protozoan *Adelina*, that reduce grub survival; levels of these diseases are lowered by cultivation in the break between cane crops and are low under burnt-cane crops. Grub survival is reduced under green-cane trash-blanketing, probably through the increased survival of diseases. Grub numbers can be reduced by proper

Figure 2. *Greyback canegrub.*

application of suSCon® Blue, but the efficacy of this insecticide is lowered in alkaline soils that arise naturally or due to excessive liming. Grub numbers can also be reduced by application of the *Metarhizium*-based bio-insecticide BioCane™ to the plant crop. Some varieties of cane show higher levels of tolerance to feeding by greyback canegrubs and should be grown in preference to others which are very susceptible.

Strategies aim to reduce the numbers of eggs laid in high-value fields by using light traps and trap crops, target grubs with insecticide, manage suSCon® Blue to maximise its efficiency or substitute the biological insecticide BioCane™, maximise natural control by diseases, and minimise the impact of feeding on the crop.

French's and negatoria canegrubs

French's canegrub, *Lepidiota frenchi* Blackburn, and negatoria canegrub, *Lepidiota negatoria* Blackburn, are closely related and have similar biologies. French's canegrub occurs in most areas south to Bundaberg. It is the most widespread canegrub in northern districts and at Mackay, but is a relatively minor species at Bundaberg. It commonly infests sandy loam soils, but also occurs in red volcanic loams, red schist soils and some alluvial loams in areas that originally supported open sclerophyll woodland. Negatoria canegrub occurs from Proserpine south to Beenleigh. It is less common at Mackay than French's canegrub, is the major species of the two at Bundaberg, and is the only one of the two at Maryborough and further south. Larvae are commonly found in forest loam and light clay soils.

Both canegrubs cause typical 2-year type damage in spring or early summer, typically resulting in poor growth and, in severe cases, death of young ratoons. Damage most commonly occurs in young ratoon cane, but can also occur in young replant and fallow-plant crops.

French's and negatoria canegrubs have a pear-shaped raster, pointed anteriorly and with a clear path between the palidia (Figure 3). Each palidium has about 50 dark pali in three or four loosely arranged rows. The apex of each palidium does not elongate to a single rank of pali at the anterior end. Head capsule widths of first-stage grubs are 2.2 mm, 4.1 mm in the second stage, and 6.6–8.1 mm in the third stage for French's canegrubs and slightly larger for negatoria canegrubs. French's and negatoria canegrub can be confused easily with caudata and

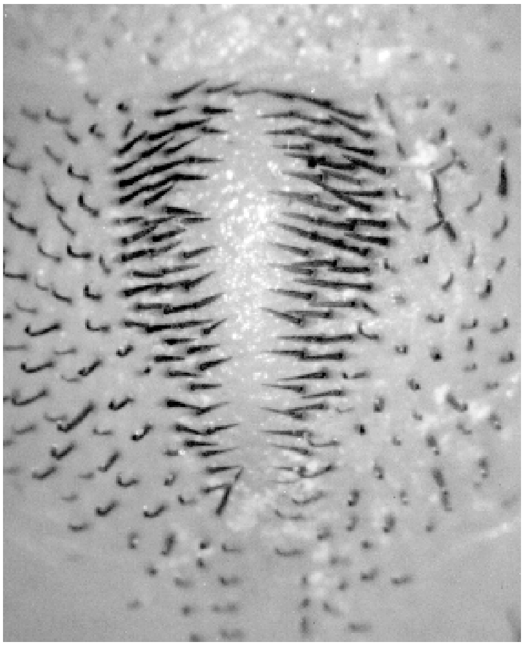

Figure 3. *Raster of French's canegrub.*

consobrina canegrubs in the north and noxia and Childers canegrubs at Bundaberg. Beetles of both species are about 25 mm long, dark brown with rounded white scales on the dorsal surface. There is a dense mass of white hairs on the underside of the thorax and closely packed scales over more than half the length of each ventral abdominal segment. Adults are best separated by the shape of the male genitalia.

Both species have a 2-year life cycle and individuals of two populations 12 months out of phase can be present in the same field at the same time. Beetles emerge and commence flying at dusk after early summer rain, usually between November and January. After a short flight over cane and open spaces, female beetles land on low objects and plants, and mate. Beetles then fly to feeding trees, chiefly Moreton bay ash, bloodwoods, and other eucalypts. However, feeding trees are not essential, and beetles can eat leaves of other plants such as sugarcane. Beetles return to a suitable site and burrow into the soil at dawn. Females carry about 31 fully developed eggs when they emerge. After about 1 week, females lay their eggs in a loose batch of about 30 eggs 170–250 mm deep in the soil. Eggs hatch in 16 days. In favourable conditions, beetles survive for up to 8 weeks following first emergence and females can lay further smaller batches of eggs.

First-stage grubs feed on organic matter and cane roots for up to 9 weeks. In the second stage, they feed mainly on living roots. In cane, second-stage grubs are initially distributed throughout the root zone. During late summer and autumn, they progressively concentrate about the stool, removing sufficient roots to loosen the stool but not causing obvious yield reduction. By spring, the larvae have moulted to the third stage and commence their main feeding. Larvae are normally fully fed by February-March if sufficient roots are available. During April-June, fully fed grubs burrow 250–600 mm deep and form chambers in which they prepare to pupate. Pupation usually occurs in October and the pupal stage lasts 1 month. Fully developed beetles remain in the chambers until the onset of suitable rainfall and temperature conditions stimulate them to emerge. This completes a full 2-year life cycle.

Control of both species presently relies mainly on the application of suSCon® Blue in plant crops. Mocap® can be used to kill grubs of both species in ratoons, and Rugby® is registered for the same purpose against negatoria canegrub.

Monitoring of crop damage or of grub numbers is essential for effective use of these knockdown compounds, which also require coulters for application and irrigation or rainfall to activate the granules. Fallowing and cultivation help to break cycles of infestation.

Childers canegrub

Childers canegrub, *Antitrogus parvulus* Britton, occurs chiefly around Childers, but also at Woongarra, Bingera and Gin Gin in the Bundaberg area. Larvae are found predominantly in red volcanic clays or clay loams, but low populations can be found in heavy alluvial soils. Childers grubs can occur with Bundaberg and negatoria canegrubs on light clay loams.

Childers canegrubs cause typical 2-year type damage with feeding by third-stage grubs through spring and summer. Damage most commonly occurs in young ratoon cane, but also in young replant and fallow-plant crops.

Childers canegrub has a raster pattern similar to negatoria and French's canegrubs. However, in Childers canegrub, the palidia are smaller and elliptical instead of pear-shaped, and each has about 35 pali; the central naked area does not have straight sides, but is oval and blocked off by several pali at each end (Figure 4). Grubs are smaller than negatoria and French's canegrubs. Head capsule widths of first-stage grubs are 2 mm, of second-stage grubs 4–4.2 mm, and of third-stage grubs 6–6.5 mm. Adults are yellow-brown to nearly

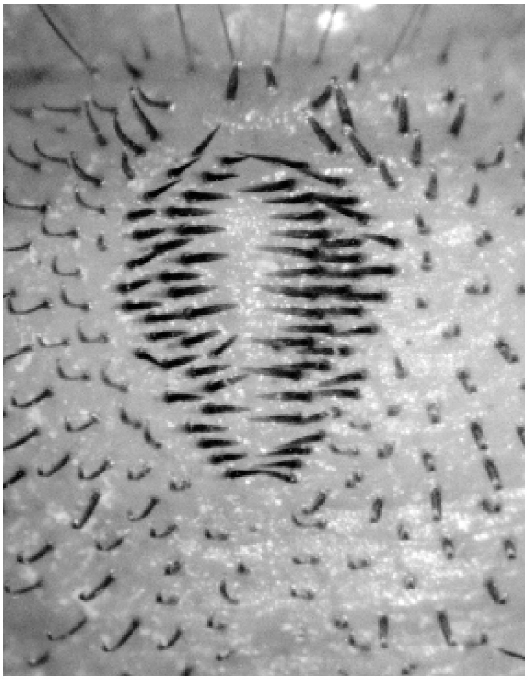

Figure 4. *Raster of Childers canegrub.*

black and 18–23 mm long (Figure 6). Males have large 7-segmented antennal clubs; females have small 5-segmented clubs. This size difference indicates that males use pheromones (chemicals emitted by females) to find females for mating.

Childers canegrubs have a typical 2-year cycle with adults usually emerging in November-December. Eggs hatch by January, and grubs are first stage until March-April. The second stage usually continues until September, but this is variable with some third-stage grubs by July, while others do not change until as late as December. Second and third stages can be common in the upper soil during winter.

Adult males are strongly attracted to lights. Females are poor fliers, emit pheromones to attract males, and usually mate on the ground near where they emerge; this means infestations often spread out from a focus.

Management of this species is similar to that outlined for French's and negatoria canegrubs.

Consobrina canegrub

A 1-year life cycle variant of consobrina canegrub, *Lepidiota consobrina* Girault, is the most common canegrub from Mossman to Cairns. A 2-year variant of the species occupies isolated pockets between Cairns and Gordonvale, where mixed infestations with French's canegrub occur. Most infestations occur in dark-coloured sandy loam soils.

Damage by consobrina canegrubs appears as typical 1-year or 2-year type depending on the race present.

Consobrina canegrubs have a raster pattern with about 50 pali arranged in four or more indistinct rows in each palidium with a clear path between the palidia. The raster is pear-shaped, similar to that of French's canegrub, except that it is slightly more angular on the posterior angles and tapers to a distinct point at the anterior apex where there are two single rows of about 6 (range 5–8) pali extending anteriorly. Head capsule widths of the three larval stages are very similar to equivalent French's canegrubs. Beetles are dark brown with oval white scales distributed evenly across the dorsal surface. They are slightly larger than those of French's canegrub. The two species differ on the lower surface of the abdomen. Adults of consobrina canegrub have more than half the length of each body segment devoid of scales, whereas on adults of French's canegrub these bare areas appear as narrow bands less than half the length of each body segment.

This species has distinct races that exhibit different life cycles. Beetles fly and mate after rain from September to January. One-year variants at Mossman tend to fly early (September-October), and 2-year variants fly later (November-January). Feeding, mating and oviposition behaviours are similar to French's canegrub. Grub development of the 1-year variant north of Cairns is similar to that of greyback canegrub. Larval development of the 2-year variant south from Cairns is similar to that of French's canegrub.

Management is similar to that for French's and negatoria canegrubs.

Southern 1-year canegrub

Southern 1-year canegrub, *Antitrogus consanguineus* (Blackburn), occurs in the Bundaberg and Maryborough areas in sandy alluvial or yellow podsol soils, especially wallum country. It is closely related to Nambour canegrub.

Southern 1-year canegrubs cause typical 1-year type damage in late summer and autumn. They can commonly invade autumn-planted plant crops as well as ratoon crops.

Grubs are distinguished by a raster pattern of two single convex rows of 19–31 (commonly 23–26) stout pali, converging towards each end (Figure 5). The species can occur with negatoria canegrub, but southern 1-year canegrub is smaller and has a different raster pattern. Adults are bright red-brown, without scales, but with short hairs on the upper surface. In males, the basal segment of the antennal club is more than half the length of the remaining 5 segments; this character distinguishes the species from the closely related Nambour canegrub.

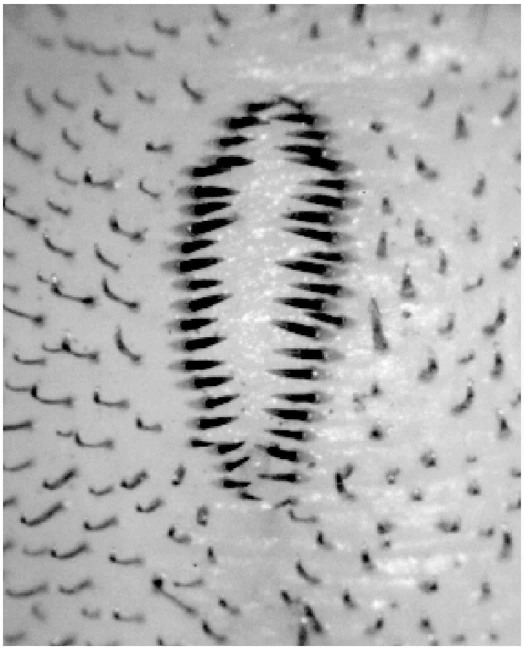

Figure 5. *Raster of southern 1-year canegrub.*

Southern 1-year canegrub has a 1-year life cycle with adults emerging in September-October following rain.

Third-stage grubs are found in the cane rows shortly after Christmas and continue feeding until late May. Larvae then descend to about 250–400 mm and pupate in late winter. Only males are attracted to light; females fly little. Neither sex feeds as an adult.

Management again relies heavily on suSCon® Blue, which is very effective against this species. Knockdown chemicals can be useful, but usually only in late-harvested ratoons that allow access in January when damage becomes apparent.

Other canegrubs

Other species of canegrubs are either very localised or, if widely distributed, of minor importance. Accurate identification is, however, important. Management depends on the life cycle of the species and generally follows that for southern 1-year canegrub if a 1-year grub and that for French's canegrub if a 2-year species.

Planiceps canegrub

Planiceps canegrubs, *Antitrogus planiceps* (Blackburn), damage sugarcane in the Harwood and Broadwater districts of New South Wales. They have been found in loams, silty loams, sandy loams and silty clay loams. Their raster pattern is pear-shaped with two palidia each with 32–39 long thin pali arranged in two rows posteriorly and towards the centre, and one row anteriorly. Palidia with lower numbers of pali lack part of the anterior portion of the rows. Adults are tan to black, without scales, and have 5-segmented antennal clubs.

The detailed life history of this species has not been determined. Third-stage larvae are present in the field in early summer. Beetles fly in October-December, but some autumn flights have also been recorded.

Rhopaea canegrub

Rhopaea canegrubs, *Rhopaea magnicornis* Blackburn, damage sugarcane at Rocky Point and Nambour in Queensland and in northern New South Wales, especially in the Tweed Valley. They usually cause typical 1-year type damage, but some individuals have a 2-year lifecycle and may damage recently harvested ratoon crops. Rhopaea canegrubs have a raster of two parallel palidia, each with about 20 short pali. Adults are dark brown, about 21–30 mm long, and with a coat of short, fine semi-erect hairs. Males have large, 8-segmented antennal clubs which are characteristic.

Rhopaea canegrubs have a 1-year or 2-year life cycle depending on weather conditions. Following a warm autumn, most larvae will pupate in August and emerge as adults in late October or early November. When the autumn is cool, a proportion of the population will feed through the following summer and complete a 2-year life cycle. Adults do not feed. Females appear not to fly and mate on the ground. Males are strong fliers, are attracted to lights, and use their large antennal clubs to detect pheromone-emitting females.

Nambour canegrub

Nambour canegrubs, *Antitrogus rugulosus* (Blackburn), occur at Didillibah and Bli Bli in the Moreton district, at Rocky Point, and in northern New South Wales, usually in sandy soils. They usually cause typical 1-year type damage, but progeny of late flights can feed in late winter and spring. Nambour canegrubs have a raster of two single convex rows of stout pali which converge towards each end. There are 19–31 pali in each palidium, most commonly 23–26, and larvae are difficult to separate from southern 1-year canegrubs. They sometimes occur with negatoria canegrubs, but are slightly smaller and have a different raster pattern. Adults are bright red-brown, without scales, but with short hairs on the upper surface. In males, the first segment of the antennal club is less than half the length of the remaining 5 segments; this character differentiates them from males of southern 1-year canegrubs.

Nambour canegrubs have a 1-year life cycle with non-feeding adults usually emerging in October–November following rain; some adults emerge as late as February in dry years. Third-stage grubs move into the rows in mid summer and feed through autumn and winter into early spring. Late-spring feeders may be the progeny of late-flying adults and could take 2 years to complete development. Only males are attracted to light; females fly little.

Noxia canegrub

Noxia canegrubs, *Lepidiota noxia* Britton, occur north of the Burnett River in the Bundaberg area in red and brown forest loams and scrub soils at Gooburrum, Sharon, Bingera and Yandaran and in coarse alluvial soils at Waterloo. They also occur at Nikenbah and Pialba at Hervey Bay, and at Yandina and west of Caloundra in the Moreton area. Damage from noxia canegrubs shows up in late summer and early autumn, usually later than damage from negatoria canegrubs. Root damage to otherwise well-grown crops causes the cane to topple and makes stools susceptible to removal during harvest. Noxia canegrubs have a raster similar to those of negatoria and French's canegrubs and often occur with those species. The head capsule width of mature noxia canegrubs is slightly smaller than that of negatoria canegrubs. Adults are dark red-brown with sparse oval white scales.

Noxia canegrubs have a 2-year lifecycle with adults emerging in September-October following storm rain. Larval development is complete by the end of the second autumn and adults remain in the pupal cells until spring rains.

Bundaberg canegrub

Bundaberg canegrubs, *Lepidiota crinita* Brenske, occur in southern Queensland and northern New South Wales, but damage sugarcane only at Bundaberg and Gin Gin, usually in forest loam and sandy soils. They cause typical 2-year type damage in spring or early summer. Damage most commonly occurs in young ratoon cane, but also in young replant and fallow-plant crops. Grubs have a raster of two parallel palidia, each with a single row of about 15 short pali, and with a naked path between the palidia. Adults are bright red-brown with the upper surface coarsely but uniformly punctured; each puncture has an elongate white scale about as long as the puncture (Figure 6). The antennal club has three segments; the first segment of the club is 1.5 mm long in males and 0.5 mm long in females.

Bundaberg canegrub has a typical 2-year cycle with adults emerging following rain in November-December. Adults appear not to feed and males are strongly attracted to lights. Bundaberg canegrubs are often found with negatoria canegrubs in forest loams and with Childers canegrubs in clay loams.

Figure 6. *Adults of Bundaberg (left) and Childers (right) canegrubs.*

Picticollis canegrub

Picticollis canegrubs, *Lepidiota picticollis* Lea, damage sugarcane in the Bundaberg area at Yandaran, Elliott Heads and Kolan, and in the Isis area at Logging Creek and Goodwood. They always occur in very sandy beach or forest soils. Damage shows up in late summer and early autumn, similar to damage from southern 1-year canegrub. Because the larvae are large, one per stool can do considerable damage. Grubs have a raster of two parallel palidia, each with 29–40 short, stout, dark pali. On some larvae, there is at the rear of each palidium a short second row of a few pali, parallel to the palidium proper. Larvae are the largest southern canegrub. They sometimes occur with southern 1-year canegrubs. Adults are large (range 25–32 mm long) and shining yellow-brown to deep chestnut with wingcases and thorax bordered in dark brown or black. Most have a distinctive orange-red patch on either side of the shoulders.

Picticollis canegrub has a 2-year life cycle. Larvae take 15 months to develop, pupate late in the second summer, and spend the second autumn and winter as adults underground. The adults usually emerge in September-October following storm rain, but some may emerge in summer or autumn.

Squamulata canegrub

Lepidiota squamulata Waterhouse is widespread throughout northern Australia and has been recorded in sugarcane fields from most regions. Common records include: Hawkins Creek, Absvold and Coolbie in the Herbert Valley; Giru, Dalbeg, Clare, Brandon and Airville in the Burdekin Valley; Blacks Beach, Andergrove and Shoal Point at Mackay; and the Elliott River near Bundaberg. Squamulata canegrubs are found only in sandy soils. They are common as lawn pests in the north. Squamulata canegrubs cause typical 1-year type damage in February-March. Mixed infestations with grata, grisea, sororia and French's canegrubs occur. Grubs have a raster of two straight palidia each with 28–40 short, stout (length:basal width ratio 2:1) pali. Palidia diverge slightly at their anterior ends. Head capsule widths of first-stage grubs are 1.8–2.7 mm, second stage 3.0–4.5 mm, and third stage 5.6–6.5 mm. Larvae can be confused with small greyback and grisea canegrubs. Beetles are 22–32 mm long, slightly larger than those of French's canegrubs. They are dark-coloured with oval white scales, prominent along the sides and underneath the abdomen and mid-section. The underside of the mid-section is almost devoid of hairs.

Squamulata canegrubs have a typical 1-year life cycle. Beetles fly after heavy rains in November-January and feed on eucalypt leaves before laying. Eggs hatch in 15 days. The first two grub stages are completed in a total of 8–12 weeks. The third stage occurs between February and May and they are fully fed and ready to pupate as early as May. All pupate by October and immature beetles are present in soil chambers from October.

Grata canegrub

Lepidiota grata Blackburn occurs throughout Queensland, mostly in light sandy soils. Damage is most common in the Burdekin and Herbert areas, but the species also occurs in cane at Proserpine, Mackay and Gin Gin. Grubs are often found in hot, dry soil under conditions that are not tolerated by other species. Damage by grata canegrubs is a combination of 1-year and 2-year types. Maturing crops are commonly stunted, but damage rarely causes lodging. The raster of grata canegrubs has two slightly curved palidia, each with a single row of 21 (range 18–26) elongate (length:width ratio 4:1) pali. Larvae are relatively small with head capsule widths of the three stages 1.9 mm, 3.2 mm and 5.0 mm, respectively. Larvae are often confused with small greyback canegrubs because of similarly shaped rasters. Beetles are relatively small, only 20 mm long. Elytra are dark brown and are uniformly covered with round white scales.

The life cycle of grata canegrubs varies in response to different field conditions. Beetles fly after rain in November and December. Under good crop growth, over 90% of larvae reach third stage by April and feed until June. Most larvae cease feeding in winter. Incompletely fed larvae recommence feeding in August. Fully fed larvae pupate in October and beetles emerge in November, completing a 1-year cycle. Remaining larvae and those from small, droughted or grub-damaged cane develop more slowly and complete a 2-year cycle.

Rothe's canegrub

Lepidiota rothei Blackburn occurs in forest country throughout northern Queensland and the Northern Territory. It has been recorded in canefields from Mossman to the Burdekin region. It rarely damages cane but grubs are very common in weedy fields and when grassy fallow fields are ploughed for planting. Rothe's canegrubs have a raster with a single, slightly curved row of 10–12 elongate pali in each palidium and the pali almost meet across the path between the palidia. Head capsule width of second-stage grubs is 3.4 mm, and third stage 5.0 mm. Large larvae superficially resemble small greyback and grata canegrubs. Beetles are smaller (range 15–19 mm) and darker coloured than other canegrub beetles, and do not have hairs on the ventral thoracic segments.

The species has an unusual 1-year life cycle. Beetles fly at dusk in early summer, and mate on low trees and shrubs. Second-stage grubs are present through winter, moult to the third stage in spring, and feed until October or November. Pupation occurs in November and beetles are formed in 24 days.

Caudata canegrub

Lepidiota caudata Blackburn has been collected from sugarcane at Babinda, Nerada, Silkwood, South Johnstone and Tully. Infestations occur in both alluvial and red volcanic clay loam soils. It lives near rainforest where preferred feeding trees exist and is a common pasture pest on the eastern Atherton Tableland. The extent of infestation by this species may be underestimated because larvae are similar to French's canegrub. Damage by caudata canegrubs is a combination of 1-year and 2-year types. The initial and most severe damage occurs from mid summer to autumn and then continues in spring. The raster of caudata canegrubs is pear-shaped, similar to that of French's canegrub, but usually with 32–40 pali in each palidium and with the palidia meeting at the front end. Beetles are shining brown on the topside with very small and inconspicuous scales, and have an almost bare area in the centre of the lower, rear segments.

Adults usually fly following rain in October-November. Most larvae become third stages by March, when symptoms of severe damage are evident. Large grubs feed until December or later, although most are fully fed by then. Pupation occurs in autumn, and immature beetles can be found in the soil in early winter.

Froggatt's canegrub

Lepidiota froggatti Macleay is confined to far northern Queensland in or near rainforest. Larvae are often recorded in cane on red volcanic loam 10 km west of Innisfail, often in association with caudata canegrubs. They cause typical 2-year type damage to ratoon cane in spring. One grub per plant can remove all roots and severely damage the underground stems as well. However, damage is not widely distributed or commonplace. The raster of Froggatt's canegrub has about 17 thick pali in each palidium. Palidia diverge towards the rear end. Pali are arranged in single rows at the front end with a second, inner row of slightly smaller pali at the rear end of each palidium. Larvae are very large with head-capsule widths of third-stage larvae about 10.5 mm. Beetles of *L. froggatti* are 30–38 mm long and are a dull felted brown colour due to the body covering of yellow-brown hairs.

Few details of the biology are known, but there appears to be a 2-year life cycle. Beetles fly after rain in October and November, usually at the same time as caudata and greyback beetles. Following a flight in October, small and well-grown first-stage grubs have been found in plant cane during December. Second stages are present in April, and partially fed third stages are found in ratoons during October.

Grisea canegrub

Grisea canegrub, *Lepidiota grisea* Britton, has been recorded in sugarcane at Yule Point near Mossman, and Behana near Gordonvale. It is suspected of damaging cane at Ayr and Ingham. It appears to prefer sandy soils. Little damage has been recorded from grisea canegrubs, but it occurs with other damaging species such as sororia and squamulata canegrubs. Grisea canegrubs have a raster of 26–34 short, stout, dark pali arranged in straight palidia. They can be confused with greyback and squamulata canegrubs, both of which have 1-year life cycles and occur in the same areas. Adults are 22–27 mm long with large white scales prominent over the entire dorsal surface. They are very similar to beetles of squamulata canegrubs. Grisea canegrub has a 1-year life cycle.

Sororia canegrub

Sororia canegrubs, *Lepidiota sororia* Moser, are found in sugarcane at Yule Point and Port Douglas near Mossman, and at Coolbie, Yuruga, Bambaroo and Braemeadows in the Herbert Valley. Beetles are common in dry areas at Smithfield near Cairns and near Arriga in the Mareeba Irrigation area. Larvae inhabit soils with relatively shallow subsoil, which can become almost waterlogged during the wet season. Grubs cause 1-year type damage and are often associated with grata and squamulata canegrubs in damaged cane at Ingham. Sororia canegrubs have an almost elliptical raster pattern, tapering at both ends, with about 45 long pali in each palidium. The pali are arranged almost in a circle around the raster, and the palidia almost meet at both ends. Beetles are relatively small (22 mm long), and light brown above with prominent white markings on the abdomen and the upper terminal segment due to densely packed body scales.

L. sororia probably has a 1-year life cycle, but the details have not been determined fully. Beetles fly as early as August, but more commonly in November and December, and often without a stimulus from rainfall.

Soldier flies

Sugarcane soldier fly, *Inopus rubriceps* (Macquart), occurs in red volcanic soil at Innisfail, in silty loam soil at Macknade (Herbert River), and more extensively in mill areas from Proserpine south to Harwood in New South Wales. The yellow soldier fly, *Inopus flavus* (James), occurs at Ayr, Proserpine, Mackay and Plane Creek. A further undescribed species has been found in sugarcane at Giru. The sugarcane soldier fly inhabits a wide range of soil types from red volcanics to sandy alluvials. The yellow soldier fly favours drier soils, but the two species may occur together on medium soils.

Larvae (Figure 7) feed on roots, including sett roots. Small larvae cut hairs from the roots. When larger, they burrow their heads and forepart of their bodies into the roots, making visible cavities. These cavities resemble asymmetric cones, distinguishing them from the cylindrical cavities made by symphylans.

Larvae may reduce germination if present in sufficient numbers at planting. More commonly, the larvae cause poor ratooning with underground buds failing to germinate after harvest. Affected stools produce few or no shoots, resulting in sparse growth or gaps in the field. Stools on the margins of cane blocks are frequently less affected. The effect on ratooning seems out of proportion to the damage caused to the root system, and the mechanism of ratooning failure is unknown. Injection of a toxin into the plant by larvae has been suggested as a possible cause, but not proven. Larvae will feed on the roots of plants other than sugarcane. Native grasses are their natural host, and infestations may develop quickly when grasslands are first brought under cane. They will also feed on introduced grasses and cereals, legumes, and some vegetable crops.

Figure 7. *Soldier fly larva.*

The adult female fly has a body about 12 mm long which tapers to the rear, lightly smoky wings, a coloured head and small black eyes. The sugarcane soldier fly female has a black body and orange-red head, whereas the yellow soldier fly has the body, head and legs orange-yellow. The male soldier fly is about two-thirds as large as the female and has large black eyes that occupy most of the head; the sugarcane soldier fly male has body and head dark grey-brown, whereas the yellow soldier fly male has a black body, brown-black head, and yellow legs.

Larvae of the two species are very similar, being legless maggots with tough-skinned segmented bodies, circular in cross section and tapered towards both ends with numerous hairs along the body and a dark brown head capsule. The pattern of hairs differs between the species. The larvae are white to brown, 1 mm long at hatching and up to 14 mm when fully grown. Female larvae grow larger than males. Eggs are white, elongate-cylindrical with rounded ends, and 1 mm long.

Adults of the sugarcane soldier fly emerge from March to July, depending on weather conditions, with peak emergence usually in May. The yellow species emerges earlier with the peak usually in April. Males emerge before females. Adults emerge during the morning. Females are sluggish fliers and tend to rest on weeds or cane leaves, while many males swarm actively less than 1 m above the ground. Females usually mate and lay eggs on the day of emergence, and live for only a few days. Eggs are laid in clumps of up to 200 about 10 mm below the soil surface, sometimes in cracks in the soil, or between the soil and overlying rotting vegetation.

They hatch in 1–3 weeks depending on temperature and the larvae then go down to feed on roots.

Larvae mature into adults in 1 or 2 years and have from seven to twelve stages. One-year adults develop after fewer stages than 2-year adults do, and males generally have fewer stages than females. Larvae concentrate along the sugarcane rows, and are usually found within 150 mm of the soil surface throughout the year. They occur deeper in summer than in winter. Larvae pupate within 10 mm of the soil surface. The pupa is formed inside the last larval skin (puparium) which becomes slightly flattened, and a cap behind the head becomes easily detachable to allow the fly to emerge. The pupal stage occupies about 1 month.

Larvae are difficult to find in winter, as most are very small. However, a proportion of large larvae may still be present, these having entered a second year of development. Pupal cases can be found on or just beneath the soil surface for several months after adult emergence and are a good indicator of soldier fly infestations. Larvae are most easily found from about October through to April.

Natural enemies, including parasitic wasps and the fungal pathogen *Metarhizium anisopliae*, attack the immature stages, and predators eat the vulnerable pupae. It has been suggested that the heavy damage recorded during the 1960s resulted from removal of the soldier fly's natural enemies by the insecticide BHC, which had been introduced for canegrub control.

No insecticide is registered for the control of soldier flies. Instead, growers need to adopt management practices that lower pest numbers while encouraging more natural enemies, and that allow the crop to tolerate some damage. The major ideas behind management are, firstly, that the main source of soldier flies in ratoons is the larvae in the field at planting; these give rise to flies that breed and multiply each year. Secondly, grasses are the primary food plants of soldier fly larvae. Egg laying and larval survival are reduced if grasses are absent. Thirdly, the build up of soldier fly larvae is slowed by a range of natural enemies, especially predators of pupae and eggs, and the fungal disease *Metarhizium*. These natural enemies will control numbers in the long term. Fourthly, natural enemies are more common in older ratoons and are killed by cultivation when crops are ploughed out. Lastly, the effects of feeding by soldier flies will be minimised if conditions for ratooning are favourable.

Six steps are recommended to control soldier flies. Affected blocks should be ploughed out as early as possible in the harvest season. This will increase the length of the fallow period, destroying food while larvae are small and vulnerable. Secondly, fallows should be grass-free, e.g. a herbicide fallow after sprayout of old ratoon under trash or a rotation with a non-grass crop such as soybeans. Larvae will then starve without grasses as food. Thirdly, new crops should be planted late, after the flight period, i.e. after June. Here, flies are less likely to lay eggs if no cane or grasses are present during the flight period. Fourthly, planting should follow minimum tillage following the herbicide fallow. By minimising soil disturbance, natural predators will be preserved in the soil. Fifthly, varieties that ratoon quickly should be planted. Soldier flies will cause less damage if ratoons come away quickly. Sixthly, plant and early ratoon crops should be harvested when ratooning conditions are good. This will ensure that effects of feeding are minimised. Crops should not be ploughed out and replanted or crops planted early in autumn after a badly infested ratoon crop.

Wireworms

Several species of wireworms are found in canefields. The major incidence of sugarcane wireworm, *Agrypnus variabilis* (Candèze), is in wetter, poorly drained soils in central districts and at Ingham. It is an occasional pest in poorly drained parts of fields north to Mossman. *Heteroderes* and *Conoderus* spp. wireworms predominate in southern districts. Other wireworm species damage cane, including some 'round' wireworms. Larvae are difficult to identify, and the whole group requires taxonomic revision.

Wireworms (Figure 8) are larvae of click beetles. The adult of sugarcane wireworm is up to 15 mm long and grey-brown. The larva grows to 20 mm long and has a firm, slightly flattened, shiny creamy-white segmented body with a hard yellow head and hard yellow forked rear end. *Heteroderes* spp. wireworms are larger than this, more orange, with a median V- rather than U-shaped notch between the central horns on the anal plate. Round wireworms have cylindrical bodies with a less prominent head, are pale brown to red-brown, and have the rear end tapered to a point.

Wireworms bore into the eyes of germinating setts or ratooning stubble, or into the growing point on young shoots. Entry is by a small (less than 2.5 mm) circular hole, and the rear part of the larva may protrude during feeding. Symptoms of damage are poor or patchy germination and dead spindle leaves ('dead hearts'). Large shoots may compensate for damage by producing basal secondary shoots.

Beetles of sugarcane wireworm emerge during November-December and lay eggs in the soil. Eggs hatch in about 8 days. Larvae require wet soil during the first 3 weeks after hatching, but can withstand drier conditions thereafter. Eight larval stages occupy a total of 10 months. Hence, larvae in central districts are pests chiefly of autumn plant-cane. Damage is less likely in spring plant-cane when larvae are almost fully fed and approaching pupation. The pupal stage lasts about 2 weeks.

Figure 8. *Wireworm.*

Wireworms will eat other soil insects, including soldier fly larvae and canegrub eggs and young larvae. However, damage caused to cane is thought to outweigh any beneficial activity.

Two insecticides are registered for control of wireworms. Chlorpyrifos is registered, either as an emulsifiable concentrate (e.g. Lorsban® and Chlorfos®) at 1.5 L of product per hectare, or as the controlled-release granule suSCon® Blue at 21 kg of product per hectare. The liquid is registered only against sugarcane wireworm and suSCon® Blue is registered only against *Heteroderes*. Bifenthrin (as Talstar®) is registered at 375 mL of product per hectare against sugarcane wireworm. The liquids are sprayed over the setts at planting, while suSCon® Blue must be applied at planting to be effective. Varieties that do not tiller vigorously are probably more prone to wireworm damage in ratoon crops.

Armyworms

Armyworm outbreaks occur in all areas. Several species of three types occur in all sugar-producing regions of Australia; night-feeding armyworms, *Leucania* spp. and *Mythimna* spp., day-feeding armyworms, *Spodoptera* spp., and sugarcane looper, *Mocis frugalis* (Fabricius). The night feeder *Mythimna separata* (Walker) is the most common species. In autumn and spring, night-feeding armyworms can infest young plant cane and ratoon shoots. In summer, day-feeding armyworms and, rarely, sugarcane loopers infest well-grown cane. Armyworm infestations most commonly occur in trash-blanketed ratoon fields.

Armyworm caterpillars (Figure 9) eat the leaves of cane. Bare leaf midribs are all that remain after severe defoliation. A single defoliation in spring or early summer may not cause any measurable crop loss, but successive defoliations can cause considerable crop loss. Yield losses are likely to be higher in the south as cane regrowth is restricted by the cooler temperatures. Severe defoliation weakens shoots under stress, and subsequent weed competition suppresses crop growth.

Night-feeding armyworms shelter in rolled spindle leaves or under leaf litter during the day, and feed mostly at night. Caterpillars range from pale olive-green to ochre with longitudinal body stripes of white, red-brown and dark colours. The head is a mottled tan without any prominent white markings. Fully grown larvae are over 40 mm long. Pupae form under trash or 10 mm underground in small chambers. Moths have uniform buff-coloured forewings with prominent venation. There is a line of small dark specks on the outer portion of the wing and a single white speck near the centre. Hindwings of *Leucania* are mostly white, whereas *Mythimna* have a large dark area on the outer half of the hindwing. Caterpillars can often be confused with others that feed only on trash.

Young caterpillars of day-feeding armyworms are bright green with tan head capsules. When about 20 mm long, they develop dark green, almost black, longitudinal stripes, and a prominent, inverted Y-shaped white line on the front of the head. Fully grown larvae are 25–35 mm long. Larvae feed on leaves and move about during daylight, commonly forming dense, black swarms as they migrate in search of food. Pupae are found in small vertical chambers just under the soil surface. The moth is small,

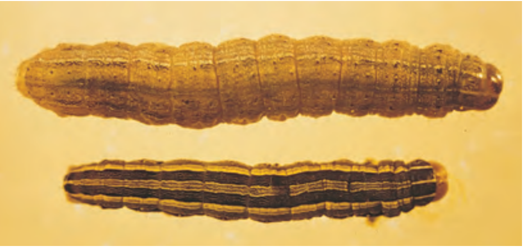

Figure 9. *Armyworm caterpillars.*

about 14 mm long, and has dark-coloured forewings with small white lines in the central area. The hindwings are pale with a light pink tint and a dark border.

Caterpillars of sugarcane loopers are long and slender, green or yellow-brown with two transverse black bands on the front part of their body. They move by shifting the raised front section forward and clasping the surface with their front legs, then releasing the hind claspers from their support and drawing the rear section forward in a 'looping' motion. During the day, caterpillars hide by remaining motionless along the margins of leaves. They make a tubular pupation chamber by rolling the opposite edges of a leaf tip together. The adult is pale buff with a dark stripe running obliquely from the apex to the hind margin of the forewing.

Rotting plant debris stimulates moths of night-feeding armyworms to lay eggs. Previously flooded fields with silt-covered leaf litter and recently harvested trash-blanketed ratoons with a distinct fermentation odour are often infested. Caterpillars will move to adjacent cane when they have completely eaten the original food source. The life cycle takes about 8 weeks, and each generation is normally highly synchronised with only one brood at a time. Within a field, there is usually only one major infestation in a season, after which the field no longer remains attractive to ovipositing moths. Rarely, successive broods follow close together, giving shoots little opportunity to produce new growth.

Day-feeding armyworms feed day and night and characteristically move as a band from one food source to another. Between December and February large numbers originate in grass, weed-infested canefields, lawns, headlands and creekbanks, before moving into cane. Each generation takes 4 weeks in mid-summer.

Sugarcane loopers originate in grass-infested cane or in grass-infested legume cover crops, and migrate into cane.

Several species of tachinid fly and at least one species of ichneumonid wasp internally parasitise armyworms. Parasites do not complete their life cycle until the caterpillar pupates and parasite pupae can be found inside the moth pupal case. Parasites are normally very active in canefields in all regions, but require at least one armyworm generation to increase their numbers to a beneficial level. Several viral and bacterial diseases also commonly infect armyworms. Diseased armyworms turn black and hang suspended from cane leaves. Second-generation larvae are usually heavily parasitised and infected by disease organisms.

Spraying armyworm infestations is often not recommended. Each field will normally receive only one major infestation in a year. Most of the defoliation has usually occurred before an infestation is noticed and the crop sprayed. Early spraying of the first generation of armyworms also eliminates parasites and reduces the natural build-up of disease organisms. A series of defoliations in early- to mid-season, particularly in damaged, weed-infested or otherwise weakened crops, may cause sufficient loss to warrant insecticide use. This will be more important in the south as cooler temperatures inhibit cane growth. The identity of small caterpillars found under the trash should be checked to make certain that they are actually armyworms before deciding that insecticides are necessary. Insecticides registered for control of armyworms are chlorpyrifos (e.g. Chlorfos®, Lorsban®) at 700–900 mL of product per hectare, permethrin (e.g. Ambush®, Pounce®) at 200–400 mL of product per hectare, and trichlorfon (Dipterex® or Lepidex®) at 900–1100 mL of product per hectare. For best results crops should be sprayed late in the afternoon when temperatures are lower and insecticides degrade more slowly. This is also when night-feeders are active.

Ground pearls

Pink ground pearls, *Eumargarodes laingi* Jakubski, occur mainly on red volcanic soils around Bundaberg, but can tolerate sandier soils. White ground pearls, *Promargarodes australis* Jakubski, occur on all soil types in all mill areas. Two other species of *Promargarodes* have limited distribution in cane.

Nymphs of all species form cysts in the soil and feed on roots through long feeding tubes. Areas affected by pink ground pearls show poor crop growth patches that expand as the insects spread. Initial symptoms are stool stunting and leaf yellowing, eventually ending in stool death. Infestations often show linear patches along rows, suggesting spread by cultivation. Yield losses of about 75% of the crop can occur.

The effects of white ground pearls are similar, but more variable. In some quite heavy infestations, no effect on growth has been detected, and the relationship is sometimes confused by the infestation being higher in sandier parts of fields. Up to 10 000 cysts of white ground pearls have been collected from the soil under and around one stool in a very heavy infestation. However, numbers of both white and pink ground pearls are normally less.

Adult female earth pearls closely resemble mealybugs, but do not have a white powdery covering and have hooked front legs (Figure 10). Pink and white ground pearls are named from the colour of the adult female. No adult males of the pink species are known. Nymphs of ground pearls are enclosed for most of their lives in a spherical, shiny cyst that crumbles like mica when rubbed. The

Figure 10. *Adults of pink ground pearl and white ground pearl.*

cyst of the pink ground pearl is creamy to brown, the covering tough, not shiny, and the strong pink colour of the adult becomes apparent through the covering when the adult is almost ready to emerge. The cyst of the white ground pearl is harder and glossy white to yellow.

Adults emerge mostly during October-January with a few in September and February. Ground pearl females are often numerous on the soil surface in the late morning. After a few days, the female forms a small cavity in the soil, extrudes into that a mass of fine white filaments and among that deposits up to several hundred eggs. She then dies. Eggs hatch in 2–4 weeks, yielding tiny white mobile nymphs that have normal legs and antennae. In 2–3 weeks, the nymph has settled alongside a root, commenced to enclose itself in the cyst, and lost legs and antennae. An extremely fine feeding tube, several times as long as the nymph, is sent out through a pore in the cyst when feeding, and withdrawn and coiled up in a body cavity during non-feeding intervals. As the nymph grows, it develops new cyst layers from the inside, pushing the old layers outwards. Ground pearls have a 1–4 year life cycle.

Infested fields should be fallowed from cane for 12 months and ploughed and rotary hoed during that period. Non-grass crops can be grown during the break from cane. This will reduce numbers, but not eliminate the pest. Some cane varieties (e.g. Q135, Q147, Q182) are more tolerant of pink ground pearls than others. The soil fumigant metam-sodium (Metham®, Vapam®) can reduce pearl numbers in plant crops, but numbers will increase in ratoons unless resistant varieties are grown.

It is of utmost importance that all machinery working in areas infested with pink ground pearls be cleaned thoroughly before moving to other fields. This is especially important in spring-summer when adults, eggs and young nymphs can be transported easily in moist soil attached to implements and vehicles.

Sugarcane weevil borer

Sugarcane weevil borer, *Rhabdoscelus obscurus* (Boisduval), is common in cane in all mill areas north from the Herbert Valley and is an occasional pest in the Mackay and Burdekin regions. It was introduced to Australia, Hawaii, Fiji and other Pacific Islands from New Guinea. In Australia, the insect is now common in rainforest, where it colonises palms. It is a common pest in palm nurseries and has been collected in palms transported to weevil-free areas in the south.

Weevil borer larvae bore internode tissues of mature and semi-mature stalks. The major loss is due to red rot and related decay organisms that invade damaged internodes, reducing sugar content. Damaged stalks are also slightly lighter, and have higher fibre content and higher dextran impurities in juice. On otherwise healthy stems, damage is confined to basal internodes that are invaded when the stem is young and soft. Stems which have been split and twisted in cyclonic wind are prone to heavy damage, as are stalks infested with top rot or damaged by rats or large moth borer. Bored stalks sprawl and lodge after strong wind, particularly in autumn. Weevils may also enter underground parts of stems.

Larvae are legless and cream with an oval red-brown head, red-brown mouthparts, and a dorsally flattened and pointed abdomen. Each larva lives in a separate tunnel. Fine sawdust-like waste material is packed tightly into the tunnel behind the larva. Oval pupation chambers of tightly bound fibre are characteristic. The adult is a dark-coloured weevil 12–15 mm long with a distinctly curved snout and red patterns on each wingcover (Figure 11).

Adult weevils hide in trash or under leaf sheaths during the day. At night they walk and fly about to feed, mate and lay eggs. Top-rot infected fields and split or cracked canes attract adults from long distances. Adults chew small cavities into the rind or split tissue of suitable cane, and lay a single,

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Figure 11. *Adult weevil borers.*

long, curved egg into each hole. Larvae hatch and burrow into the internode tissue, packing the tunnel behind with chewed fibre and waste. They require mature or semi-mature cane with expanded internodes to complete their development, but can develop in sound billets and tops that resist drying. Larvae develop in about 12 weeks. They then chew small exit holes in the rind as an escape route for the adult and pupate in fibrous cocoons. Under favourable conditions, weevils complete three generations a year, and adults can survive for 10 months.

Weevils breed most successfully in canes with soft rinds and low fibre content. Current plant selection of varieties with higher fibre content and harder rinds does not favour weevil borer.

During the 1930s when unburnt cane was harvested manually, windrowed trash, tops and lengths of cane partially buried in soil provided ideal conditions for weevil breeding and survival of adult weevils between crops. From the 1940s, weevil damage was eliminated where preharvest burning of trash and burning of crop residues were introduced. From the mid-1970s, mechanical harvesting of unburnt cane and surface retention of crop residues have been associated with more weevil borer adults and damage. Crop residues left by harvesters provide shelter for adults, and, if billet-sized, can allow breeding.

A combination of options is useful for managing borer damage while retaining a green-cane trash-blanket system. Billets, whole stalks and cane attached to tops that are left after harvest allow borers to continue breeding. Borer harbourage can be reduced by ensuring that harvesters are operating efficiently, using a shredder-topper to break up cane attached to tops, and using a trash mulcher to break up pieces of cane left after harvesting. Borers also readily invade damaged stalks, especially those caused by rat damage. It is important to control rat damage. Varieties such as Q117, Q135, Q161, Q175[ɸ] and Q178[ɸ] are most resistant to borer damage and should be used where possible. The insecticide fipronil (Regent®) can be applied December-February when the crop has produced its first millable internode of cane. The insecticide should be applied at 5.7 mL per 100 m of row to cover the base of the stools and up the stalk to a height of 400 mm with the soil and trash on both sides of the stool treated to 100 mm on either side. Monitoring using billets wrapped in black plastic may be useful to confirm the presence of beetles. Weevil borer can be spread in infested planting material. Strict quarantine of sugarcane and palms should be observed. The only known parasite of weevil borer is a tachinid fly, *Lixophaga sphenophori* (Villeneuve), introduced from New Guinea in 1911. This parasite is established in Australia, but is rare.

Black beetles

African black beetle, *Heteronychus arator* (Fabricius), occurs from Maryborough south. An accidental importation from Africa, it was recorded in New South Wales in 1920, at Rocky Point in the 1950s, Moreton in 1979 and Maryborough in 1990. It could probably breed further north. Strict quarantine should be observed against transfer of live specimens or contaminated material. Native black beetle, *Metanastes vulgivagus* (Olliff), is a similar native insect and occurs in all cane areas, but is more prevalent in areas with wetter soils. Both species are associated with paspalum and similar grasses.

Adults of both species damage both plant and ratoon cane. They chew ragged deep cavities into young shoots, causing dead hearts. A shoot attacked near the base cannot recover, but shoots attacked above developing nodes are likely to compensate by developing basal secondary shoots. For this reason, it is not unusual in northern Queensland for a satisfactory stand of cane to develop where there has been quite heavy attack. In southern Queensland, attack by either species is much more prevalent and intense in spring than in autumn. However, damage by native black beetle in northern Queensland occurs as much in autumn as in spring. In southern Queensland, damage from African black beetle is most common when cane is newly planted into ground previously under grass.

Grubs of both species grow to 25–30 mm long. The soft part of the body is blue to grey-white, and the head rough surfaced and dark red-brown. As neither species has a characteristic raster pattern, they and the redheaded whitegrub, *Dasygnathus dejeani* Macleay, a harmless feeder on decaying vegetable matter in the soil, are not easily distinguished. However, the head of *Dasygnathus* is dark red rather than red-brown.

Beetles of the two species are very similar in appearance, being shining black above, red-black underneath, with the upper surface of the thorax smooth and the wingcases with several parallel fine ribs along their length. Native black beetle is usually about 15 mm long, and African black beetle is slightly smaller, 9–15 mm long. The head of *M. vulgivagus* bears two tubercles and has the anterior rim at the front upturned to two points; these characters are not present in African black beetle.

There is one generation of each species each year. The beetles mostly emerge from midsummer until the end of autumn and then hibernate during winter. They become very active in spring, when their voracious feeding results in damage to cane. Egglaying begins early in September and continues until February. Eggs of both species are laid singly in soil. They hatch in about 4 weeks in the cooler spring weather, this period decreasing with rising temperature to 2 weeks in December. The three grub stages of both species take about 3 months together and the pupal stage 2 weeks, so there is considerable overlapping of stages present during the reproductive spring-autumn period. The grubs feed mainly on organic matter in the soil, but as third stages may feed voraciously on roots of grass, the favoured habitat.

When land under heavy grass is broken up for planting cane, the infestation which may be present should be reduced or eliminated by intensive cultivation and, if possible, a fallow of several months. Legumes are not favoured hosts, and a legume cover crop may discourage reinfestation. Autumn planting is preferred to spring planting, because beetles are less active in autumn and the autumn-planted cane will have grown too large to be susceptible to damage when the beetles become active in spring. Chlorpyrifos (e.g. Lorsban®, Chlorfos®) is available for control of African black beetle in plant cane, at the same application rate as used for wireworms, 1.5 L/ha.

Funnel ants

Funnel ants, *Aphaenogaster pythia* Forel, are regarded as pests of sugarcane in areas between Mossman and Tully. They naturally inhabit areas of wet sclerophyll forest adjacent to rainforest and are often associated with blady grass. Granitic gravel loams and some sandy clay loams are the preferred soil types. Funnel ants are found at Ingham and Bundaberg, but do not cause damage to sugarcane in these areas.

Funnel ants construct mounds of loose pellets of earth and subsoil along the cane rows. Burrowing and soil inversion activity loosens soil about the root mass, so that stools are not firmly anchored. Weakened stools sometimes pull out during harvesting, and soil from mounds contaminates cane for milling. Plants also suffer moisture stress in dry conditions. Root masses of infested stools are often reduced, perhaps due to root damage by ants.

Mounds are up to 250 mm in diameter and 200 mm high with conical sides and a funnel-shaped opening at the top. Worker ants can be found by digging into the mounds and below ground, but are not easily found during the day. Workers are honey-coloured and about 5 mm long (Figure 12). They do not attempt to bite. Sexual stages are darker-coloured and have wings; males are 5.5 mm long and females 11 mm long. Funnel ants can be distinguished from other yellow ants by two backwardly directed spines on the rear segment of the thorax.

Sexually mature ants swarm from nests in mating and dispersal flights during November. Mating takes place in the air, and females return to the ground to commence new colonies. The total development period for worker ants is 49–60 days. Tunnels 7 mm in diameter are excavated under the stool and into the subsoil. In deep sandy subsoils tunnels can be deeper than 2 m. Ants do not tunnel into clay subsoil. Oval chambers 50 mm by 20 mm are constructed for brood rearing. Ants inhabit shallow chambers in the stool zone during the wet season and deeper chambers during the dry.

Funnel ants are probably omnivorous, feeding on bodies of dead insects and honeydew secretions. Ants lacerate roots and lap at sap exudates when small colonies are caged with cane plants. They also care for several species of planthopper that share ant tunnels and feed on cane roots; ants feed on sugary exudates from the planthoppers.

Figure 12. *Funnel ant.*

Funnel ant activity is estimated by numbers of mounds present. In healthy crops, up to 3500 mounds per hectare will not reduce yield below that of uninfested parts of the field. In second ratoon crops of highly susceptible varieties, reduction of mound densities from 4500–11 000 per hectare to 2200 per hectare or fewer resulted in a 20–30% yield increase. Of current varieties, Q107 and Q120 are particularly prone to damage. No insecticide is registered for the control of funnel ants.

Cicadas

Both brown cicada, *Cicadetta crucifera* (Distant), and yellow cicada, *Parnkalla muelleri* (Distant), are common in all regions of coastal Queensland. Brown cicada has damaged crops at Mossman, Mulgrave, Tully, Abergowrie, Proserpine and Fairymead. Yellow cicada has damaged crops at Mulgrave and in the Burdekin region. Green cicada (*Cicadetta* sp.) has damaged crops at Gin Gin.

Ratoon stools heavily infested with cicada nymphs fail to ratoon. Lightly infested stools ratoon poorly and fields have a gappy appearance. Sometimes, small ratoon shoots become yellow and withered at the tips and margins and die. Zones of poor growth surround areas of complete failure. Damage is most common in old ratoon crops. Light damage occurs with as few as 20 nymphs per stool, while moderately damaged stools commonly have 40–60 nymphs, and heavily damaged (dead) stools have 80–300 nymphs per stool. Recent emergence or disease epidemics rapidly reduce numbers of nymphs.

Cicada nymphs have sucking mouthparts. They construct tunnels in the soil, using their flattened and hardened forelegs as burrowing and plastering tools. The forelegs do not change in size throughout the stage, and can be used to identify each growth stage. Brown cicada nymphs have dark brown or black bands on the posterior margin of each abdominal segment, and pronounced marking on the thorax. Yellow cicada nymphs have clear bands on the posterior margin of each segment, and pale cream colouring and markings on the thorax. Final-stage green cicadas have green abdomens. Adults of brown and green species are 14–18 mm long with two pairs of clear wings, large compound eyes, and sucking mouthparts held ventrally between the forelegs. Brown cicada males are dark-coloured and the female is pale bodied with a prominent ovipositor projecting 6–8 mm behind the tip of its abdomen. The yellow cicada has a black Z-shaped mark in the outer part of each forewing. Both sexes of the yellow cicada are cream-yellow, and the female has a small inconspicuous ovipositor.

Most research has been conducted on the brown cicada. Few details are known of the yellow or green cicadas, but all species have many features of their biology in common. Eggs are laid in punctures in the midribs of sugarcane leaves. Brown cicada makes a series of elongate ragged punctures with raised tufts of broken leaf fibre along the lower side of mature green leaves towards the base of the plant. Females also lay eggs in flower stems of crowsfoot grass and nutgrass, and in the midribs of blady grass.

Yellow cicada lays into midribs of dead leaves, creating small, conical and only slightly raised punctures along the lower margin. Females will also lay in dry leaf trash and billets, poles, and stems of dead weeds such as blackberry nightshade. Eggs of the brown cicada hatch 8 to 11 weeks after laying. Up to 40% of eggs are destroyed by larvae of microscopic wasps. Between early March and April, small (2 mm) nymphs wriggle out of their chamber, then drop to the ground in search of cracks and crevices through which to enter the soil. Predation during this period, particularly by the coastal brown ant, *Pheidole megacephala* (Fabricius), is the most significant biological control on the brown cicada in sugarcane fields.

Nymphs construct galleries alongside one or more roots and suck sap from the vascular tissues. Development is completed in the gallery. After about 8 months, fully grown nymphs emerge above ground between November and February to moult into adults (Figure 13). Emergence commences on sunny days shortly after rain, and ceases if overcast conditions persist. Nymphs climb onto a support and hang backwards. The adult forces its way from the nymphal skin and then hangs for a short time to expand its wings and harden its body. Adults can fly within 30 minutes. Males emit mating calls from vantage points. Females come to the males, mate once and commence egglaying within 24 hours. The average number of eggs is 250 and adults live for up to 7 days. Adult brown cicadas will move up to 150 m into small, gappy crops less than 0.75 m tall, but move only 5–10 m into fields with a dense canopy 2 m high. Adults emerging from grassland adjacent to cane prefer to oviposit into grass. The brown cicada commonly infests blady grass and is often forced to fly into cane if the grass has been burned, denying adults food, and shelter and oviposition sites.

No insecticide is registered for controlling cicadas. Damage by both brown and yellow cicadas is controlled by cultural methods

Figure 13. *Adult cicada emerging from nymphal skin.*

using a planting rotation designed to break the cycle of migration and reinfestation from infested fields to clean ones. Once the cycle of infestation has been broken, farmers are able to return to continuous cropping cycles without cicada infestation redeveloping. All severely infested fields and parts of fields should be ploughed soon after harvest, and the area fallowed over the summer flight period. Ploughout destroys over 90% of nymphs in the soil and disrupts the survivors sufficiently to prevent adult emergence. Fallowing ensures that the few survivors soon perish and do not establish 'nucleus' mating colonies that attract immigrants into the newly planted crop. Lightly infested fields should be managed to prevent further expansion of the infested area. Infested old ratoons adjacent to younger non-infested fields should not be kept, and the margins of infested fields should be destroyed and fallowed. This creates a small border which adult cicadas are reluctant to cross. Any portions showing ratoon failure or heavy infestation should be ploughed and fallowed, as these areas are unlikely to produce significant crop growth and are the major source of further population expansion into new areas. Priority should be given to fallowing these fields after the next harvest.

Symphylans

Symphylans, *Hanseniella* spp., are present in all districts and on most soil types. Damaging infestations have occurred from Mossman to Babinda, at Tully, in the Herbert Valley, and at Mackay and Gin Gin. The most severe damage has been on coarse-grained granitic sandy loam at Mossman and Tully, and on clay loam soils at Macknade.

Symphylans eat actively growing root tissue and root primordia (buds). All stages excavate small (0.5–1.0 mm diameter) cylindrical pits through the soft fleshy cortex (outer tissue) of roots, as far as the central stele. Root elongation stops when the growing point is damaged, and the root branches. Often the side branches are also stubbed, and the plant develops a small restricted root-ball. Damaged plants wilt easily in dry weather. Damaged plant cane is usually very slow to develop secondary tillers. Damage most often occurs to sett and shoot roots of young plant cane, but mature crops can sometimes show signs of severe infestation. Severe damage is sporadic and is mostly associated with planting in May and June followed by a cold, wet winter. Damage can persist into spring months, resulting in poorly tillered crops with few stalks.

Symphylans are 5–10 mm long, elongate, white or cream in colour, and resemble miniature centipedes. They have two long slender antennae and 12 pairs of legs when mature. They live in cracks and soil crevices, often concentrating in the small cavity at the base of the shoot, and can be very difficult to find.

Symphylans are present all year round. Females lay clusters of 10–20 eggs that they tend until hatched. Immature symphylans resemble the adults, but have fewer legs. Populations increase rapidly when decaying vegetable matter is available, such as when a legume cover crop is ploughed in. Symphylans use natural cracks and crevices to move around and between roots, and are most active in loose soil or naturally cracking loams.

Spring plantings are not normally damaged as rapid germination and root growth seems to outstrip the ability of symphylans to stunt the root mass. Anything that promotes quick germination of setts also appears to reduce damage. The insecticide chlorpyrifos (e.g. Lorsban® or Chlorfos®) sprayed over cane setts at planting at 2 L per hectare is registered for controlling symphylans in sugarcane.

Field crickets

Black field crickets, *Teleogryllus* spp., live in soil crevices in damp locations near drains and water channels, and in loam soils which form deep cracks. They have been recorded as pests at Babinda and on new expansion areas near Clare in the Burdekin region.

Crickets damage plant cane, particularly in wet areas or in heavy soil where setts are planted close to the surface. Adults and nymphs eat out swelling eyes on setts, leaving a shallow, cleanly scooped-out depression in the bud area, and eat young shoot spikes as they emerge above ground. Extensive damage to buds necessitates replanting gaps. Damaged shoots usually sideshoot with little yield loss.

Adults and nymphs are shining black or brown with hind legs modified for jumping. There is a strongly patterned area of venation on top of the folded forewings. Antennae are long and slender. Females have a long ovipositor protruding behind the tip of the abdomen (Figure 14).

In wet areas, crickets live in burrows and crevices in soil along banks of channels and drains. In dry areas, they shelter in deep cracks in dry soil, moving close to the surface and hiding under vegetation and loose soil when the soil becomes wet. When furrows in plant cane are wet, the crickets can be found under loose soil crumbs in the hilled-up portion of the interspace during the day. They emerge and feed at night. Nymphs behave like adults. Crickets can be detected by the calling songs of the males.

Crickets are sporadic pests. No insecticide is registered for cricket control in sugarcane, and chlorpyrifos sprayed for wireworm control does not appear to control crickets. Slightly deeper soil cover over setts appears to reduce damage.

Figure 14. *Adult field cricket.*

Mole crickets

Mole crickets, *Gryllotalpa* sp., occur in all cane areas, but are usually pests only in areas of poor drainage. They burrow underground and gnaw at eyes and young shoots on germinating setts. They may bore into the sett, making a characteristic clean-cut circular hole.

The adult is a strong-bodied insect, 25–30 mm long, covered with dull velvety dark brown to grey-brown short hairs. The head is blunt and broadly convex and there is a restriction between the thorax and abdomen. Wings are folded flat on the back of the body, and the forewings reach only about halfway back over the abdomen. Legs are short and stout, and are usually held close to the body; the first pair are broadened and strongly clawed for burrowing. Cerci about 5 mm long protrude from the rear of the body. Nymphs are similar, except they are smaller and do not have wings.

Mole crickets feed at night and adults are attracted by lights. Mole crickets make deep permanent burrows in the soil. In damaged crops, they can be found more readily by following the burrows than by digging around damaged setts. Eggs are laid in a chamber in the soil and the nymphs take several months to develop to adults.

Damage usually occurs before mole crickets are seen. Damaged setts should be replaced. No insecticide is registered for control of mole crickets.

Locusts

All locusts are sporadic pests, usually originating from outside cane areas. Australian plague locust, *Chortoicetes terminifera* (Walker), can occur in southern districts, migratory locusts, *Locusta migratoria* (Linnaeus), can occur in northern and central areas, spur-throated locusts, *Austracris guttulosa* (Walker), can occur as far south as Bundaberg, and yellow-winged locust, *Gastrimargus musicus* (Fabricius), can occur in all districts.

Adult locusts and hoppers chew the leaves of sugarcane, to the extent that in heavily infested cane only the midribs remain. Weeds then proliferate because the cane canopy is lost.

Locusts are grasshoppers that at times multiply into large numbers in particular areas and band into dense swarms capable of migrating considerable distances.

Adults of Australian plague locust are distinguished by the red shanks on the hind legs and by a black tip to the otherwise clear hindwing. They are smaller than other locusts (less than 30 mm). Hoppers are grey with mottled black markings.

Adults of migratory locust are brown when in swarms and green when in the solitary phase. They are thick set with brown or green hind legs. Hoppers are green or grey in the solitary phase and black and tan when in bands.

Adults of spur-throated locust (Figure 15) are pale brown or buff with a cream-yellow stripe down the back, and have a prominent spur between the front legs. Hoppers are green or brown with a black stripe down the back; older hoppers have the spur on the throat.

Adults of yellow-winged locust are brown or green and have a large yellow patch edged with black on the hindwing. They make a characteristic clicking noise when flying. Hoppers are green, grey, brown or black.

Figure 15. *Spur-throated locusts.*

Locusts lay batches of eggs in a pod in the soil, usually in concentrated egg bands in hard, bare areas. On hatching and leaving the soil, the hoppers cast off tiny white skins, which can be seen scattered on the soil surface. There are five or six nymphal or hopper stages. Locusts have two forms or phases. They usually exist as scattered populations of individuals in the solitary phase. With correct conditions of food supply and soil moisture, they build up into large numbers forming hopper bands and adult swarms. It is then that they do economic damage.

Adult Australian plague locusts sometimes appear in early summer, blown on winds preceding a cold front. They can have 2–3 generations each summer. Eggs remain in the soil over winter. Infestations in sugarcane usually last only 1–2 generations before dying out.

Migratory locust swarms usually originate on the Central Highlands of Queensland. They have 3–4 overlapping generations each year with the hopper stage taking 4 weeks in summer. Adults lay soon after reaching maturity and continue to produce batches of eggs for 1–2 months. Young hoppers can move into and feed on cane.

Swarms of adult spur-throated locusts may appear in coastal areas during October-November. They have only one generation per year. Eggs are laid fairly diffusely in cultivated fields or grass, but a great many are laid in fallow fields under legume cover. Hoppers hatch in early- to mid-February, and usually feed on grasses in weedy fields before invading and feeding on cane. The hoppers develop to adults by mid-April. Adults then overwinter, frequenting large cane and scrub, before laying eggs in October-November.

The yellow-winged locust has two generations per year. In the summer brood, eggs hatch in November-December, and the hoppers mature to adults in February-March. The eggs laid by these adults overwinter and hatch from August onwards, maturing to adults by November-December. Egg pods contain about 60 eggs and are laid in cultivated fields, hard bare soil or the forest floor. Eggs hatch in 17 days in summer.

Good kills of eggs can be achieved by cultivating the egg beds before the hoppers hatch. Generally locusts are not worth trying to control with insecticides; the long-term damage they do to cane is usually insignificant and infestations die out within a couple of generations. Parasites can cause significant mortality of eggs. Insecticides are most effective when applied to hopper bands. Bands should be sprayed at dusk and dawn while they are stationary and clumped together. Insecticide should be sprayed around the margins of the hopper band to contain the hoppers, and then across the band. Control of adults is difficult because they are more mobile and more dispersed. Spur-throated adults can be sprayed when they roost at night. Insecticides registered for control of locusts in sugarcane are chlorpyrifos (e.g. Chlorfos® or Lorsban®) at 350 mL of product per hectare for Australian plague and migratory locusts and at 1.25–1.5 L of product per hectare for spur-throated locust, and diazinon (Diazinon® or Gesapon®) at 700 mL of product per hectare for Australian plague locust and at 700–850 mL of product per hectare for migratory and spur-throated locusts.

Moth borer

Sugarcane and maize stemborer, *Bathytricha truncata* (Walker), occurs in and damages cane in all sugarcane regions south into New South Wales. It usually infests cane in relatively dry, well-drained environments. Caterpillars bore into the growing points of both small and large cane, causing ‘dead hearts’. They also tunnel inside semimature stems, often completely circling the rind at each node. Stalk rots invade bored stems and reduce sugar content. Bored stalks sucker and sideshoot. In young cane this usually compensates for lost shoots. Heavily infested areas sometimes fail to recover, resulting in gappy plant or ratoon crops. Weakened semimature stems often break, particularly in strong wind, and symptoms resemble climbing rat damage.

Fully grown caterpillars are 35–40 mm long with a purple or pink tint along the upper surface, and small black spots on the thorax and abdomen. The head capsule is red-tan. Caterpillars can be found in tunnels within dead shoots or tops, or, more usually, in nearby shoots or tops where the inner leaves are just beginning to wilt and appear silver-grey. Frass (faeces) falling from a small entrance hole made behind the leaf sheath is characteristic. Tunnels are filled with coarse, loose, wet frass, often fetid, which is obviously different from the fine, relatively dry and tightly packed material left in tunnels by weevil borer larvae. Moths are dull-coloured with small dots along outer margins of wings and in a cluster in the middle of the wing.

Moths commence egglaying in early spring. Eggs are laid in small clusters under the edge of tightly folded sheathing leaf bases on grasses and young sugarcane shoots. Moths lay 500–800 eggs. Crowsfoot grass, Guinea grass, red Natal grass and Rhodes grass are preferred as oviposition sites over sugarcane shoots and para grass. Moths will not lay on large sugarcane shoots. Eggs hatch in 8 days. Young caterpillars feed on the inside of the sheathing leaf base for several days before burrowing through the rind of the plant. Thereafter, caterpillars regularly move from one shoot or stem to another as the tissues begin to putrefy. One larva damages several shoots and stems in its life. Young caterpillars can burrow directly into grass and young sugarcane shoots, but are not able to burrow directly into stems of large sugarcane. Caterpillars invading large cane are usually fourth stage or older and migrate into cane from grass or young cane shoots or suckers. Caterpillars will cross bare headlands to reach cane. There are five or six larval stages that occupy a total of about 6 weeks.

Fully grown larvae have a non-feeding period of several days before pupating. The pupal stage lasts for 12 days in summer. Total generation span is about 9 weeks, and moths continue breeding until February. The species probably overwinters as pupae.

Large moth borer is a relatively minor pest. The key to successful management centres on effective control of grass weeds that are an intermediate host, attracting oviposition and providing food for the early stage caterpillars. Caterpillars and pupae are parasitised by at least two small braconid wasps, two ichneumonid wasps and a tachinid fly. The small white cocoons from the emerging wasp parasites can be found clustered on the cadaver of a caterpillar. The coastal brown ant is also an aggressive predator of migrating caterpillars. In most instances, the second generation is heavily parasitised, and damage does not persist beyond November.

Ratoon shoot borer

Ratoon shoot borer, *Ephysteris promptella* (Staudinger), has damaged cane at Meringa, the Herbert Valley, Proserpine, Mackay and Sarina, but occurs as far south as Brisbane. It is widely distributed in the Mediterranean, Africa and Asia. Larvae bore into young shoots to 300 mm high, often killing them and causing ‘dead hearts’. If the basal leaves of the shoot are removed, the tiny pin-hole entrance to the tunnel can be seen. Damage is confined to ratoon crops, and heaviest infestations are in crops harvested midseason. All reports of severe damage have occurred under drought conditions.

Eggs are pale green-yellow, shot with iridescent blue and gold-pink, and are 0.7 mm by 0.4 mm. Larvae are yellow caterpillars, about 5 mm long. Pupae are boat-shaped, about 4 mm by 1 mm, and are concealed in a frail cocoon of silk covered with excreta or fine debris. Adult moths are 3–4 mm long with a wingspan of 7–10 mm; males are smaller than females. The wings are dark grey with white flecks on females and black dots on males.

Eggs are laid on the cane stalk and probably take a few days to hatch. Larvae tunnel into the stalk and eat the juicy basal part. They then move to another stalk. Pupae occur on the soil surface or in crevices of dead twisted leaves. Adults emerge 10–14 days after pupation.

No insecticide is known to control this insect, probably because larvae are well concealed and most damage has been done by the time it is first noticed.

Bud moth

Sugarcane bud moth, *Opogona glycyphaga* Meyrick, occurs throughout Queensland and northern New South Wales, but most frequent damage to cane occurs in the Herbert and Tully regions. Larvae are sporadic pests of minor importance. They often bore and kill bud eyes, ruining sources of planting material in susceptible varieties. Damaged buds are hollow. Germination failures result from planting infested stalks. Larvae living on cane prior to planting remain underground on the setts and bore into shoots, causing ‘dead heart’ symptoms similar to wireworm damage.

Caterpillars are buff with dark red-brown heads and prominent hairs on the head and body. They are up to 16 mm long and have dark blotches anteriorly and small dark spots laterally along the abdomen. Caterpillars live behind the sheathing leaf base on mature stems. They make irregular shallow feeding scars on the inside of leaf sheaths and on the rind, and burrow small entry holes at the tip of the bud or under the bud scales. Pupae are found under leaf sheaths in silken cocoons covered with debris. Adult moths are 8 mm long with a shining purple head and thorax, and yellow wings with purple tips. Moths rest with wings close to the body and antennae straight out in front.

Moths probably breed all year, but large numbers of moths and larvae occur during autumn and most damage to eyes occurs then. In addition to feeding on leaf sheaths and buds, larvae also tunnel amongst and bore into prop roots at the base of stools. Larvae are also pests of bananas and granadillas.

Chemical control is not considered practical, as treatments would have to be applied during the middle of the wet season. Stripping trash from plant sources is considered beneficial in some instances by reducing damage to eyes.

Rhyparida

Two species of rhyparida are known to damage cane in Queensland: black rhyparida, *Rhyparida nitida* Clark, and brown rhyparida, *Rhyparida dimidiata* Baly. Rhyparida beetles mainly occur in the central and southern districts, but there are records of minor damage in the Lower Burdekin and at Ingham.

In September-November, small larvae bore into the fibrous bases of shoots, causing dead hearts. Damage is most frequent in ratoons, but can occur in plant cane. Prolonged attack may kill all shoots, and thus kill the stool. A less severe attack may only weaken the stool, and a mild attack may kill only ‘surplus’ shoots. Adults eat sugarcane leaves, giving the leaves a tattered appearance, but this causes no economic damage.

Over the past few years, the incidence of rhyparida damage in sugarcane fields has increased markedly in the Bundaberg and Isis districts. Losses from damage have ranged from 10–30% crop losses to areas having to be ploughed out and replanted after damage from rhyparida. For the individual farmer, losses can be substantial both in yield and CCS.

Grubs of both species are stout bodied with a yellow-grey body and a shiny red-brown head (Figure 16). They are about 9 mm long when fully grown. Adults of black rhyparida are about 6 mm long, dark shining black, and with a rounded outline. Adults of brown rhyparida are 6–7 mm long, medium brown, and with the sides more parallel.

Larvae are active in spring and become adults by December-February. Adults of black

Figure 16. *Rhyparida larva.*

rhyparida frequent taller grasses, and are often found on cane leaves in large numbers. Adults of brown rhyparida often shelter on or under the bark of Moreton Bay ash or blue gum. Eggs of black rhyparida appear to be laid in late summer and larvae develop slowly through winter, becoming active in spring. Brown rhyparida overwinter as adults, laying the next batch of eggs in spring.

By the time damage is seen it is too late to attempt control of these pests. At present there are no insecticidal or cultural controls to minimise the effect of rhyparida or destroy it. A better understanding of the pests’ life cycle is required before controls can be established.

Aphids

Aphids are found on sugarcane in all cane areas. The main species is the sugarcane aphid, *Melanaphis sacchari* (Zehntner), which feeds in colonies on the undersides of leaves. Heavily infested leaves become spotted and dry up. Sooty mould grows on the sugary excreta (honeydew) of the aphids and disfigures heavily infested crops. This species does not transmit viruses. The corn aphid, *Rhopalosiphum maidis* (Fitch), rarely colonises sugarcane, but is often common on surrounding grasses such as wild sorghums. It transmits sugarcane mosaic virus. The oriental grassroot aphid, *Tetraneura* *nigriabdominalis* (Sasaki), feeds on roots, sometimes producing a red-purple discolouration of the leaves. Many other aphid species will move through sugarcane crops, and individuals will probe to test the suitability of the plant for feeding. Some of these can transmit sugarcane mosaic virus, even though they feed on sugarcane for only short periods.

Sugarcane aphid is ovate and light-coloured, ranging from yellow-white to green- or brown-tinged. It has two projections, the siphunculi, from the rear upper part of the body. Corn aphid is larger, more elongate, and darker, ranging from pale olive to yellow-green. The base of each siphunculus has an olive-brown blotch. Oriental grassroot aphid is found only on roots and does not have siphunculi.

Aphids have complex life cycles. Eggs may be laid or live nymphs produced by females. Reproduction can be with or without fertilisation. There are winged and wingless forms, the former tending to develop when the colony becomes large and needs to disperse.

Control of aphids is usually not warranted. Parasitic wasps and predators such as ladybirds, lacewings and hover fly larvae usually control dense infestations.

Weevils

Sugarcane butt weevil, *Leptopius maleficus* Lea, is widespread, but damage occurs only near Innisfail. Damage occurs in spring and early summer to both plant and ratoon cane. Larvae hollow out ratoon stubble and setts, gouge long channels into and destroy the rind, and gouge eyes and root primordia. They also tunnel into and gouge large holes in the base of new shoots, causing dead hearts and wilted shoots. Severely damaged cane will die. Larvae do not feed extensively on roots, and so moderately damaged shoots can recover if growing conditions are suitable.

Butt weevil larvae are legless and slightly curled with a relatively small head, and taper slightly towards the rear end of the body. They are cream-yellow with a pale head capsule and black mouthparts. Fully grown larvae are 20–24 mm long. Adult weevils (16–21 mm long) are grey or reddish with many rounded protuberances on the body. The mouthparts are on a broadly elongated snout. The body is much broader at the rear end of the wingcovers than at the front end.

The larval cycle occupies several years and the number of stages is not known. Large larvae have been maintained in the laboratory for at least 1 year with little change in body size. Weevils are found in canefields between August and March, usually feeding and mating on foliage of both young and mature rattlepod and other plants; they do not readily feed on cane leaves. Adults can fly, but remain stationary when approached and handled. Females need to feed on leaves for at least 2 months to mature their eggs and develop up to 45 mature eggs by February.

Butt weevil damage is sporadic and of minor importance. Some farms are infested regularly, but no severe losses have been encountered in recent years. No insecticide is registered for control of butt weevils. Control of adult host-plants appears to limit butt weevil populations in canefields.

Whitefringed weevil, *Naupactus leucoloma* (Boheman), originated in South America and occurs in all canegrowing areas. Adult weevils chew the foliage of cane, but rarely cause any economic damage. Larvae attack the roots of germinating setts or ratoons, causing the plant to die or to be severely reduced in vigour. Damage often follows legume cover crops or fallows with large numbers of legume weeds, but is rarely of economic importance. No insecticide is registered for use against the pest in sugarcane.

Larvae are stout-bodied legless grubs, growing to 15 mm long. They are white with pale yellow heads and black mouthparts. The adult weevil is 12 mm long with a short snout. It is light fawn with a characteristic white line on the outer edge of each wingcover. All whitefringed weevils are females and reproduce without mating. Eggs are laid during summer and autumn in batches of 12–60 attached to plant stems, dead leaves or stones. Each female can lay up to 1500 eggs. Eggs hatch in 2–4 weeks in summer and autumn and in up to 3 months in winter. Larvae take 6–18 months to develop, depending on the quantity and quality of food. New adults remain in the pupal chamber until rain triggers emergence. Adults can not fly, but can move easily into adjacent crops. Adults lay more eggs and larvae develop faster and survive better when feeding on legumes rather than grasses. Infestations rarely persist for more than one generation in weed-free canefields.

Stenocorynus weevils, *Stenocorynus* spp., have been found at Meringa, on many farms at Proserpine, and at Racecourse and Eton in the Mackay district. Damage to cane has also been observed at Meringa and Kelsey Creek. Weevils found in poor ratoons at Childers may belong to this genus. Larvae gnaw the rind of the internode and the root band of germinating setts or ratoons, destroying root primordia, and often also the eye. If the eye survives, root damage causes poor germination and weak growth. Larvae may also bore into setts. Larvae are stout-bodied legless grubs, up to 12 mm long. They range from white to yellow with pale yellow heads and black mandibles. The adult is a typical snouted weevil, 12 mm long. It is light fawn with darker brown stripes along the head and body. The back is smooth and convex. Little is known of the life cycle. In one infestation, larvae damaging cane were first found in August and commenced pupating in October. During October-November, larvae, pupae and adults were present in the soil. Larvae had all pupated by the end of November and adults emerged from the soil in mid-January following heavy rain. Adults fed on nut grass, flannel weed and common sida, but not on cane leaves. The pest occurs sporadically, and no control measures have been determined.

Wart eye

Wart eye, caused by unidentified mites, can be a problem in the Mossman, Innisfail and southern Babinda areas and occasionally at Meringa and Mackay. The germinating eye, instead of developing into a pointed shoot, swells and becomes broad and flat. The surface becomes scarified and rough through feeding by the mites. The name is based on the resultant wart-like appearance of the eye; the mite is very small and not likely to be seen.

Chemicals added to the fungicidal dip or sprayed over the setts and soil during planting fail to significantly reduce infestation. Good-quality planting material should be used so that good germination by unaffected eyes will offset the failure due to wart eye. Cane varieties vary in susceptibility, but current varieties have not been rated.

Termites

Giant termite, *Mastotermes darwiniensis* Froggatt, damages cane only in the Lower Burdekin in sandy or sandy loam soils. Other termite species are found in all canegrowing areas.

Termites hollow out germinating setts, reducing germination. They hollow out standing cane stalks for the entire length from below ground to the growing point. This leaves only a shell that shows few external signs of damage and can transport sufficient water to maintain living foliage.

Adult termites may be workers, soldiers or reproductives. Giant termite workers are white and 10–12 mm long. Soldiers are slightly longer and have powerful mandibles. Reproductives are the wingless females (queens) and the winged males and females which establish new colonies. The wingless queens are about 15 mm long, but the winged adults have a body length of about 18 mm and including the wings are about 35 mm long.

Termites form colonies consisting mainly of workers and soldiers. Giant termites are often found in logs and stems of shrubs and trunks and branches of dead or living trees, but the nest proper is underground. Nests are difficult to find as underground tunnels can be 1 m deep and may run more than 100 m from the nest.

In canefields, the only practicable control is to remove logs and trees from the borders of fields. No insecticide is registered for termite control in sugarcane. Other smaller species of termites damage cane in small areas, but infestations usually do not persist.

Sugarcane planthopper

Sugarcane planthopper, *Perkinsiella saccharicida* Kirkaldy, occurs in all cane areas, but is important only where Fiji disease also occurs, as it is the only known vector of Fiji disease in Australia. Nymphs can acquire the Fiji disease virus only within a few days of hatching. Older nymphs transmit virus effectively, and the subsequent adults retain this power. Nymphs and adults suck sap from the leaves, causing yellowing and mottling. Sooty mould grows on the excreta of planthoppers and is associated with heavy infestations that develop on varieties favourable to the insect.

Adults are about 15 mm long, brown-black, and shaped like an elongate triangle tapering towards the rear from a broad head. When approached, adults resting on a cane stalk will retreat rapidly to the other side of the stalk. Adults will often move sideways, giving them the common name of sidewinder. Nymphs are plump, wingless insects mottled with brown. They have five stages.

Adults prefer the upper stalk where they shelter and feed in the young leaf axils. Banana-shaped eggs are laid mainly in the upper leaf midrib near the leaf axil and in the rind exposed by the sheathing leaf base. They form two parallel rows and are inserted into the spongy palisade cells through a puncture made by the female's ovipositor. First-stage nymphs force a white, waxy seal off the egg mass and move down the stalk to behind the leaf sheaths. The later stages are found on or near the leaf spindle. Planthoppers are not common in fields from May to November, but numbers increase rapidly in summer to reach a population peak of nymphs in January-February and adults in February-March. Adults can swarm in large numbers in February and March and are strongly attracted to lights.

Resistant sugarcane varieties give good control of Fiji disease. Insecticides will kill planthoppers, but are unnecessary and are not registered. Egg predators (small red or green bugs) and egg parasites are the main factors curbing planthopper numbers in summer.

Sugarcane mealybug

Pink sugarcane mealybug, *Saccharicoccus sacchari* (Cockerell), is an introduced pest that occurs in all cane areas. Mealybugs usually do not damage cane, but very high populations will weaken cane. Sooty mould growing on the bug's excreta disfigures crops.

The adult pink sugarcane mealybug is a soft, oval, wrinkled, wingless insect up to 5 mm in diameter, covered with a powdery white secretion. Nymphs are similar but smaller. Colonies are usually found on stalks behind leaf sheaths, but can also occur on the underground stems. Mealybugs survive harvests on underground parts of the plant. Crawlers reappear above ground in spring following the formation of stalks. As new nodes are formed, colonies establish behind the leaf sheaths. Numbers are highest in February-March and then decline because of lower temperatures and parasite and predator activity. Development from eggs to adults takes about 4 weeks. Dispersal between fields may be on planting material, wind, or by ants.

Control is not warranted. Tighter-trashing varieties are more prone to infestation. The parasitic wasp *Anagyrus saccharicola* Timberlake, the fungus *Aspergillus parasiticus* Speare, the habitat-destroying fly *Cacoxenus perspicax* (Knab), and a range of general predators help to control numbers, particularly in late summer.

Linear bug

Linear bug, *Phaenacantha australiae* Kirkaldy, occurs in northern Queensland, as far south as the Sarina district. It may be introduced, as it appeared suddenly in 1917. It feeds on the lower surfaces of leaves, with the leaves turning yellow and the tips drying; the side of infected leaves that face the sun can turn a red-purple. Damaged leaves are more susceptible to fungal attack.

The adult is elongate, about 9 mm long, and orange-brown to dark green-brown. Nymphs are similar, but are wingless and orange-yellow. There are five nymphal stages. Linear bugs occur throughout the year on grass or cane, but can be extremely numerous in spring. Eggs are laid on the soil surface around the roots of grasses. Young nymphs feed in protected areas near the base of plants. Linear bugs are usually associated with grassy fields.

Numbers of linear bug will not increase in grass-free fields, and natural enemies generally keep them in check. Insecticides are not warranted.

Froghopper

Sugarcane froghopper, *Eoscarta carnifex* Fabricius, is native to northern Australia. Infestations in sugarcane are restricted to the Herbert Valley and the Tully district, but they have been seen at Gordonvale. Infested fields have a 'scorched' appearance. Fresh damage appears as short yellow and red streaks in the top leaves. Yellow chlorotic streaks extend progressively, developing reddened central stripes and khaki necrotic tissue where streaks extend to leaf margins. Fully expressed symptoms are visible on fifth and older leaves.

Adults are 5 mm long and appear as dark bugs resting upright on the top portion of cane leaves. They have an orange head, prothorax and body, and dark purple-black forewings with central orange patches (Figure 17). They readily come to light at night. Nymphs are yellow or pink and live on roots within a mass of bubbled foam, resembling spittle, which encases their body and protects them.

Figure 17. *Froghopper.*

Adults lay eggs in the soil. Eggs laid in autumn do not hatch until the following summer months, usually in December. Nymphs live underground in cracks and crevices, at the surface under cane trash, or among stilt roots at the base of sugarcane stems, and suck sap from cane roots. Nymphs can be extremely difficult to locate. There are usually three and sometimes four generations of froghoppers each year, although later generations overlap.

There is a strong varietal component to froghopper host preference and to expression of leaf symptoms. No insecticide is registered for control of froghoppers. Overseas experience suggests that insecticide treatment would be unprofitable and impractical. Assassin bugs, wasps and fungal diseases affect adult froghoppers. Larvae of a hover fly attack nymphs.

Sugarcane scale

Sugarcane scale, *Aulacaspis madiunensis* (Zehntner), occurs on crops as far north as Mackay, Invicta and Ingham, but is important as a pest only in southern Queensland and northern New South Wales. Scale insects suck the juice of the cane through the rind of the stalk. This weakens cane, lowers sugar content, and with heavy infestation the stalk shrinks and dries up. Heavily infested stalks

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may be almost completely sheathed in a coating of scale. The insect can cause appreciable damage in drought-stressed standover cane, because of the long period available for population build-up.

The adult insect is concealed below a flat, circular pale-green to grey scale about 3 mm in diameter (Figure 18). The scale is firmly pressed against the stalk. Newly hatched crawlers are as small as 0.2 mm and difficult to see. Nymphs disperse by crawling or being carried by wind. Scales are immobile.

Scale-free planting material should be used to minimise the chance of establishing infestation in a clean field. Varieties may differ in susceptibility, but the effects of scale insect on current varieties have not been measured.

Figure 18. *Sugarcane scale.*

Rodents

Two types of rodent damage cane in eastern Australia (Figure 19). The canefield rat, *Rattus sordidus* (Gould), has a predominantly coastal distribution, occurring down the eastern coast of Australia to northern New South Wales. It favours refuges such as grasslands, open forest, swamps and drains and is a severe pest in sugarcane-growing regions from Mackay to Mossman with the exception of the Burdekin district. Canefield rats are not as common in southern cane-growing areas where other Rattus spp. may also occur in cane.

Grassland melomys, *Melomys burtoni* (Ramsay), is found in cane paddocks adjacent to tropical and subtropical grasslands, sedge and swampland, and forested areas with grassy understoreys or fringes. Fawn-footed melomys, *Melomys cervinipes* (Gould), is less common and is found in canefields adjacent to closed forest, usually north of Mackay. The habitat separation between the grassland melomys and the fawn-footed melomys is striking, matching the abrupt changes from grassland and open forest to closed forest. Small grassy areas in clearings or along tracks in closed forest often shelter a few grassland melomys, while the fawn-footed melomys lives in the surrounding dense forest.

Canefield rats chew sugarcane stalks. Damaged stalks are invaded by rots, resulting in reduced sugar content and stalk weight. The canefield rat is a poor climber and damage to cane and other crops is usually confined to those parts which the rat can reach from the ground.

Both species of melomys can damage cane below and above ground (Figure 20). Damaged stalks are vulnerable to bacterial and fungal degradation, resulting in loss of weight and sugar content. Although melomys are not as fecund as the canefield rat,

Figure 19. *Adult climbing rat (top) and ground rat (bottom).*

significant damage may still occur if populations of grassland or fawn-footed melomys are allowed to increase.

The canefield rat is a small, dark rodent with a coarse, spiny coat that is grizzled dark-brown to black; colour is lighter in the southern parts of its range. Guard hairs as long as 45 mm are prominent on the rump. The belly fur is light grey-buff. The tail is dark brown to black, usually shorter than the head-body length, and has pronounced scale rings. The ears are light grey, and females have five pairs of teats.

The grassland melomys is a small rat-like species that is variable in appearance. Back colour varies from grey to red-brown and the belly colour is white, grey or cream, sometimes grading to pale orange on the sides of the body. The ears are pale grey or brown, and the tail dark grey, brown or black, sometimes lighter on the underside. Females have four teats. It has a characteristic thick-necked appearance and mosaic-scaled tail.

The fawn-footed melomys is extremely variable in colour, partly due to age. Back colour ranges from light orange to dark grey-brown in adults with the ventral surface white, cream or grey. Young animals are often grey on both back and belly. The tail and ears are dark grey to almost black, and the tail is slender and tapering with a distinctive naked appearance and is sometimes much lighter-coloured on its undersurface. The ears are short and rounded, the head broad, and the tail usually about equal to the head-body length. The hind feet are wide, the eyes bulge conspicuously, and long dark whiskers are present on the snout. Females have four teats. Fawn-footed melomys is similar to grassland melomys in body form, but is generally larger.

Figure 20. *Climbing rat damage.*

Canefields supply the canefield rat with its major habitat requirements of friable soil and good ground cover. The canefield rat makes extensive burrows with tunnels 50–100 mm in diameter, often sloping downwards to a nesting chamber about 150 mm in diameter containing a ‘bed’ of dry grass. It lives in groups and forms networks of runways between burrows. The burrow systems are less than 400 mm deep in canefields. Burrows often follow cane rows, whereas in uncultivated areas burrow openings are found near grass clumps, stumps, fence posts, and large stones. Females with young force other colony members away from their nests, but in non-breeding periods as many as 23 rats have been found occupying a single nest chamber.

A well-defined breeding season occurs each year and commences between November and March with the first appearance of grass and weed growth in and around crops. The intensity of breeding depends on environmental conditions that regulate weed growth. Breeding intensity peaks 1–2 months after the pregnancies occur and declines rapidly thereafter. Breeding ceases around July regardless of climatic conditions. The population begins to disperse and decline with the progress of crop harvest. Females are sexually mature at about 65 days. The oestrus cycle is about 6 days and the gestation period is 20–27 days. Litter sizes range from three to 14 with an average of six. Females exhibit a postpartum oestrus, mating and becoming pregnant soon after giving birth.

Melomys tend to forage from non-crop refuges. Therefore, damage to sugarcane is frequently concentrated around the perimeter of fields. This form of damage is more obvious than that of canefield rat and can overshadow canefield rat damage that may be occurring in the same field. Little is known about the reproductive cycle of either species of melomys. The oestrus cycle of grassland melomys appears to be around 14 days, but the gestation period is unknown. The fawn-footed melomys has a gestation period of about 38 days, one of the longest amongst native rodents. The oestrus cycle is also long, 8 to 22 days, averaging about 17 days. The young can be weaned at about 20 days old.

Damage to cane crops by canefield rats can be minimised by the following steps. Firstly, in-crop weeds should be eliminated during the breeding season (November-March) by using herbicides and/or trash blanketing. Secondly, crop margins should be kept weed free since breeding animals from the crop will forage widely to obtain the nutrition necessary to maintain breeding conditions. Thirdly, grasslands should be mowed or grazed heavily to render them unsuitable for use as between-crop refuges. Fourthly, canopy closure in grasslands and open forests should be encouraged. Open forests should not be burned in an attempt to rid the area of rodents. Regular firing opens the canopy, encourages regular grass growth and provides rats with a favourable habitat. Fifthly, headlands and grass verges should be mown closely over the June-January period to frustrate movement between crops. Small grassy areas can support large colonies of rodents.

The rodenticides coumatetralyl (Racumin®) and zinc phosphide (Ratoff®) are used under permit for the control of rats in sugarcane. The materials should only be used after fields have been monitored for rats. Because the main species are protected native mammals, permits are required before any population mitigation or management is undertaken.

Owls prey upon rodents, and some farmers are installing nesting boxes to encourage these birds into their area.

Research into the control of melomys in sugarcane has been limited, and a separate management strategy for these rodents has not been developed. However, given that melomys utilise the same non-crop habitats as canefield rat, any controls aimed at reducing populations of canefield rats should similarly affect melomys populations.

The losses caused by rats can be estimated by surveys of damage. The percentage of rat-bitten stalks in fields should be assessed at time of harvest. Sugar losses can then be estimated using a set of assumptions that relate damage to losses of both yield and CCS. Estimation of losses district-wide requires a survey of fields spread across the district and across the harvest season, and including both burnt and green-cane trash-blanketed fields.

Feral pigs

Feral pigs, *Sus scrofa* Linnaeus, are found in all cane areas. They are similar to domestic pigs, but are leaner, have narrower backs and shoulders, and the neck is more heavily developed. Colour is very variable, but is mainly black, red-black, or black and white. Reds, whites, fawns and roans occur and animals with white saddles and spots are sometimes present. Most have a large head and large ears, small eyes and a long snout. Feral pigs can stand 800 mm tall (height at shoulder) and can weigh up to 136 kg (males) and 70 kg (females).

Where small quantities of cane are chewed, very little yield loss occurs. Where the pigs are left uncontrolled, whole colonies will invade blocks of cane and make wallows or runs. They will push over stools in wide areas and uproot the ground, overturning stools and seriously affecting subsequent ratoons. Pig-damaged stalks are usually broken and then chewed. Pig damage first occurs well inside the block, where it is not noticeable from the headland.

Feral pigs prefer habitats such as closed and open forests, watercourses and swamps. Females build bulky nests up to 2 m in diameter in dense vegetation to hide litters.

Camps are usually found in heavy vegetation near water. Feral pigs are mainly active at dusk and dawn, but sometimes feed in late afternoon. They have a matrifocal social organisation, with mature females typically accompanied by other females and juveniles. Groups forage up to 15 km. Boars have larger home ranges and are generally solitary, except when females are in oestrus. Feral pigs attain puberty at about 6 months or 30-kg weight. Breeding occurs throughout the year under good conditions. The gestation period is about 115 days, and litter sizes vary between 3 and 12. One or two litters are produced each year. The sow constructs a grass nest and stays with her young for the first 2 weeks. Piglets are weaned at about 3 months and leave the mother's group before the end of their first year. Feral pigs live up to 12 years.

In Queensland, feral pigs are declared pests under the *Lands Protection Act 1985* and it is the responsibility of every landholder to control them. They are difficult to control for a few reasons. Pigs are nocturnal, wary and camp through the day in thick inaccessible vegetation wherever possible. The reproductive potential of pigs is high, so repeated control programs must be conducted before any worthwhile population control is achieved. Pigs are omnivorous. They have a wide range of available food sources, making successful pre-feeding during baiting campaigns difficult. Their home ranges are large, between 5 and 50 km^2, so control programs must be conducted over a large area to be effective.

Pig control can take various forms (Figure 21). Trapping is an important technique for reducing feral pig numbers and is most successful when the pigs' food resources are limited. Pig traps are species-specific and pose little or no danger to other wild or domestic animals. There are several trap designs, but all are principally a steel-mesh, live trap with a one-way gate. Free-feeding prior to activating traps is an essential prerequisite to trapping success. Poisoning is one of the few methods available which may reduce a pig population quickly. Several poisons are available for poisoning pigs. In Queensland, sodium monofluoroacetate (1080) and phosphorus-based poisons are used in control programs. Pre-feeding is the most important step in poisoning operations. Free-feeding with unpoisoned bait should be performed for a number of days prior to laying poisoned baits. The number of feral pigs killed by a poisoning program is determined by the number of pigs that find the poisoned bait and the number that eat sufficient bait to ingest a lethal dose. By wise selection and presentation of bait material, landholders can be target specific in their use of poisons.

Shooting from helicopters is effective in inaccessible areas such as broadacre crops, swamps and marshes where pigs exist in reasonable numbers and are visible from the air. The cost of control varies with pig density and the efficiency of the operators. Ground shooting will only be effective where the operation is intensive and concerns a small isolated population of pigs that are accessible. Dogs may be used to remove the few pigs remaining after poisoning and trapping campaigns as they are able to locate and flush pigs out of areas of thick cover.

Figure 21. *Feral pig captured in a cane field.*

However, dogs or shooting should not be used before or during poisoning or trapping operations.

Fencing can be an expensive but successful method of pig control. Generally, the effectiveness of a pig-proof fence is related to how much the landowner is prepared to put into the fence. The pig-proof fence must be constructed before the pigs begin to be a problem. Once pigs are used to feeding in a particular paddock, construction of fences around that paddock will not keep them out. Pigs will charge an electric fence to get through, and, unless the fence incorporates fabricated netting, the pigs will breach it. A three-wire electric fence with the wire at various spacing and posts 10 m apart should be effective.

Wallabies

Wallabies are pests in all cane areas. Agile wallabies, *Macropus agilis* (Gould), are a northern species, occurring down the eastern coast to about Rockhampton; they are common in tropical to subtropical forests and woodlands with adjacent grassy areas. Red-necked wallabies, *Macropus rufogriseus* (Desmarest), occur in southeastern Australia, north to about Rockhampton. Whiptail wallabies, *Macropus parryi* Bennett, occur along the eastern coast from Cooktown to northern New South Wales.

Wallabies cause damage to sugarcane only in dry periods when moisture and bush green feed are scarce. If populations are high, setts may be uprooted and stools in ratoon cane may not recover (Figure 22).

The agile wallaby is sandy grey above and whitish below. The head may have a median dark brown stripe between the eyes and ears, and a faint light buff cheek stripe. There is a distinct light buff stripe on the thigh, and the edges of the ears and tail tip are black.

Male red-necked wallabies are grizzled medium grey to reddish above with a pronounced red-brown neck that is white to pale below. Females are somewhat paler. In both sexes the muzzle, paws and largest toe are black, and there is a white stripe on the upper lip.

Whiptail wallabies are light grey in winter and brown-grey in summer, both with white below. The forehead and base of the ears are dark brown, there are white stripes on the upper lip and hip, and there is a light brown stripe down the neck to the shoulder. The tail is long and slender, and has a dark tip.

Wallabies sleep for most of the day in dense vegetation and can forage into crops by night. Wallabies are social, moving in groups of about 10 and forming larger feeding aggregations. Females are sexually mature at about 14–24 months and males at about 16–24 months. Breeding is continuous if conditions allow. The young vacate the pouch at about 30 weeks and are weaned at about 48 weeks. Wallabies can also express embryonic diapause, suspending the growth of unborn young if environmental conditions become unfavourable.

Wallabies can be controlled in cane in three ways. Six- and seven-wire vertical electric fences are effective against wallabies. More information can be obtained by consulting the BSES Cane Notes 'Electric fencing for sugarcane paddocks' (Publication No. 5/91). Positioning of the bottom earth wire close to the ground is essential to prevent animals crawling under the fence.

Figure 22. *Wallaby damage in young plant*

The top two wires are electrified (live) to prevent shorting if they are twisted together.

A permit may be obtained from the local Cane Protection and Productivity Board to kill agile, red-necked and whiptail wallabies, where they are damaging cane or are likely to damage cane. A permit should always be obtained before any attempt is made to kill these animals, as penalties for taking fauna in an unauthorised manner are very severe. Permits are not granted to shoot kangaroos and other species of wallabies; these species are protected.

SHO-ROO® is an electronic device that deters wallabies by emitting a high-pitched sonic beam. This is inaudible to humans and other animals, but unpleasant to wallabies within range. Making non-crop environments such as woodland or scrub more attractive to wallabies than sugarcane has also proved successful in some areas. Burning woodland and scrub and promoting regrowth of grasses provides these animals with a palatable food source other than the cane crop. When meat-meal is spread evenly throughout a threatened paddock, its unpleasant smell causes wallabies to look elsewhere for food.

Foxes

Foxes, *Vulpes vulpes* (Linnaeus), occur in the canegrowing areas of central and southern Queensland and northern New South Wales. Foxes damage cane by gnawing at stalks and leaving the cane plant exposed to rots. This results in reduced stalk weight and sugar content. A strong musky odour is normally indicative of a fox's presence.

Breeding is seasonal and pregnancies occur between June and October, with most births between August and September. Foxes have a 51-day gestation cycle, and can give birth to up to four cubs in a litter. Young are born with their eyes closed and begin to disperse at around 8 weeks. Foxes live in a cavity in the ground, beneath an overhang, in dense vegetation, or in a hollow log or tree.

Generally no control is required as foxes usually do little damage.

Birds

Eastern swamphens, *Porphyrio porphyrio* (Linnaeus), (redbill or coot) are widespread and common birds damaging cane in all districts. Although regarded as minor pests of sugarcane, they may move in large numbers from swamps and lagoons to adjacent cane paddocks and destroy sugarcane. They damage cane by scooping out the pith of a stalk with their bill, leaving the plant exposed to rots and resulting loss in sugar and weight.

Sulphur-crested cockatoos, *Cacatua galerita* (Latham), are also found in all cane areas. Cockatoo damage usually occurs on the perimeter of blocks adjacent to timbered harbourage areas. Flocks of birds infest the edges of blocks and shred cane with beaks designed specifically for crushing and tearing hard objects. Mounds of shredded rotting cane that resemble heaps of fibre are all that remain after a cockatoo infestation.

Canegrowers may be issued a permit to shoot eastern swamphens or cockatoos in cane by their Cane Protection and Productivity Board. This permit allows for the shooting of the birds in cane only. Birds can

Damage from eastern swamphens.

be deterred away from cane paddocks with gas or boom guns or any other periodic or timed device. However, the birds soon learn that any device used to frighten them cannot harm them, so their feeding is interrupted for only a short time.

FUTURE OUTLOOK

Research on key pests has shown that there are farm-management methods that will reduce the propensity of pests to increase to damaging levels. These management methods are likely to become more important in the future with increasing environmental restrictions and a limited pool of pesticides. They may not replace pesticides, but may reduce the demand so that pesticides are available when they are most needed.

Use of pesticides could also be rationalised by monitoring fields and treating only when necessary. A culture needs to be developed where pesticides are seen as scarce resources and where growers are encouraged and helped to change to programs that restrict pest losses.

Cockatoo damage.

Management options must be practical, must address growers' problems, and growers must be encouraged to try these options and adapt them to their own situations. One way to achieve this must be to involve growers as partners in the research and development of pest management programs.

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