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INSECT PESTS OF SUGAR CANE

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A catalog of the sugar cane insects of the world lists over 1500 species which have been reported feeding on the sugar cane plant, *Saccharum officinarum* (21). Each geographical region has its own distinctive pest fauna, which is composed mainly of indigenous species on continents and of introduced species on oceanic islands (131). Regional lists of sugar cane insects with notes on their importance or nature of their damage have been published recently for the Pacific (129), Papua and New Guinea (154), Cuba (142), and Venezuela (62). A useful and recent summary of present knowledge of sugar cane insect pests, which places emphasis on the broader aspects of the subject and on pest groups rather than on particular pests, has been edited by Williams (164). Some recent regional reviews of the status of important pests and their control have been published for the Americas (18), Puerto Rico (108), and India (14, 91). A review of the use of insecticides against soil pests was recently prepared by Wilson (165). It is our intention in this paper to summarize briefly the nature of the major insect problems encountered in sugar cane culture, to describe how they are dealt with, and to discuss critically the present state of knowledge of those problems which have been important in the last 15 years in Louisiana, to which the authors' experience with sugar cane insects has been mainly confined.

Foliage Feeders

The foliage feeders most frequently reported on sugar cane are caterpillars (Lepidoptera) and locusts (Acrididae) which mainly devour leaves in various portions and amounts, but sometimes also kill the growing points of canes. Lepidopterous leaf-rollers (92) and leaf-miners (10, 26, 137) are known, but only as minor pests which are commonly held in check by parasites.

Outbreaks of the cutworm, *Pseudaletia separata*, have occurred in northeastern India where comparatively young or lodged cane was completely defoliated, but later recovered following monsoon rains (133). Control methods have included the trapping of pupating larvae in barriers of dead leaves which are later burned, the application of toxaphene dust in conjunction with controlled flooding of fields, and the use of dusts or sprays of aldrin, BHC, DDT, endrin, and heptachlor (16, 141). Heavy infestations of the army cutworms, *Pseudaletia unipuncta* and *Spodoptera furgiperda* have occasionally occurred in Louisiana, particularly in grassy fields. However, they seldom affect cane yields there. They may be controlled by the application of azinphosmethyl spray or granules as recommended against the sugar cane borer, *Diatraea saccharalis,* or by toxaphene dust or spray (51).

About 60 species of locusts and grasshoppers are reported to have damaged sugar cane by devouring foliage and destroying the growing points of canes (24). The migratory plague locusts have been responsible for the greatest damage to cane crops inflicted by acridids. The destructive potential of these pests may be illustrated by the observation that one locust swarm in Kenya ate all the green leaves, leaving only midribs, within 2 hr after settling on a cane field (1), and that the average effect of a severe locust attack may be estimated at about 14 percent loss in cane yield or more, depending upon the time of attack in relation to cane growth (24). Bullen & MacCuaig (24) have constructed a chart showing the rate of cane foliage destruction by adult locusts at varying population densities. Control of large swarms is the work of national and international control organizations which employ aerial application of ultralow-volume sprays directly on the flying locusts. Bands of immature hoppers may be prevented from entering areas by spreading poison bait over them, dusting or spraying. Insecticides used include gamma BHC, dieldrin, aldrin, malathion, carbaryl, fenitrothion, and naled (24). Acridids have not been an important problem on sugar cane grown in the United States.

The fact that defoliating insects are not important pests of cane in the United States is probably due only to the infrequent occurrence of destructive infestations in cane fields of this country. The ability of these pests to reduce sugar yields has been adequately demonstrated elsewhere (24, 162).

Sap Feeders

Disease vectors.—Aphids are proven vectors of two virus diseases of sugar cane, the most important of which is mosaic (130). Sugar cane mosaic virus (SCMV) occurs in most of the major sugar-producing countries of the world (11), and is potentially one of the most damaging diseases of cane, although its destructive effects are checked in most cane growing areas by the use of resistant varieties (2). The losses caused by the virus are mainly in the tonnage produced, resulting from poorer growth of infected cane, although reduced germination from infected seed cane may also cause losses which vary with the cane variety and virus strain present (2).

The ability to spread the SCMV from diseased to healthy sugar cane has been demonstrated experimentally with the following aphid species, listed in chronological order of the proofs of their roles as vectors: *Rhopalosiphum maidis* (22), *Hysteroneura setariae* (82), *Schizaphis graminum* (83), *Carolinaia cyperi* (155), *Acyrthosiphon pisum* (3), *Dactynotus ambrosiae* (3), and *Nasonovia lactucae* (3). Also, *Aphis gossypii* has been observed to transmit the virus from corn to corn (100) and *Myzus persicae* from sorghum to sorghum (13). It seems likely that other aphid species not presently known to be vectors may also be involved. While it has been recognized for some time that the numbers and kinds of insect vectors present must have a great influence on the rate of spread of the SCMV (2), there has been much speculation concerning the relative importance of different vector species and the main periods of virus spread.

Abbott (2) stated that SCMV spreads more rapidly in spring months than during summer, and that considerable spread may also occur during fall in young summer-planted cane. He questioned whether this higher spread during spring and fall was due to a greater susceptibility to infection in young plant tissues or to seasonal differences in vector activity. It is generally believed that young leaves of virus-infected plants are better sources of inoculum than old leaves, and it is claimed that unpublished data from Louisiana have shown that viruliferous aphids transmitted SCMV more efficiently when the sugar cane plants were less than two months old (130). However, Komblas (97) and Komblas & Long (98) found the rate of mosaic spread in Louisiana to be approximately equal among plants of different ages, which suggests that the rate of spread of mosaic may not be very much related to plant age, at least in areas like Louisiana where sugar cane normally does not mature. Several workers have overemphasized the relative importance or magnitude of fall spread of the SCMV. Zummo (170) reported on the spread of mosaic in the fall, but did not determine the relative amounts of spread which occur during other seasons of the year. Steib & Chilton (150) concluded that the appearance of a high incidence of SCMV symptoms in mid-May resulted from "a very heavy fall and possibly some early spring spread." However, their data show that sugar cane plots covered with insect-proof screen cages during spring showed by June 15 only 17.8 percent mosaic compared to 84.9 percent in uncovered plots which were exposed to natural aphid populations during fall and spring. If the 84.9 percent be considered 100 per cent of the total disease spread during fall and spring, then 79 percent of the total spread may be calculated to have occurred during the spring. The latter figure agrees very well with a conclusion reached by Komblas (97) and Komblas & Long (98) that probably more than three-fourths of the total virus spread in one crop year occurred during late winter and spring. These workers periodically determined the incidence of SCMV symptoms in experimental plots and attempted to relate virus spread with aphid populations, which were sampled by sticky traps and also observed on sugar cane plants. They found high and significant correlations between amounts of mosaic spread and populations of alatae, including several of the known SCMV vectors, which were flying during weekly or biweekly intervals throughout the year, and they believed that the majority of aphids migrating over sugar cane fields might reasonably be considered potential SCMV vectors. They also observed that approximately 80 percent of all aphids that migrated over sugar cane during a 12-month period, while some living portions of cane plants were exposed above the soil surface, did so between March 1 and May 31. In Florida, it has been shown that the great majority of alatae migrate from January to May with maximum movement occurring during February and March (168).

SCMV has been shown to behave like a typical nonpersistent or stylet-borne plant virus (171). It is generally agreed that such viruses are naturally transmitted only by aphids, and mainly by alatae that do not prefer as food the particular crop plants being affected (90, 94, 95). Nevertheless, with some workers there still appears to persist an idea that colonizing aphids are of great importance as SCMV vectors. For example, Pemberton & Charpentier (130) point out that *R. maidis* has been shown to be a much more efficient vector than *S. graminum* or *H. setariae*. They further state that "sugar cane in Louisiana is a host for *R. maidis* for only a limited time during the winter and spring months while it is a favorite host for *H. setariae*," and that "*H. setariae* may thus be largely responsible for spread of mosaic in cane fields when other vectors are not prevalent." As a matter of fact, among the known SCMV vectors, alatae of *A. gossypii*, *A. pisum*, *H. setariae*, *M. persicae*, *R. maidis*, and *S. graminum* have all occurred during periods of virus spread in sufficient numbers to be considered of probable importance as vectors (98). Present knowledge appears to be inadequate to permit accurate rating of vector species in terms of their relative importance in the field.

Generally, it has been observed that vector control with insecticides has shown little or no promise for controlling SCMV spread (2, 34, 35, 84, 130). Most reported attempts to control virus spread by this means have been made in small field plots not more than ½ acre in area and commonly from one to three rows wide (34, 35, 84). Such trials were unduly predisposed to failure since the likelihood of substantially reducing the numbers of migrating alatae in any field should tend to increase with the size of the area treated with insecticide. Only in two relatively recent studies of this sort have insecticide-treated plots been as large as 5 to 15 acres. In one of these studies little or no control of SCMV spread was obtained from three fall applications of demeton or malathion followed by five biweekly spring applications of demeton (35). However, these spring applications probably were begun at least three to four weeks too late to have had any effect on a large proportion of the alatae which probably migrated early in the year. Komblas (97) is the only worker who has combined adequate plot size with attempted insecticide (demeton and disulfoton) protection throughout the season of potential virus spread, and he was able to measure reductions in spread of only 45–58 percent, which do not constitute adequate control. Virus spread also has been limited, but to a lesser extent, by applications of whole milk, skim milk, milk diluted with water, and casein in water sprays, which act as virus inhibitors, but which were phytotoxic to sugar cane plants (12, 97). Disease control is presently dependent upon methods other than vector control. These include use of resistant varieties, roguing seed cane, and using seed cane which is as free from infection as possible and planting it as far removed as possible from infected fields (52). The importance of controlling weeds and grasses which harbor SCMV or its vectors has also been mentioned by several workers (84, 107, 130).

The other virus disease of sugar cane also known to be transmitted only by aphids is grassy shoot (GSV). According to recent reviews, (78, 130), this potentially serious disease was seen first in India in 1949 and has been observed since then in Taiwan and Thailand. GSV may be transmitted mechanically and thus might be expected to have vector-virus relationships similar to SCMV and other nonpersistent stylet-borne viruses. This may suggest a low probability of successful control of this disease through vector control with insecticides, since Broadbent's statement (23) that "no current insecticide which will remain effective for days on or in a plant can kill quickly enough to prevent infection" remains true today, particularly where vectors of nonpersistent viruses are involved. GSV is known presently to be transmitted by three species of aphids, two of which have sugar cane as a preferred host plant (130). Further studies would probably reveal that other species of aphids are also potential vectors.

Fiji and streak disease are potentially destructive virus diseases found mostly in cane growing regions of the Pacific and Africa, respectively (11). The former (FDV) is known to be transmitted by three delphacid planthoppers of the genus *Perkinsiella,* and the latter (SDV) by a cicadellid leaf-hopper, *Cicadulina mbila.* All of these vectors breed on sugar cane and probably also on other grasses and sedges (130). All attempts to transmit either virus by mechanical means have failed (79, 152). Once viruliferous, *Perkinsiella vastatrix* was found to remain infective for life, and adults transmitted FDV only if fed on healthy plants for at least 24 hours (127). *Perkinsiella saccharicida* nymphs have been shown to transmit FDV in a 20-hour feeding on healthy cane and to remain infective for at least 16 days after removal from diseased cane (124). Heavy infestations of *C. mbila* seldom occur in the field, but a single insect can infect healthy cane with SDV after feeding on diseased plants for a few days, and viruliferous adults remain so for life (151). These observations indicate that FDV and SDV are persistent viruses which probably are transmitted mainly within infected fields from diseased to healthy plants. The possibility of controlling such diseases by vector control with insecticides is much better than is the case with nonpersistent viruses (23). In fact, insecticides have been used to control Fiji disease in Madagascar (144). However, major reliance has been placed upon resistant varieties together with production of disease-free seed cane by regular inspections and roguing of diseased plants from seed plots (79, 152).

Chlorotic streak is believed to be a virus disease of sugar cane with world-wide distribution (11). It has been reported to be transmitted by the leafhoppers *Draeculacephala portola* (5) and *Sphenorhina liturata ruforivulata* (60). However, several workers since have been unable to demonstrate insect transmission (130), and the virus is now generally believed to be transmitted in some manner through the roots (2, 130).

Spike disease, believed to be caused by a virus (130), was found first in South Bihar, India, in 1954 (80). It is reported to be spread by the mealybug, *Pseudococcus saccharifolii* (9), but details of the presumed vector-virus relationships apparently are little known. The vector is recorded from Florida and India with sugar cane as its only known host (130).

Direct damage.—Arthropods with piercing-sucking mouthparts may damage sugar cane directly by sap removal and also by toxic salivary secretions, although Fennah (56) noted that available evidence indicates that fulgorid saliva, including that of many species found on sugar cane, "does not contain intrinsically toxic substances that are capable of causing serious damage in all circumstances." He suggested that variable extents of damage caused by a feeding puncture may be attributed mainly to differences in metabolic state of the host plants, and that this is mainly a result of any one or more of several environmental factors (most commonly adverse soil conditions) which may affect the water relations of the crop. He indicates that such environmental stresses may cause metabolic derangements leading to reduced synthesis of soluble nitrogenous compounds into protein and to more rapid breakdown of protein; the resulting increase of soluble nitrogen in plant sap may make it more nutritious than normal sap to at least some Homoptera which lack proteases in their saliva. He believes that sugar cane is most susceptible to damage by Homoptera when the plants are 1–3 ft high and during the 5 months following the period of most rapid growth, that nitrogen-deficient plants are relatively less subject to attack, and that damage may be prevented where means for controlling soil moisture are available.

Cicadellid leafhoppers apparently are not of much importance as pests of sugar cane. Reference has already been made to the questionable role of *Draeculacephala portola* as a vector of chlorotic streak virus. Nevertheless, in Louisiana, leafhoppers of this genus are frequently very abundant on sugar cane where both nymphs and adults feed almost entirely in the central whorl of leaves (86).

In a review of the biology of froghoppers (Cercopoidea), Fewkes (58) lists 66 species and subspecies which are known to feed on sugar cane. He indicates that most of these occur in the tropics and subtropics of the New World where species of the genera *Aeneolamia, Mahanarva, Sphenoclypeana, Sphenorhina,* and *Tomaspis,* but particularly the first mentioned, are pests of considerable economic importance. Some species insert their eggs in leaf tissues, but most lay them in the soil where the nymphs emerge to feed on sugar cane roots. Heavy infestations of nymphs may cause yellowing and browning of leaves and stunted plants, but adults are the main cause of froghopper "blight" which results from feeding on the border parenchyma of cane leaves where most of the chloroplasts are found, and possibly also from the toxic effects of salivary secretions. This loss of photosynthetic tissue causes leaf necrosis, reduced growth and thin stunted internodes. Sugar cane froghoppers have two or more generations per year, and pass the dry winter season as diapause eggs. Fewkes (59) further states that since 1900 they have become major pests of sugar cane in Trinidad, Venezuela, Mexico, Brazil, British Honduras, and Guyana. He cites experiments which have shown that moderate froghopper blight damage reduced sugar yields by 40 percent and that losses of more than one ton of sugar per acre are common in blighted cane. No varieties truly resistant to froghopper damage have been reported. Reduction of ratooning and rotation of cane with other crops have been recommended cultural practices; however, it is cheaper to use insecticides than to plow and replant fields frequently (57). Biological control attempts by introduction and augmentation have been unsuccessful to date. Fewkes (57) states that at present the only practical methods of controlling froghoppers require insecticides. He reports that in areas where infestations persist in the cane fields throughout the year, satisfactory control of nymphs is obtained by dusting the soil surface about the bases of the stalks with insecticides ("root dusting"), although this is a laborious and expensive operation. He further suggests that aerial applications timed to control first brood adults as they emerge may prove cheaper and more effective. In other places where damage is caused mainly by adults which fly into the fields from uncultivated areas, control is achieved by aerial or ground application of insecticidal dusts or sprays to plant foliage. Insecticides successfully used have included gamma BHC, carbaryl, carbophenothion, DDT, dieldrin, endosulfan, imidan, isobenzan, phorate, and toxaphene. Resistance to gamma BHC, DDT, dieldrin, aldrin, and chlordane developed in Trinidad in 1954 after about five years of intensive use of chlorinated hydrocarbons. However, this resistance subsided after four or five more years of widespread use of organophosphate and carbamate insecticides (59). The only froghopper commonly encountered in Louisiana sugar cane fields is *Prosapia bicincta*, which occurs throughout the eastern United States on a variety of grasses and other plants (117), but which seldom if ever causes economic damage to sugar cane here.

Several planthoppers (Fulgoroidea) are or have been major pests of sugar cane. In a recent review of the relationships between sugar cane and Fulgoroidea, Fennah (56) indicates that these insects produce several generations per year on sugar cane or on other plants (mostly grasses). They usually insert their eggs into leaf tissues, although *Pyrilla perpusilla* lays them in rows on the leaf surface and covers them with masses of white threads from the anal glands. Nymphs and adults suck sap from leaves, the preferred feeding sites on the plant varying somewhat with different species, and fecundity of some species has been found positively correlated with nitrogen content of sap (56). He indicates that plant injury may result directly from feeding, from numerous oviposition wounds which also may provide easy entrance for the red rot fungus, from sooty mold which reduces photosynthesis, or from a combination of these factors which may retard plant growth and lower juice quality. He points out that prolonged hot dry weather often suppresses infestations, although outbreaks of *Saccharosydne saccharivora* are usually terminated by the onset of rains in Venezuela, and entomogenous fungi play a major role in the natural control of this insect in Jamaica. *S. saccharivora* breeds on sugar cane in the New World from Louisiana to Trinidad and Venezuela (56). In Jamaica, where it is a major pest of cane (119), biological control has been unsuccessful, and major reliance has been on the application of malathion, which should be applied only to young plants and to canes growing in conditions likely to retard their growth (118), since canes under these conditions are particularly susceptible to infestation and damage (56, 118). Metcalfe (118) indicates that the best time for treatment is when most of the nymphs have hatched out before the first new adults have migrated or oviposited, and that this is possible in Jamaica where there is noticeable synchronization of development. *Numicia viridis* breeds on a variety of grasses in parts of southern Africa, and has recently been recognized there as an economic pest of sugar cane in dry irrigated areas where growers have resorted to the application of malathion dust for control (32, 44, 56). However, Carnegie (31) states that the justification for insecticide application has not been clearly demonstrated, and that studies are in progress on the introduction of the egg predator, *Tytthus (Cyrtorhinus) mundulus*, from Mauritius (32). *Perkinsiella saccharicida* was accidentally introduced into Hawaii around 1900 and became a very serious pest within a few years, but by 1923 was brought under virtually complete control by the introduction of several insect enemies, among which the egg predator, *T. mundulus*, is often given major credit (145). *P. perpusilla* is considered an important pest in Ceylon and India (56). Frequently recommended control measures have included hand collection of egg masses, collection of adults by hand nets, and spraying with BHC, DDT, endrin, toxaphene, malathion, and parathion (27). Butani (27) states that no variety is immune to attack and that little success has been achieved through biological control.

Mention of whiteflies (Aleyrodidae) occurs only infrequently in the literature on sugar cane insects. However, Indian workers have been concerned with the biology and control of two species, *Aleurolobus barodensis* and *Neomaskellia bergii* (28). The sugar cane whitefly, *A. barodensis*, has produced nine generations during a year at Jullundar, India, and is reported to retard growth, promote development of sooty mold, and decrease sucrose content of juice by as much as 40 percent, being particularly serious on neglected ratoons in poorly drained soils (139). In trials by Sandhu & Singh (140) a number of insecticidal sprays gave good initial control of nymphs, but poorer control of puparia. An application of endrin effectively checked increases in nymphal populations for two weeks, BHC for one week, and several organophosphorus insecticides for only three days. More recently ultra-low volume sprays of fenthion, malathion, and phosphamidon have given satisfactory control of nymphs and adults at approximately one-third the cost of conventional sprays (8).

In a recent review of biological control of sugar cane aphid pests, Stary (149) states that aphids are harmful to cane mainly because of their transmission of virus diseases, although in some cases economic damage may be associated directly with sap feeding. Gaud et al (61) report that the yellow sugar cane aphid, *Sipha flava,* has destroyed several thousand acres of young cane and retarded growth in extensive areas of Puerto Rico during some seasons. Infestations normally start on the under surfaces of leaves near their tips, and cause intense yellowing, which may be followed by browning and death of leaves if increasing aphid populations are not checked. Outbreaks of this aphid and the recent increase in its importance in Puerto Rico have been attributed by Gaud et al (61) to prolonged periods of drought during spring and autumn which are unfavorable to an important entomophagous fungus, increased areas of an alternate grass host, and the absence of an effective combination of natural enemies. However, outbreaks of other aphids, reported to cause economic crop damage by direct feeding, may not be prompted by the same environmental conditions. In India, damaging outbreaks of *Aphis* (*Longiunguis*) *sacchari* and *A.* (*L.*) *indosacchari* caused withering of leaves and development of sooty mold on lower leaves after flooding rains followed by bright sunshine (41). Diazinon, malathion, methyl parathion, and Di-Syston® have been used for control of the yellow sugar cane aphid in Puerto Rico (61). *S. flava* has long been present in Louisiana cane fields where it seldom does economic damage. However, carbaryl, infrequently used in the past for sugar cane borer control in Louisiana, has precipitated outbreaks of this aphid, presumably by adversely affecting some of its natural enemies.

Rao & Sankaran (136) have recorded 35 species of scale insects on sugar cane in various parts of the world. Their review indicates that important pests among these include species of soft scales (Coccidae) of the genus *Pulvinaria,* and armored scales (Diaspididae) of the genera *Melanaspis* and *Aulacaspis.* They state that common causes of sudden increases in populations of these insects are susceptible sugar cane varieties, drought, and the absence of effective natural enemies. Heavy infestations of a soft scale have occurred on sugar cane foliage in experiment station greenhouses at Baton Rouge and Houma, Louisiana, and also rarely in localized areas within cane fields of Louisiana. Specimens sent to the U.S. National Museum in 1959 were identified as *Pulvinaria elongata.* There has been some taxonomic confusion between *P. elongata* and *P. iceryi.* However, Rao & Sankaran (136) state that, according to D. J. Williams, probably all specimens of *Pulvinaria* collected on sugar cane in the Western Hemisphere are

P. elongata. In the greenhouse, sugar cane plants ultimately may be killed if infestations of *P. elongata* go unchecked, while the most severe symptoms observed in Louisiana cane fields have been intense yellowing of leaves of infested plants in late summer and fall. Greenhouse infestations have been controlled by spraying with malathion or parathion and also soil application of the systemic insecticide, carbofuran. Mamet and Williams have observed whole stools to be killed by limited and sporadic outbreaks of *P. iceryi* in Mauritius (136). According to Rao & Sankaran (136), *Aulacaspis tegalensis* and *A. madiunensis* in the western Pacific, islands of the Indian Ocean, and Africa, and *Melanaspis glomerata* in India, are armored scales which are of more importance. They state that these scales congregate on stalks under leaf sheaths, producing several generations per year, and doing most damage to varieties with persistent and adherent leaf sheaths. They report that severe attacks by *A. tegalensis* may cause losses of 5–10 tons of cane per acre and reductions of as much as 35 percent of sucrose in juice. The use of uninfested cane for planting reduces spread of these scales and prevents impairment of germination by them according to these writers. They also indicate that organophosphorus insecticides with a contact action satisfactorily kill crawlers, but not eggs and fixed stages. Hymenopterous parasites, coccinellid, nitidulid, and mite predators help to reduce large populations (163); however, no serious effort at biological control of these scales has been made (136).

Some species of mealybugs (Pseudococcidae) can cause significant crop losses (45), although they seldom approach major pest status. Ali (9) regards them as minor sporadic pests which, in areas of heavy infestation, may adversely affect germination, growth, yield, and juice quality. Williams (160), in a review of the mealybugs of sugar cane, rice, and sorghum, lists 30 species which attack the crop, while Dick (45) lists 21. Some, like *Pseudococcus saccharifolii* and *P. saccharicola,* feed on leaves, while others such as *Saccharicoccus sacchari* and *Dysmicoccus boninsis,* occur on the stalk under leaf sheaths; some, like *Trionymus radicicola,* feed underground on roots, and others, like *D. brevipes* and *Ripersia sacchari,* infest roots or stalks near ground level (45). *D. boninsis* has long been considered a minor pest in Louisiana where it may occasionally cause some yield loss and make syrup manufacture more troublesome (86). Factors which may contribute to increases in mealybug populations include certain ants which reduce the effectiveness of natural enemies, remove honeydew waste, and transport mealybugs from one place to another, drought conditions which inhibit development of entomogenous fungi, continuous cropping, and plant varieties with closely adhering leaf sheaths which provide a large protected area for stalk-infesting mealybugs (45, 163). Most parasites of mealybugs are hymenopterans of the family Encyrtidae, and the most effective predators are coccinellid beetles (45). Insecticidal treatment for field control generally is considered justifiable; however, cultural practices such as the planting of uninfested seed cane and destruction of crop residues should be practiced to avoid or reduce infestation and losses (45, 86).

SOIL INSECTS

The pests mentioned here include those which damage or have been considered to damage sugar cane plants mainly below the soil surface. Wilson (165) has recently reviewed the use of insecticides to control soil-inhabiting pests of sugar cane including symphylids (Myriapoda), bristletails (Thysanura), springtails (Collembola), crickets (Gryllidae), mole crickets (Gryllotalpidae), termites (Isoptera), burrower bugs (Cydnidae), cicadas (Cicadidae), ground pearls (Magarodidae), mealybugs (Pseudococcidae), wireworms (Elateridae), white grubs and dynastid beetles (Scarabaeidae), long-horn beetles (Cerambycidae), Rhyparida grubs (Chrysomelidae), soldier flies (Stratiomyiidae), and ants (Formicidae).

Beginning in 1954 and continuing through 1964, the application of 2 lbs per acre of chlordane on seed cane in the planting furrow was recommended and widely practiced in Louisiana to control a miscellaneous group of small animals, sometimes only identified as "injurious soil arthropods" but generally considered to include springtails, bristletails, symphylids, snails and other small soil animals (85, 110, 111, 113). Insecticidal control of "small soil arthropods" in heavy soils was justified mainly by the observations that these soils contained an abundance and variety of small soil animals including one species of Gastropoda (*Zonitoides arboreus*), two of Symphyla (*Hansiella unguiculata* and *Symphylella* sp.), one of Thysanura (*Japyx* sp.), two of Diplopoda, three of *Collembola* (*Onychiurus armatus, Proisotoma minuta*, and *Pseudosinella petterseni*), and one of Dermaptera, which gnawed pits in sugar cane roots or grazed upon root hairs (81, 147), and that soil application of chlordane resulted in yield increases of several tons of cane per acre (30, 85, 110, 113). Claimed correlations between yield reductions and numbers of presumed injurious soil arthropods are not accompanied by data which can be analyzed statistically (29, 85, 148), and sometimes fail to identify the arthropods except as "injurious soil insects" (85). These claims are currently unconvincing in the light of more recent studies which have shown that soil treatment with chlordane had no significant effect on field populations of any Collembola or other microarthropods frequently encountered in sugar cane soils, and which suggest that a small yield difference favoring chlordane treatment might result from direct stimulating effects of the insecticide on plant growth (104). For these reasons soil insecticide application is no longer recommended for control of these small soil animals in Louisiana.

Termites have occasionally attacked sugar cane in most countries where it is grown, but are important pests only in India, Queensland, China, Congo, and the Caribbean (67). Harris (67) states that most damage is done soon after planting by termite workers, which may completely devour the interior of planted seed cane, thereby destroying stands, although mature canes and ratoons may also be attacked. He indicates that termite damage is generally most pronounced during drought conditions. Control has been achieved by the application of BHC, aldrin, and other chlorinated hydrocarbon insecticides in the planting furrow, by dusting or dipping the ends of seed pieces in these insecticides before planting, or by a broadcast application of insecticide which is then worked into the soil (165). Destruction of visible termite nests in surrounding areas is also considered useful (67).

Germination and root growth of sugar cane is reported to have been significantly increased in Brazil by applying lindane, toxaphene, or chlordane in the furrows before planting the cane to control a burrower bug, *Scaptocoris castaneus* (165). We can recall only one occasion on one farm in Louisiana during very dry weather when burrower bugs were thought to have damaged cane in parts of some fields. However, two burrower bugs, *Pangaeus bilineatus* and *Sehirus cinctus,* are often observed in Louisiana cane fields where they have appeared to be most abundant during spring and early summer (87).

During the last decade, cicadas have become important cane pests in Madagascar, Queensland, Taiwan, and Argentina (40, 47, 165). Nymphs emerge from eggs laid in cane leaves and enter the soil, where they suck sap from roots for up to two years (47); if 30 or more nymphs are present per stool, they may cause failure of the cane to stubble or kill the plants while they are small (165). Dubois (47) mentions three practices which have contributed to the current problem with a cicada, *Yanga guttulata,* in Madagascar—the increasing popularity of growing more ratoon crops from the same cane, the burning of fields to destroy leaves before cutting, and the mortality of cicada predators caused by aldrin and endrin soil treatment. No satisfactory chemical control methods have been developed, according to Wilson (165).

Ground pearls have been found on sugar cane roots in Barbados, Brazil, the Virgin Islands, Queensland, and Southern Rhodesia (76, 165). Depending on the species, development may require from one to five years, and field populations as high as 10,000 live cysts per stool of cane are often encountered in Queensland (76). In 12-gallon drums of soil such infestations have reduced cane yield by 21 percent after 14 months, but comparable results have not been obtained in field trials because the insecticides tested have not been sufficiently effective against these insects (76).

Other root-feeding Homoptera include the diaspid scale, *Lecanopsis sacchari,* which may seriously affect sugar cane in Formosa (136), and the mealybugs, *Trionymus radicicola* in Cuba and *Neorhizoecus* sp. in Barbados (165). According to Metcalfe (165), the latter pest is not very important now that fewer ratoon crops are grown.

Wireworms are most injurious in Louisiana during fall and winter months, when they destroy the buds on stalks of fall-planted seed cane before growth starts, thereby preventing good stands (86); however, they may also damage ratoons (101). In 1947–48, Bynum et al (29) obtained significant increases of as much as 3369 lbs of sugar per acre from soil treatment with chlordane in an area heavily infested with wireworms of the genera *Melanotus, Conoderus,* and *Aeolus.* They also showed that stand losses could be reduced almost as effectively by early planting (August 1 to 15 instead of September 20 to October 10) as by soil treatment with chlordane. Our observations since 1957 indicate that wireworms have only rarely caused noticeable damage to Louisiana sugar cane (possibly due in part to widespread insecticide application), and when infestations have occurred, they have been restricted to relatively small portions of fields and farms. Because of growing concern over contamination of the environment by persistent pesticides, diazinon is now recommended in lieu of chlordane to control wireworms here.

Scarabaeidae are major pests of sugar cane in Africa, Australia, India, Mauritius, Philippines, Puerto Rico, and some other cane growing areas (15, 153, 165). The great majority of these pests are destructive as larvae (white grubs) which feed mainly on roots. However, in the subfamily Dynastinae the adults of some species also attack cane by feeding on the buds and root primordia of cane setts and by gnawing ragged holes in the young shoots at or just below the soil surface (166). In Louisiana this sort of damage by the sugar cane beetle, *Euetheola rugiceps,* is reported to have caused heavy losses in the 1930's (86), but in recent years sugar cane beetle damage has seldom been seen here and no control measures are practiced to prevent it. However, in other places, depending on the species, soil and other prevailing conditions, serious crop damage may result from populations of one or more white grubs per stool (166). Avasthy (15) states that in years of severe infestation almost 80 percent of the crop has been lost in India. Wilson's recent reviews (165, 166) of the biology and control of white grubs in sugar cane indicate that summer cultivation to destroy grubs in the upper soil, timing of planting to permit root development before grubs attack, and use of resistant cane varieties have all contributed to the control of some species. Avasthy (15) states that the plant traits associated with resistance are abundant tillering, rapid growth, large amounts of root tissue, and rapid regeneration of roots from numerous root primordia following grub damage. In reviewing the biological control of sugar cane pests, Simmonds (145) indicates that the introduction of scoliid wasps of the genus *Campsomeris* from the Philippines gave excellent control of *Anomala orientalis* in Hawaii and of *A. sulcatula* in Saipan. However, Wilson (166) believes that wherever native species of grubs have long posed a serious problem, soil insecticides are providing the most effective solution to the problem. He further indicates that the use of insecticides (primarily BHC and other chlorinated hydrocarbons) to control these and other soil pests is now a matter of prevention rather than cure, but that such use may be unnecessary or wasteful where infestations are restricted or sporadic and the cost of insecticide is high. He discusses how the proper timing and methods of applying insecticides are influenced by the biology of the insect, including its life cycle, behavior, and seasonal occurrence, the potential phytotoxicity of the insecticide, and the prevailing methods of cultivation in the problem area.

Frequently present in Puerto Rico with white grubs, though not as destructive, is the curculionid larva, *Diaprepes abbreviatus*, which bores inside the stools (108). Larvae of the sugar cane weevil, *Anacentrinus subnudus*, tunnel below or near the soil surface in seed cane, young plants, and stubs. They usually become increasingly abundant in successive ratoon crops and sometimes contribute to reduced stands (86). In Puerto Rico and Mexico, soil applications of insecticides are used against these insects (165), while in Louisiana, where only *A. subnudus* is reported on sugar cane, the weevil is considered a minor pest not justifying chemical control measures.

Other beetles discussed by Wilson (165) as soil pests of cane include the long-horn beetle, *Dorysthenes hydropicus*, in Taiwan which tunnels in the underground portions of stalks thereby killing them, and the larvae of leaf beetles of the genus *Rhyparida*, in Queensland, which burrow in the bases of young shoots killing heavily infested stools. Other soil pests in Queensland mentioned by him are the funnel ant, *Aphaenogaster pythia*, which lacerates roots, causing progressively poorer cane growth in successive ratoon crops, and larvae of the soldier fly, *Altermetoponia rubriceps*, which may prevent germination of planted cane and reduce stands in ratoon crops. Various methods of soil insecticide application are used for the control of all of these insects.

Stalk Borers

The larvae of about 50 species of lepidopterous borers are recognized as pests of sugar cane. None are cosmopolitan and many attack other cultivated hosts, especially Gramineae. The close botanical relationship of sugar cane with many wild grasses suggests that most, if not all, are indigenous species that have adopted sugar cane as a host consequent to its cultivation in different regions of the world. Many Old World species belong to the genera *Chilo* and *Sesamia*, whereas those in the New World are mostly *Diatraea* species. Bleszynski (20) states that "*Chilo* Znk. and *Diatraea* Guild. form a compact monophyletic group and are kept as distinct genera mainly for practical purposes." With the exception of Australia and Hawaii, species capable of causing economic losses in sugar yields are found in all major sugar-producing regions.

There are at lest seven economically important species in India, several of which occur together in most parts of that country. *Chilo tumidicostalis*, *C. auricilius C. indicus*, and *Scirpophaga nivella* damage the crop mostly after internode formation (7). *Sesamia* species, especially *S. inferins* and *S. uniformis*, are mostly borers of young shoots (134). *S. inferins, C. auricilius C. sacchariphagus*, and *Argyroplace shistaceana* occurred only occasionally on sugar cane in Java before 1942, but have been much more important since 1945 (138). *C. infuscatellus, S. nivella, S. inferins*, and *A. shistaceana* are serious pests of sugar cane in the Philippines (114) and the latter three are pests of sugar cane in Taiwan (102). *C. sacchariphagus* is the most destructive moth borer attacking sugar cane in Mauritius (161) and is also a major pest in Reunion (54). *S. calamistis* and *Eldana saccharina* are the only moth borer pests of sugar cane in South Africa (102) and *C. agamemnon* damages sugar cane in the United Arab Republic (55). *D. saccharalis* is the most important species found in the Western Hemisphere (102). It is the only species of moth borer attacking sugar cane in Louisiana and is also a major pest in Cuba, Peru, Puerto Rico, Jamaica, Trinidad, Mexico, and Florida. Other pest species in Mexico are *D. considerata, D. magnifactella, D. grandiosella,* and *Acigona loftini. D. centralla* is the major moth borer pest of sugar cane in Guyana and Trinidad (102). *Elasmopalpus lignosellus* is a sporatic pest of sugar cane in the Western Hemisphere. Box (21) lists this species from sugar cane in Argentina, Guyana, Cuba, Mexico, Peru, and the United States.

Yield losses.—Yield losses reported for most species of moth borers are ascribed to reductions in crop stands before young shoots form internodes and reductions in stalk weight and juice quality after internode formation is initiated. The amount of yield loss associated with shoot destruction is uncertain for many species (120). In Louisiana, shoot destruction by larvae of *D. saccharalis* never exceeds 10 percent annually, yet commercial varieties grown here can tolerate as much as 33 percent reduction before yields are significantly reduced (73). Varieties grown in Louisiana tiller profusely early in the spring when *D. saccharalis* larvae are destroying shoots, and attain densities of 50,000 to 80,000 shoots per acre. Stands then progressively decline, apparently due to plant competition, to levels of 30,000 to 40,000 millable stalks per acre at harvest time in the fall. Other examples of crop compensation for shoot destruction by different moth borer species are reported by Rao & Rao (135), Doss (46), Khanna (96) and Van Dillweijn (159).

Dame by larvae of moth borer species after internodes have begun to develop usually consists of killing the growing points of stalks, thus preventing further development of internodes, and tunneling within stalks which impairs growth, causes stalks to break and lodge, and is reported to reduce juice quality (120). Loss in weight of cane results mostly from impaired growth. Severe attack may cause desiccation or rotting of whole stalks, development of side shoots and late tillering (120). The use of severely bored seed cane results in poor germination and reduces yields (75). Larval tunnels serve as entry points for infection by bacteria, fungi, and yeasts (115). Red rot, *Physalospora tucamanensis,* has been associated with *D. saccharalis* damage (106); however, its extent and severity depends largely on the variety of sugar cane (4). Secondary attack by weevils, especially *Metamasius* species, is sometimes reported to be important in the Western Hemisphere (156, 167).

Surveys of symptoms of damage, especially percentage of stalks damaged or internodes bored, have been widely used to estimate crop losses caused by moth borers. Some of the advantages and weaknesses of these methods are discussed by Metcalfe (120). Mathes et al (112) related percentage of internodes bored by *D. saccharalis* to yields in an experiment with a single sugar cane variety in Louisiana and calculated a reduction of approximately 0.5% in yield of sugar/acre for each 1 percent internodes bored. Dugas et al (50) reported similar studies in Louisiana with 10 commercial varieties which indicated the average reduction in sugar yields for all varieties amounted to about 1 percent for each 1 percent internodes bored. Hensley & Long (70) compared yields from insecticide-treated and untreated plots in 14 variety trials conducted from 1959 to 1965 and showed a wide response among varieties to damage by *D. saccharalis*. It can be calculated from their data that reduction in weight of cane were 0.38%, 0.42%, 0.41%, 0.52%, and 0.54%, respectively, for each 1 percent of internodes bored in the varieties NCO 310, CP 36–105, CP 52–68, CP 48–103, and CP 44–101.

Jepson (89) describes a method that has commonly been used to estimate losses ascribed to moth borer species. Samples of bored and unbored stalks are obtained throughout the harvesting season and analyzed for brix, sucrose, and purity. These data are then used with information on crop yields/acre and percent of damaged stalks to calculate losses/unit area of cropland. Ellis et al (53) concluded that an expression of internodes bored/unit weight of cane would be more consistently correlated with sugar loss than would estimates of the number of internodes or stalks bored. Some workers have emphasized the importance of moth borer damage on juice quality (17, 77, 120) while others emphasize the effects of their damage on the weight of cane (46, 53). An unpublished compilation of results from field experiments conducted by the authors in Louisiana show that loss in weight of cane from attack by *D. saccharalis* is at least four times as important as losses in juice quality. McGuire et al (116) calculated a correlation equation, based on empirical data for one sugar cane variety, to express the relationship between yield loss and *D. saccharalis* damage. This equation takes into account both percent and location on the stalk of internodes bored and probably relates damage to crop loss accurately. To date, correlations with overall loss have been worked out only for *D. saccharalis* in Louisiana, and correlations with partial losses refer almost exclusively to the same species (120). For maximum accuracy in loss estimates, there appears to be no way to avoid the need for establishing an empirical relationship between indexes of infestation and associated crop losses for each particular moth borer species and sugar cane variety in each geographic region. Average results from replicated field experiments in which sugar yields are compared in moth borer controlled plots and in check plots appear to offer the most direct and accurate estimates. These procedures require relatively more effort than damage surveys but satisfy more objectives.

Biological control.—Attempts to control moth borer species attacking sugar cane with biological agents have mostly involved introduction and establishment of exotic parasite species or rearing and release of native egg parasites, especially *Trichogramma* species. Bennett (19) lists five species of tachinids—*Lixophaga diatraeae, Metagonistylum minense, Paratheresia claripalpis, Palpozenillia palpalpis,* and *Diatraeophaga striatalis*—that have been used as biological control agents, and reports that economic control of *D. saccharalis* has been obtained in several regions of the Western Hemisphere with *M. minense* or *P. claripalpis.* Twenty-one species of exotic parasites have been released in Louisiana for control of *D. saccharalis* (37). However, only *L. diatraeae* has become established and it parasitizes less than 4 percent of the *D. saccharalis* population annually (68). Furthermore, parasitism appears to be highest in heavily infested fields and in the fall when *D. saccharalis* is infesting internodes in the tops of stalks and causing little crop damage. Reasons set forth for failure of these parasites as biological control agents are that winter temperatures in Louisiana may be below their survival limits and that there is not sufficient host population available in the winter to maintain parasite populations from one crop season to the next (38).

Control of *D. saccharalis* has often been ascribed to population enhancement programs involving release of *Trichogramma* egg parasites reared in the laboratory (49, 74, 158). However, other studies (25, 88, 122) show that releases at rates of 5000 to 45,000 parasites per acre failed to provide control. *Trichogramma* species have also been released for control of moth borer species in China, Taiwan, Philippines, India, Madagascar, and Mauritius (121). Metcalfe & Breniere (121) conclude that many claims for successful control of moth borer species with *Trichogramma* are unfounded and that liberations are of no value in the United States, Barbardos, Guyana, and Madagascar. They also state "that the *Trichogramma* method should be re-examined in its remaining strongholds." Recent studies of natural *Trichogramma* parasitism of two lepidopterous stalk borers attacking rice in Louisiana (*D. saccharalis* and *Chilo plejadellus,* show that economic control by high levels of parasitism (above 90 percent) was occasionally attained, but only after natural populations of *Trichogramma* had reached levels of 300,000 to 800,000 per acre. More recently, native predatory arthropods have been found to be beneficial as biological control agents of *D. saccharalis* in Louisiana (72, 125, 126). A complex of ants, spiders, and carabids are especially valuable in early summer, when their suppressive effects on *D. saccharalis* populations may delay the need for insecticide applications in many fields for two to four weeks.

Cultural control.—Cultural methods for controlling moth borer species have been advocated in various sugar cane-producing regions for many years. However, there are few regions where they are used effectively. Charpentier & Mathes (36) indicate that early planting, flooding of fields, destruction of infested crop residues, either mechanically or by burning, and using corn as a trap crop are valuable for control of *D. saccharalis* in Louisiana. However, none of these has been used to any extent during the past decade. Reasons for lack of grower interest in these practices are high labor costs required for their employment, the low degree of control provided and highly effective control with insecticides. Currently useful cultural practices employed by Louisiana growers include only the planting of uninfested seed cane and removal from fields of heavily infested crop residues, whenever labor is available to permit the latter. Cultural practices reported to be effective for control of other moth borer species include post harvest flooding of fields for 48 hr to reduce larval populations of *Castnia licoides* in Guyana (36), elimination of grass from fields in Queensland to prevent migration of *Bathytricha truncata* from grass to cane (36), destruction of infested shoots to reduce populations of *S. nivella* in Java (89), and the use of light traps in combination with manual collecting of moths and egg masses in India (63).

Host plant resistance.—There are numerous reports in the literature on observed differences among sugar cane varieties to attack by moth borer species (109). However, much speculation is presented on the host plant resistance mechanisms involved and little experimental data has been published to confirm these speculations. Mathes & Charpentier (109) cited unpublished data indicating the following plant characteristics as unfavorable for establishment of *D. saccharalis* on sugar cane plants: (*a*) rind hardness; (*b*) light stalk color; (*c*) wax coating of stalks; (*d*) high fiber content of stalks; (*e*) plant height—varieties possessing tall thin stalks with long internodes are more resistant; (*f*) stalk diameter—thin stemmed varieties are resistant; (*g*) degree of pith in stalks—varieties without pith are resistant; and (*h*) leaf shedding ability of stalks—varieties that shed the lower leaves and leafsheaths are resistant. There are few published data to indicate that these are valid resistance mechanisms for *D. saccharalis* or other moth borer species. Studies conducted in Louisiana within the past six years to determine the host plant mechanisms responsible for variety NCO 310 being more resistant to *D. saccharalis* than in CP 44–101 show that: (*a*) oviposition preference was not a factor, (*b*) about 60 percent fewer larvae of the first two instars survived on NCO 310, and (*c*) the close fitting leafsheaths of NCO 310 serve to exclude some small larvae from feeding sites and thus are partially responsible for failure of many larvae to establish and survive (39, 99). Review articles containing information on host plant resistance to species of moth borers attacking sugar cane have been published by Jepson (89), Agarwal (6), and Mathes & Charpentier (109).

It has been shown that low levels of resistance to *D. saccharalis* are already present in some commercial varieties grown in Louisiana and that this resistance is important in terms of higher yields and the need for fewer applications of insecticide for economic control. Hensley & Long (70) summarized results from 14 replicated variety trials in which yields from plots treated with insecticides, to exclude season-long infestations, were compared to those from comparable untreated plots. Differences among varieties in percent yield loss attributed to *D. saccharalis* were highly significant and ranged from a low of 14.6 percent for NCO 310 to a high of 28.6 percent for CP 44–101. CP 44–101 and CP 48–103 were much more susceptible to *D. saccharalis* than NCO 310, CP 36–105, or CP 52–68. These five varieties comprised more than 90 percent of the sugar cane produced in Louisiana from 1959 to 1965. Surveys of grower use of azinphosmethyl from 1966 to 1968 showed that an average of 1.3 applications/season was made for control of infestations on NCO 310 compared to 2.9 for the susceptible variety CP 44–101; thus, 50 percent less insecticide was used for control of *D. saccharalis* on NCO 310.

Insecticidal control.—Insecticides are not used intensively for control of moth borer species attacking sugar cane in any region of the world except Louisiana (102, 143, 146). Aldrin has been used to control *C. licoides* in Guyana, when 48-hr flooding was not practical as a cultural control measure. Endrin 2 percent granules are used occasionally on fixed application schedules in the state of Sinaloa, Mexico, for control of *D. grandiosella* or *A. loftini*. However, the main reason reported for failure of many farmers to follow insecticide recommendations is the expense involved. One application of endrin spray is sometimes used against *D. saccharalis* in Puerto Rico, especially when young shoots are heavily infested; however, insecticides are not used to any great extent there because of low average infestations. Diazinon spray is used to control *A. shistaceana, C. infuscatellus,* and *S. inferins* in the Philippines. The insecticide is first applied when young shoots are infested and applications are repeated at monthly intervals until three have been made (102). In India, where 6 to 7 economically important moth borer species occur, beneficial experimental results against individual species have been reported (143, 146), but little use has been made of insecticides in commercial cane production.

Insecticides historically have assumed a major role in control of *D. saccharalis* in Louisiana. Prior to 1959, ryania or cryolite provided only about 50 percent control when used on fixed weekly application schedules for season-long control of three generations (48, 105). The synthetic organic insecticides, first, endrin and later azinphosmethyl, have provided much more effective control than ryania or cryolite, and thus have been widely accepted by growers (68, 105). Two percent endrin granules applied at rates of 0.25–0.30 lb ai/acre provided about 90 percent control for two to three weeks and were used almost exclusively by growers from 1958 to 1963, when resistance to endrin and other chlorinated hydrocarbons developed in *D. saccharalis* populations (169). Azinphosmethyl, applied as 5 percent or 7 percent granules or as a spray at rates of 0.75–1 lb ai/acre, has replaced endrin and provides 80–90 percent for two weeks. It is currently the only insecticide recommended for control of *D. saccharalis* in Louisiana. Reductions in bored internodes of more than 85 percent and yield increases that ranged from five to nine tons of cane per acre have been obtained following three to four applications of endrin or azinphosmethyl for control of moderate to heavy second and third generation infestations (68, 105). Based on the current value of a ton of sugar cane in Louisiana ($11.00), growers have often realized savings of approximately $50–$100 per acre in yield increases by following insecticide control programs which have required maximum expenditures of less than $10.00/acre for endrin or $15.00/acre for azinphosmethyl.

Comparisons of spray and granule formulations of endrin or azinphosmethyl for control of *D. saccharalis* have shown little difference in effectiveness between formulations (42, 43, 71). Experimentally, ultralow volume spray concentrates of azinphosmethyl have provided control comparable to that obtained with conventional spray or granule formulations (42, 43). However, this method of application has not been recommended to growers because of inherent hazards of insecticide drift. Damage by insecticides to beneficial insects and aquatic organisms, especially fish, was a problem in the Louisiana sugar industry from 1959 to 1961 when large quantities of endrin were applied on fixed application schedules; however, there have been fewer problems with azinophosmethyl, primarily because it is less toxic to these organisms than endrin and also because fixed application schedules have been discontinued. Development of resistance to insecticides in *D. saccharalis* populations has been and probably will continue to be a problem in Louisiana. The effectiveness of endrin was negated by resistance after six years of extensive use. To date, levels of resistance that would prevent obtaining economic control with azinphosmethyl have not been detected in field populations. However, should it occur, carbofuran, which has shown much promise for control of *D. saccharalis* in experimental plots, may serve as a replacement in control programs.

During the past decade, several changes in control procedures recommended to Louisiana cane growers has resulted in reducing the maximum number of insecticide applications required annually for control of *D. saccharalis* from 12 to 3. Changes in control procedures most responsible for reductions in applications are: (*a*) discontinuance of insecticidal control of the first generation, after research had shown that larvae of this generation did not destroy enough young shoots to reduce yield, and that insecticidal control of the first generation did not provide sufficient suppressive effect on the second generation to justify cost (73); (*b*) discontinuance of late season applications, after it was found that treatment of infestations in September and October, when larvae are tunneling nonmillable internodes in the tops of stalks, does not increase sugar yield, or exercise any appreciable suppressive effect on larvae in diapause preparing to overwinter (93, 103); (*c*) discontinuance of fixed application schedules after a reliable economic injury threshold had been established; treatment or retreatment of second and third generation infestations is recommended only when 5 percent of the stalks are infested with small larvae (68); (*d*) improvement in field survey methods for detecting potentially damaging infestations; instead of a system based on superficial signs of feeding by larvae that may later have been eliminated by predators or other ecological mortality agents the present system is based on the presence of live larvae in leafsheaths (68); (*e*) use in control programs of highly effective synthetic organic insecticides that permit longer intervals between applications and that cause minimum damage to arthropod predator populations (68, 105); and (*f*) more emphasis on host plant resistance as a means of controlling *D. saccharalis* (68, 70). This system of pest management takes full advantage of the suppressive effects of arthropod predators, varietal resistance, and adverse weather conditions on *D. saccharalis* populations. However, it relies on the judicious use of insecticides for control of infestations which overwhelm these natural control agents. It is anticipated that reliance will continue to be placed on insecticides used in this manner for the foreseeable future.

Sex attractant.—Discovery of a sex pheromone emitted by *D. saccharalis* females (132) has stimulated research to identify and synthesize the pheromone and to study its potential as a control measure. Synthetic diets for rearing *D. saccharalis* and bioassay techniques for determining active fractions of the pheromone have been developed (64, 69). Significant reductions in *D. saccharalis* damage to sugar cane have been obtained in replicated small plots when sticky traps, each baited with one virgin female, were maintained continuously in plots at rates of 400–800 traps/acre. Significant reductions in damage were not obtained when trap density was reduced to 80/acre; however, male catch/trap was increased approximately 2.5-fold (65). Differences in numbers of males recaptured from points of release were not significant when releases were made at distances of 40, 80, 160, and 320 ft from a trap baited with virgin females; however, recapture of males was only 4.44 percent. Dispersion of males from release points before they became responsive to the pheromone may have been responsible for the low percentage of recapture and also may have contributed to the lack of significant differences when the males were released at different distances (128). Lack of species specificity of the pheromone has been demonstrated. During two years of field work, traps baited with virgin females of *D. saccharalis* attracted large numbers of males of *Crambus teterrellus* (66). Progress on identification of the pheromone has been made (157); however, it has not yet been identified.

Coleopterous stalk borers.—Only a few species of Coleoptera are recognized as stalk borers of sugar cane. The pests mentioned here include those that bore mainly within stalks above the soil surface. *Rhabdoscelus obscurus* is a pest of sugar cane in New Guinea, Queensland, and many Pacific Islands (123). It is the major pest of sugar cane in Hawaii, where it has been effectively controlled, except in low-lying wet areas, by a Tachinid parasite *Lixophaga (Microceromasia) spenophori* (33). The eggs of this species are mostly inserted into internodes near ground level, but may also be placed in leafsheaths and leaf midribs. Larval development and pupation occurs within stalks, and the life cycle from egg to adult averages about 99 days (123). Chang et al (33) believe that increases in populations of *R. obscurus* in Hawaii in recent years can be attributed to increases in the amount of cane trash in fields, which is favorable to weevil development and affords more protection against parasite attack. They suggest use of weevil-resistant varieties to reduce damage. *Metamasius* species are invariably secondary pests of sugar cane in Peru, Bolivia, and the Caribbean Islands, and are capable of contributing to increases in damage initially caused by rats, wind, moth borers, and "cracks" in cane (145). *M. bilobus* causes considerable crop loss in Bolivia. Traps baited with pieces of cane soaked in insecticides have been suggested as a possible means of control (156).

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