IX. INTEGRATED PEST MANAGEMENT

INTEGRATED PEST MANAGEMENT

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INTRODUCTION

Integrated Pest Management (IPM) is a broad concept which refers to a pest population management system that uses all suitable techniques in a consistent manner to reduce and maintain these populations below those levels that cause economic damage (Smith and Reynolds, 1966). It combines and integrates chemical, cultural, physical, ethological, genetic and biological methods, for the purpose of reducing economic losses. In decision making, the fundamental question on which it is based, is the need to know how many insects may cause certain damage and if it is significant to initiate control. Clearly, population evaluation through monitoring should involve a decision-making process, and according to Pedigo (1966) this knowledge fall in Bioeconomics, defined as the study of the relationship between pest density, host responses to injury, and resulting economic losses. On decision rules, none has been more successful than those related to the concept of economic injury level (EIL) from Stern *et al*. (1959). This concept is the basis for most integrated pest management programs that are currently used, with the advantage of practical and simple application in most situations. The economic injury level should be interpreted as the pest population density, in which the cost of the control measure equals the expected economic benefit, so, the control action "saves" a part of yield, which would have been lost without pest control management decision making.

This condition is expressed by the equation:

C = ID*D*P*K

From where:

C = Cost of the management tactic per production unit.
ID = Injury units per pest.
D = Pest density
P = Market value of product, managed resource.
K = Proportional reduction in pest attack.

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Saved or protected yield has a monetary value, which is estimated using biological and economic parameters that are represented by (ID, D, P, and K). It should equal the value spent on the control action (C), in other words, EIL is the pest population density where the value of saved yield covers the cost of control. The injury unit (ID) is the loss of sugar (pounds, kilograms or tones) per hectare, associated with a unit of pest density or damage. To determine ID, experiments are designed in order to provide insight and quantify the relationship between pest density and its effect on yield reduction in sugarcane weight or sugar recovery. The IPM-CENGICAÑA program in collaboration with the IPM committee (CAÑAMIP) generated values of postharvest losses and injury levels for the major pests, which are represented in Table 1. These values are relative and variable, according to local conditions and management values of each sugarmill.

Table 1. Loss factor and injury level estimated for the main pests in Guatemala. CENGICAÑA-CAÑAMIP

Pest	Loss Factor	Injury Level	Economic Threshold
Sugarcane Froghopper	8.21 TCH/1adult/cane 5.83 kg Sugar/t/1adult/cane	1465 kg Sugar/ha/1 adult/cane	0.05-0.10 nymphs and adults/stem
White Grub	0.62 TCH/larvae/m^2	70.9 kg Sugar/ha/1 larvae/m^2	10 larvae/m^2
Field Rat	0.5 TCH/1% infestation. 2.19 kg Sugar/t/1% infestation	65 kg s/ha/1% infestation	6% damaged cane
Sugarcane Borer	0.36 kg Sugar/t/1% infestation	32.4 kg Sugar/ha/1% infestation	7% infestation
Brown Burrowing Bug	0.053 TCH/insect/m^2	6.09 kg Sugar/ha/insect/m^2	100 insects/m^2
Subterranean Termites	0.45 TCH (CP72-1312) 0.22 TCH (CP72-2086)	23.3-47.7 kg Sugar/ha/ 1% infestation	10% damaged cane in harvest

INTEGRATED STEMBORER MANAGEMENT IN SUGARCANE

Borers from *Diatraea* genus

Species of *Diatraea* genus (Lepidoptera:Pyralidae) have greater economic importance and geographic distribution in Guatemala. *Diatraea* nr. *crambidoides* (Grote) has a relative abundance of 73 percent in the lower and coastal stratum, compared with 27 percent of *D.saccharalis* (Fabricius). Other species such as *Xubida dentilineatella* (Lepidoptera: Crambidae), *Phassus phalerus* Druce (Lepidoptera: Hepialidae) and others yet undetermined, occurring at altitudes above 300 meters in the temperate and humid sugarcane region. The biology of *Diatraea* indicated that both species deposit their eggs in clusters (Figure 1) and require between 5 to 6 days to hatch (Figure 2). The larval development period is significantly different, since in *D.saccharalis* is 21 to 23 days, while in *D.nr.crambidoides* extends from 33 to 43 days. That's why the average life cycle is estimated between 41 and 57 days respectively. *D.saccharalis* larvae have dorsal mesothoracic tubercle transversely elongated and rounded at the front; while *D.nr.crambidoides* has the dorsal mesothoracic tubercle in an elongated B-shape form, with an anterior midline incision (Figure 3). The pupal period requires 8 to 10 days; afterwards adults emerge (Figure 4). The adult stage averages 3 to 8 days. Rarely, adults are seen in the field, since they are nocturnal and short range flying, attracted by artificial lights at night.

Figure 1. Oviposition of *Diatraea* nr. *crambidoides*

Figure 2. Borer larvae emergence from egg cluster

Figure 3. Mesothoracic tubercle from *D. saccharalis* (left) and *D. nr. crambidoides* (right)

Figure 4. Female and male adults of *D.nr. crambidoides*

The damage is the result of larvae feeding activity, which may cause the death of meristems in young sugarcane tillers that have not formed aboveground internodes (deadheart), but in elongation and maturation periods, damage is associated with the construction of tunnels, where the larvae lives most of its cycle (Figure 5). The reduction in tonnage appears not significant, in contrast to juice quality due to the presence of fungus *Colletrotrichum falcatum* in borer tunnels. *C. falcatum* is responsible of sugarcane red rot causing reductions in Pol, Brix, and increase of fiber percentage. CENGICAÑA-CAÑAMIP studies indicate that the loss factor is 0.36 kg sugar/t, for every one percent of damaged internodes. For an average production of 90 t/ha, an injury level of approximately 32.4 kg sugar per hectare/ 1 percent damaged internodes is estimated. The greatest losses occur in the Pacific coastal stratum, where at least 57,075 hectares have been monitored, of these about 11.9 percent exceeded the action threshold of 5 percent intensity of infestation (i.i.) in the 2010-2011 harvest.

Figure 5. Drilling on the stem and borer larvae within the gallery.

Phassus phalerus Druce

Phassus phalerus (Lepidoptera: Hepialidae) is a borer of seasonal occurrence between July and November, in sugarcane fields located at altitudes above 300 masl. According to Marquez et al. (2009), the relative abundance is between 19.9 and 20.8 percent in Guatemalan temperate and humid sugarcane regions. In Figure 6, there are larvae, pupa, and adult of this borer.

Figure 6. *Phassus phalerus* borer life forms in sugarcane. IPM-CENGICAÑA program

Elasmopalpus lignosellus Zeller (Lepidoptera: Pyralidae)

The larvae has a variable coloration, from pale to greenish yellow, then pale green and finally blue green coloration. Reddish purple transverse bands and several reddish brown longitudinal lines are present on the larvae's back, which are interrupted at the end of each segment (Figure 7). The highest infestation occurs every year between January and April (15.7-19.9 percent), when soil is dry and the crop is in tillering stage. The larvae pierces the seedlings neck, penetrates and builds a gallery where it feeds, causing drying of the central bud (deadheart). *E. lignosellus* larvae disappears when rain is established or due to irrigation period. Is not considered a specie of economic importance.

Figure 7. ***Elasmopalpus lignosellus*** **larvae**

Control strategies

Tillering: Based on the measured damage value at harvest, ranges are established to program a basic sequence of control. Low ranges between 0.001 and 2 intensity of infestation (i.i) requires at least two releases of *Trichogramma exiguum* (Hymenoptera: Trichogrammatidae), an egg parasitoid, at the rate of 40 square inches per acre. Ranges of 2.01 to 4.00 require the same release rate of *Trichogramma* (Figure 8) and “deadheart” thinning to extract larvae, between 60 and 90 days after harvest. Between 4.01 and 6 percent, requires three Trichogramma releases, deadheart thinning and consider the application of commercial biopesticides, like *Bacillus thuringiensis*, Nuclear Polyhedrosis Virus (NPV), Cytoplasmic Polyhedrosis Virus (CPV). Damage greater than 6 percent requires the capture of adults with light traps, 20 days after harvest; four release program of *Trichogramma*; dead heart thinning, when sampling indicates larval density greater than 1300 larvae/ha; as well as the possibility of three biopesticide applications. Weed control in and out of the plantation is necessary to get rid of alternate hosts.

Elongation: Control actions are reduced due to the difficulty to enter the fields, but according to prioritization obtained with damage and larval density sampling, it will be necessary to implement an alternative program of *Cotesia flavipes* (Hymenoptera: Braconidae) and *Paratheresia claripalpis* (Diptera: Tachinidae) releases. This action must be supported by parasitism sampling, which is obtained by collecting borer larvae 15 and 30 days after release (Figure 9 and 10).

Maturation: Infestation is growing at this stage, associated with the dry season establishment and high crop development, however, control actions taken in previous stages should show an effective reduction. In cases of high infestation, aerial biopesticide application or Tebufenozide can be made. It is recommended to harvest in blocks, ensure a flush cut sugarcane and remove the buds, as they become alternate host for the next crop cycle.

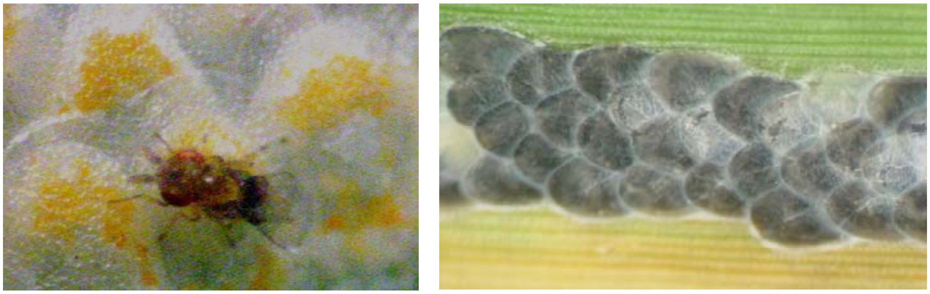


Figure 8. *Trichogramma exiguum* wasp on borer oviposition (left) and detail of parasitized borer eggs

Figure 9. *Paratheresia claripalpis* adult (left) and borer larvae parasitism

Figure 10. *Cotesia flavipes* adult (a), release cups (b), and cocoons resulting from parasitization

FOLIAGE PESTS

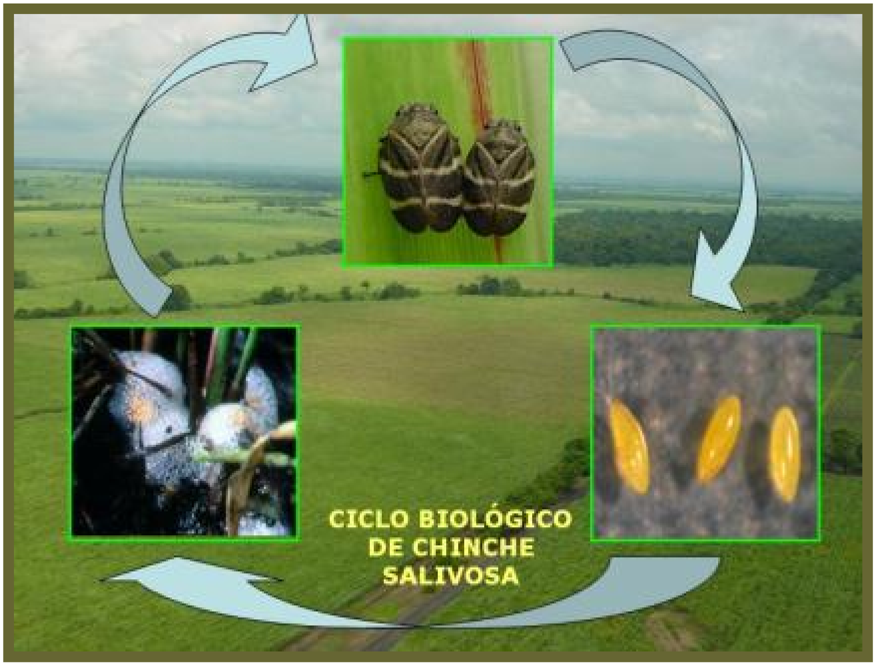
Integrated Pest Management of Sugarcane Froghopper (Homoptera: Cercopidae)

Aenolamia postica and *Prosapia* simulans are the important species in sugarcane plantations, with 96 and 4 percent abundance, respectively (Marquez et al., 2002). These are insects with sucking mouthparts, feeding from xylem of a wide variety of neotropical grasses. Sugarcane infestation is repeated every year with diapausic eggs deposited on the ground the previous cycle. These eggs give rise to the first nymph generation in the rainy season, and from there, several adult generations arise with no diapausic eggs which hatch in 15 days, increasing field population density (Figure12).

Figure 11. Froghopper spittle inside which a nymph can be found

Both nymphs and adults use their stylus to make feeding tunnels, ending in the xylem (Byers and Wells, 1996). Due to low nutritional quality of xylem sap, nymph state lasts for at least 30 days, forming a foam around its soft body and remain in the adventitious roots of the crop. When they reach adult stage, these insects migrate to the foliage and while feeding, they introduce a toxic substance that destroys and interferes with the formation of chlorophyll (Figure 13), which is known as “scorch”, symptom that affects the plants normal development and sucrose accumulation.

Based on the biology, it is clear that successful pest control relies in the reduction of diapausic eggs and nymphs, reduce or delay the occurrence of the critical period that produces high adult densities (Marquez et al., 2009) between July and August. Due to accumulation of diapausic eggs through time and high humidity conditions, there are fields that quickly reach the status of "high infestation" where leaf damage is greater than 60 percent and since the critical period of occurrence is 6 to 8 months crops age, the loss rates can achieve 8.21 TCH and 5.83 kg sugar/t, for every adult/cane (Marquez et al., 2001).



En la figura traducir: Biological cycle of froghopper
Figure 12. Life cycle sugarcane froghopper

Figure 13. Leaf damage caused by sugarcane froghopper (left) and scorch symptom in a sugarcane field

Diapausic egg control after harvest

The Integrated Pest Management Committee (CAÑAMIP) and the Integrated Pest Management Program of CENGICAÑA have documented a basic reference sequence that includes information about timing for each activity, how it is done, using criteria, equipment, operating efficiency, and special conditions to ensure execution effectiveness (Marquez, 2010). Integrated management success is based on egg population reduction, through a basic sequence of mechanized work, which includes implements like the harrow health, barber roll or Lilliston (Figure 15), hilling, taking away all the heaped soil over the plant, crop-hilling and drainage improvements of fields that are flooded during the rainy season. The purpose of cultural control is to reduce the number of diapausic eggs, by means of sun and predator exposure. These tasks are performed immediately after sugarcane harvest, to avoid damaging strain-sprouting and ensure at least 60 percent egg reduction.

Figure 14. Use of harrow health

Figure 15. Use of barber roll or Lilliston

Nymphs and adults control: When rainy season starts, is necessary to initiate monitoring of nymphs and adults, either by using yellow sticky traps around the field edges, or visual sampling using the tiller as observation unit. The action threshold for land applications of *Metarhizium anisopliae* varies between 0.05 and 0.10 insects/stem aimed at controlling nymphs' first generation, which will cause the epizootic in adult's infield (Figure 16). Areas with a history of severe damage in previous harvests, requires an analysis that considers the option of applying preventive synthetic chemicals (Thiamethoxan, Imidacloprid), changing the fields harvest time or the crops renewal.

Figure 16. Appearance of adults parasitized by *Metarhizium anisopliae*

Foliar damage should be measure by late September or early October and, based on percentages, sort fields in categories of slight damage (0-40%), moderate (41-60%) or severe , more than 60% foliar damage.

Sugarcane Lace Bug, *Leptodyctia tabida* (Hemiptera: Tingidae)

Lace bug is an insect with sucking mouthparts, which was first described by Eric Schaeffer as *Monanthia tabida* in specimens collected in Mexico in 1839, although later was named *Leptodyctia tabida* by Champion, in 1900. Adults have flattened body, with oval, semitransparent, elongated wings, extending beyond the abdomen with ribs that simulate a fine lace, hence their name "Lace Bug" (Figure 17). The antennae are yellowish, long and thin; pronotum is narrow in the front. Nymphs are flat, whitish with many spines branched, straight and long. Nymphs molt five times and reach maturity in about 15 days. Eggs are very small, deposited in the parenquima cells of leafs´ underside.

According to Chang, 1985, lace bug have been reported on corn (*Zea mays*); Guinea grass (*Panicum maximum* Jacq); Johnson grass (*Sorghum jalapense*); *Echinochloa crus-galli* (L.) *Beauvois*, Bamboo; Sugarcane (*S. officinarum*) and Teosinte *(Zea mexicana*). There seems to be a relationship between levels of stress in plantations caused both by excessive moisture and drought, which favor the emergence of the pest and its eventual dispersal.

The presence of lace bugs in Guatemala (Figure 18) has been increasingly evident infield, as reported in the Harvest Analysis 2007-2008, where at least 19,670 hectares had some degree of incidence. Heavy rains during July-September period influence the reduction of lace bug infestation, because it drops nymph colonies to the floor. For now, rain is a beneficial factor in sugarcane fields and thereby reduces the risks of adverse effects in development. Infestation preference was determined on variety CP88-1165, which is widely distributed in the sugarcane region.

Figura 17. Detail of lace bug adult and colony formation in sugarcane

Figure 18. Appearance of sugarcane fields with lace bug infestation

West Indian Canefly or "Coludo"; *Saccharosydne saccharivora* (Homoptera:Delphacidae)

This is an insect with sucking mouthparts known as West Indian Canefly, or Green Leaf-Hopper. It has been important in regions of the Caribbean and

Jamaica, although its distribution occurs from southern United States through the Caribbean to Venezuela. The adult male (Figure 19) has transparent, well-developed wings, while females and nymphs have white waxy filaments, attached to the abdomen (Figure 20), from where derives its Spanish name “Coludo”. Direct damage is a general weakening of the plant, but indirect effects results from the rapid colony development, where both nymphs and adults, produce large amounts of honeydew that falls on the lower leaves. This secretion serves as a substrate for sooty mould development (*Capnodium* sp.), which covers the leaves with a thick black crust that consists of sooty mould spores. This layer blocks gas exchange through leaves, affecting severely transpiration, photosynthesis and, consequently limits plant growth (Giraldo-Vanegas et al., 2005). Systemic insecticide control is recommended in sugarcane plantations less than three months old, especially in seedcane condition, plus a nitrogen fertilizer to speed recovery.

Figure 19. Sugarcane Leafhopper adult

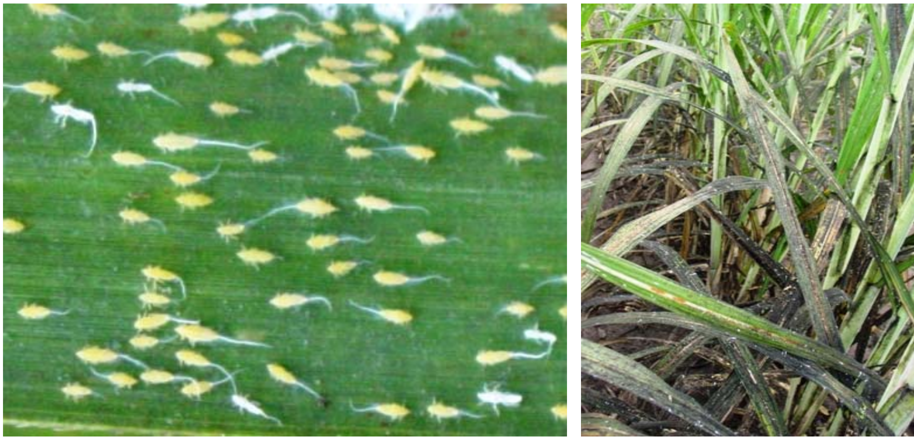


Figure 20. Sugarcane Leafhopper nymph colony (left) and presence of sooty mould in lower leaves (right)

Sugarcane Delphacid: *Perkinsiella saccharicida* (Homoptera: Delphacidae)

Perkinsiella saccharicida (Figure 21) is native to Australia and its occurrence in sugarcane produces yellowing, slow growth, shortened internodes, premature leaf drying and in severe cases, death of young plants. Nymphs and adults excrete a sugary liquid that covers the foliage and serves as a substrate for sooty mold development. In general, both Cane Leafhopper and Sugarcane Delphacid appear together in sugarcane fields. However, the real importance of this insect lies in being the transmitter of Fiji disease virus, pathogen not reported in the region.

Figure 21. ***Perkinsiella saccharicida* adult**

Yellow Sugarcane Aphid: *Sipha flava* Forbes (Homoptera: Aphididae)

Aphids are manifested gregariously, forming colonies located on the underside of leaves, and are characterized by their yellow color, which differentiates from the gray aphid *Melanaphis sacchari*. Major infestations in Guatemala are presented between February and April in a warm and dry environment, when the crop reaches 3 to 4 months old (Figure 22). Aphid populations increase, mainly by asexual reproduction (parthenogenesis), where females are not fertilized because there are no males, thereby placing small adult aphids. Damage symptoms are characterized by yellow color on the leaves of the edge and apex, which consequently dry up, causing a delay in crop growth.

Figure 22. Aphid colony and symptoms in sugarcane

Control Strategies

Sprinkler Irrigation: It is an effective measure when the initial focus of infestation is detected and when feasible, efficiency is higher with the use of vinasse in irrigation.

***Crysoperla carnea* larvae releases**: This aphid predator known as "Aphid Lion" (Figure 23) whose air or land release requires at least 23,000 larvae/ha. Also recommended coccinelid larvae releases (*Hippodamia convergens*, *Cycloneda sanguinea*). In Guatemala's sugarcane region, *Cycloneda sanguinea* larvae, is frequently found preying on aphids (Figure 24).

Figure 23. *Crysoperla* spp. larvae

Figure 24. *Cycloneda sanguinea* adult

RODENTS

Integrated rat management; *Sigmodon hispidus* (Rodentia:Crecetidae)

Sigmodon hispidus (Figure 25) is the predominant rat species in Guatemala´s sugarcane tropical region, with 93 percent of abundance, compared with other genus occurrence, such as: *Peromyscus*, *Heteromys*, *Liomys* and *Oryzomys*. Distribution is associated with large grassland areas, riverbanks, vacant areas and crops such as corn, rice, sorghum, and sugarcane. *Sygmodon hispidus* population increases due to the high reproductive capacity, expressed by female's continuous polyestrous cycles, bicornuate uterus and rapid sexual maturity, 40 to 60 days old. The average gestation period is very short and requires only 27 days for a litter that can be from 5 to 12 offspring. Longevity is 3 to 5 years, but under cane's natural condition, life expectancy is about 6 months.

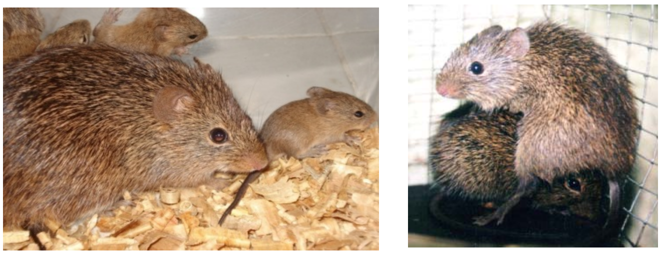


Figure 25. *Sygmodon hispidus*, the most abundant species in Guatemalan sugarcane

For Guatemala, the largest rat population and damage increases is recorded in the Pacific Ocean´s seashore stratum, where approximately 10, 949 monitored hectares indicate levels above the five percent threshold of damaged crop stalks, for 2010-2011 harvest. Damage is caused by rodents feeding activity and the need to wear down the incisors, biting stems, which eventually lead to lodging and further plant deterioration. Studies by IPM-CENGICAÑA claim that the stem's weight reduction is more significant than the juice quality, and the loss factor is 0.5 TCH for every percent of damaged stems at pre-harvest time (Marquez, 2002; Estrada et al., 1996).

Harvest as population reduction factor: Sugarcane harvest affects rat population by destroying its habitat and reducing their primary food source, which forces a dispersion process of survivors to the surrounding areas. Machinery for lifting and transporting sugarcane is the main factor of mortality and dispersal in high infestation areas, and it is the right time to start a healing process within and outside the fields, for the purpose of reducing the shelter and making the environment less favorable for rat survival. Mechanical control when burning is a necessary activity for those areas located in low and coastal stratum, wherein preharvest sampling presents a value greater than 30 percent capture. It is an extreme measure for controlling high populations infield at harvest, to avoid dispersion and further damage to adjacent fields.

Figure 26. Devices for mechanical control when cane burning; metal structure designed by Pantaleon Sugarmill (left) and other, rubber-based, designed by La Union Sugarmill (right)

Biological control in tillering: This is the appropriate stage to take advantage of biological control by placing structures called “hangers” (Figure 27), that facilitate the predatory action of owls *Tyto alba* (Figure 28) and hawks (*Buteo platypterus*), that still occur in sugarcane fields. The preservation and promotion of natural reserve areas in farms and the use of nesting boxes, placed in leafy trees (Figure 29), are other important activities.

Figure 27. Bamboo hangers, properly designed to facilitate the predatory action of owls and hawks in sugarcane fields (Palo Gordo Sugarmill)

Figure 28. Owl *Tyto alba* (Pantaleon Sugarmill)

Figure 29. Wooden boxes for owl nesting (La Union Sugarmill)

Weed control is key in elongation phase: Generally, rainy season starts (May) at this stage and is the factor that promotes vegetation abundance in cane fields neighboring areas. These areas can easily become breeding grounds called "source habitats", where the rat population has ideal conditions for a higher birth rate, driven by grass-weed seeds abundance, that provide supplemental protein to females for continuous periods of gestation and lactation. It is also a period in which, exploratory pulse increases, hence expanding their range of action, thereby colonizing new areas of food and shelter. These conditions significantly increase the probability of population survival and with this abundance, begins the process of social organization, ending with the formation of a hierarchical structure composed of the "dominants" which are burly, aggressive and skillful, individual adults and the rest, accept the "subordinate" role. Dominant individuals have preferential access to water resources, food, space, and reproduction. To counteract this phenomenon, weed control is recommended (Figure 30) in and out of sugarcane fields.

Figure 30. Weed control to eliminate "source habitats" as breeding grounds for rats.

Another element that has been successful in most sugar mills is a program of massive catches with "Victor traps" or "guillotine" and "cage-type" (Figure 31).

Figure 31. Mass capture with traps require specific maintenance and distribution

The tiller overturning, due to strong winds, creates an excellent coverage and protection for rat population, another favorable factor to population increase. Monitoring and chemical control, by using first-generation anticoagulant baits, is recommended as a rational choice at the end of this stage.

Colonization process in the maturation period: In sugarcane's maturation phase, rat populations find the right conditions for growth as the sugarcane increases its energy value and thus becomes the most abundant food source. The high population density leads to the emergence of strong competition between rats, which force them to make further trips in search for food, mating or space, favoring the uniform infestation of sugarcane fields. Also, in October, sugarcane's prostrate condition and residual moisture stimulate the emergence of new shoots (suckers) that rats use as an alternate water source.

In the last months of that the maduration period (November-February), the rat has additional energy expenditure due to lower night temperature, which forces them to thermoregulate their body temperature. Rats are "homeothermic" individuals, meaning that they maintain a constant body temperature and also "endothermic" because what determines its internal temperature is metabolic heat. Thus, rats are able to modify their metabolism to maintain constant body temperature, being this process the core component of thermoregulation (Coto, 1977). Consequently, the energy deficit produced by thermoregulation is offset by higher daily food consumption. But this process is also responsible for a reduction in rat's reproductive activity, since this power is now intended to subsidize the search for food and space. Understanding these aspects of rat ecology in sugarcane's production system, justifies resources and preventive plan implementation with unavoidable rationality and greater efficiency to reduce losses infield (Figure 32).

Figure 32. Damaged stems by rats infield

Gophers; *Orthogeomys hispidus* (Rodentia: Geomydae)

Gophers are mammalian rodents, moderately small sized; without clear neck differentiation; unremarkable ears and small eyes (Figure 33). Legs are short, with well developed muscles; nails are long and strong, curved and sharp. Due to their eating habits and underground life, these mammals have become a pest of economic importance in areas of high and middle strata of Guatemala's sugarcane areas. They are responsible for tiller depopulation, by destroying the root system until causing plant's death (Figure 34).

Figure 33. Gopher specimen causing depopulation in Guatemala's sugarcane plantations.

Figure 34. Tiller destruction by gopher in sugarcane

Control strategy: Gopher's integrated management depends mainly, on the skill and cunning of gopher hunters in capture programs, either using bellow traps or traps with rod and spear. Chemical control is not recommended as it exposes people that use gopher as a food source. Habitat modifications by weed and stubble control, deep fallow, live hedgerows with repellent shrubs, such as Castor oil plant, are important cultural strategies.

ROOT PEST COMPLEX

The pest complex that inhabits the root system has variations, depending on the region and altitude. Within this complex the following white grub species have been identified: *Phyllophaga dasypoda* (Figure 35); *Phyllophaga latipes*; *Phyllophaga parvisetis* and *Phyllophaga anolaminata*. Wireworm genus and their relative abundance are: *Dipropus* spp (92%); *Horistonotus* spp (3.3%); *Agrypnus* spp (2.6%) and *Dilobitarsus* spp (2%). Also other insects have integrated like the Brown Burrowing Bug (*Scaptocoris talpa*), weevils (*Sphenophorus* spp) and termites (*Heterotermes convexinotatus*).

The combined insect population that affects roots is expressed as the number of individuals per square meter and the size of the sampling unit is a block of 0.90m X 0.60m X 0.40m deep, reviewing all insects that occupy the soil and roots. Subterranean termites (Isoptera: Rhinotermitidae) are social insects that commonly infest Guatemala's sugarcane fields, and studies carried by CENGICAÑA with the collaboration of Dr. Rudolf H. Scheffrahn from University of Florida, show that at least four species have been identified: *Heterotermes convexinotatus*, *Microcerotermes* nr. *gracilis, Amitermes beaumonti* and *Nasutitermes nigriceps* (Marquez, 2006), however, the most abundant is *Heterotermes convexinotatus* (Figure 37).

Figure 35. ***Phyllophaga dasypoda*** **larvae, adult and male genitalia shape**

Figure 36. Wireworm larvae and Brown Burrowing Bug nymph in Guatemala's sugarcane.

Figure 37. Soldier, colony and sugarcane stalk damage by *Heterotermes convexinotatus*

Control strategy: Sampling before soil turning and planting is the basis for decision making either for cultural or chemical control. Good soil preparation with deep plowing and the dredge use with long fallow at least for 15 days have shown high efficiency, to reduce by 73 percent white grub larvae population, and 40 percent of wireworm (Marquez, 2001). The largest possible debris-crumbling of previous crop roots infested with Wireworm larvae, Termites or Bidentate Scarabs (*Euetheola bidentata*) is necessary to increase mortality and reduce reinfestation. The use of light traps (Figure 38), night tours with tractor lights or personnel with flashlights during April-June period is effective for massive capture of white grub adult. Another strategy is to plant "Flamboyan" (*Caesalpinia pulchemina*) and "Caulote" or "Guacimo" (*Guazuma ulmifolia*) due to the attraction exerted on adults, and then spray them with an insecticide solution. Chemical control in ratoon cane is recommended when grub populations exceed the action threshold of 10 larvae/m^2 and applications must be made between June and July. Currently biological control is promoted and experiments are carried on with strains of *Metarhizium anisopliae*, *Beauveria bassiana* and entomophatogenic nematodes of *Heterorhabditis* genus.

Native parasitoids of the genus *Ptilodexia* (Diptera: Tachinidae) have been observed in white grub host, as shown in Figure 39. The use of entomopathogenic nematode *Heterrorhabditis* spp. in a 60 million/ha dose, is a suitable biological option in endemic areas.

Cambiar título en la figura 38: Light traps
Figure 38. Different types of light traps to capture white grub adults

Figure 39. *Ptilodexia* parasitoid larvae affecting white grub larvae

Scarab beetle; *Podischnus agenor* in sugarcane

The Scarab bettle, *Podischnus agenor*, Oliv (Coleoptera: Scarabaeidae, Dynastinae) is a potential pest in sugarcane that usually appears during the rainy season, between June and August. It is known by other common names like "Rhinoceros Beetle", "Coco", "Cucarron", "Mayate Rinoceronte" and "Escarabajo Cornudo". Their life cycle is annual, females lay eggs in soils with high organic matter content. Larvae complete their development in the soil, but unlike other coleopteran larvae, these feed only on decaying plant material. Larval stage may last 4-8 months, with a pupal stage of 2-3 months, and adults can live for up to 2.5 months (Mendoça, 1996). Adults damage the stem when they drill them in the middle and upper part of the plant (Figure 40), or by introducing themselves beneath the floor to drill the base of young sprouts, killing the leaf primordium giving the "deadheart" symptom (Figure 40). Adult males emit a pungent odor that will attract other adults of both sexes, which can be used to improve light trap catches infield. Because galleries serve as their home for one or two weeks, every adult will damage several stems during his lifetime, with greater activity at night. The areas with high adult infestations may have a lot of holes in the ground, which can be an indicator to locate them.

Figure 40. *Podischnus agenor* and damage in sugarcane

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