Mexican Rice Borer, *Eoreuma loftini* (Lepidoptera: Pyralidae) in the Lower Rio Grande Valley of Texas: Its History and Control[1]

Jesusa C. Legaspi, Benjamin C. Legaspi, Jr., Edgar G. King[2], and Robert R. Saldaña

Texas Agricultural Experiment Station, 2415 East Hwy. 83, Weslaco, TX 78596

ABSTRACT

In the late 1970s and early 1980s, the sugarcane industry in the Lower Rio Grande Valley of Texas was dramatically affected by 3 events: 1) the decline of the sugarcane borer, *Diatraea saccharalis* (F.) (Lepidoptera: Pyralidae) from a key to a minor pest; 2) the rise of the Mexican rice borer, *Eoreuma loftini* (Dyar) (Pyralidae) from an unrecorded pest to the key pest; 3) the establishment of *Cotesia flavipes* (Cameron) (Hymenoptera: Braconidae) as a control agent against the sugarcane borer. It is interesting to speculate on the degree to which the 3 events may be causally related. Currently, MRB comprises about 95% of sugarcane stalkborers, causing damage of 20-30% bored internodes. This represents an annual loss >$10 million. Several research avenues are being explored to control the rice borer. Biopesticide formulations of *Beauveria bassiana* (Bals.) Vuill. (Deuteromycotina: Hyphomycetes) and *Steinernema riobravis* Cab. Poin. & Raul. (Rhabditida: Steinernematidae) display high levels of virulence in the laboratory but may not be as effective in the field. Breeding for resistant varieties of sugarcane, and development of insect-resistant transgenic varieties continue to be exciting research avenues. A synthetic pheromone was evaluated as a mating disruptant, but sugarcane damage in all treated fields was almost identical to that in control fields. Chemical agents such as growth regulators are being tested against stalkborers and their parasites to find those least disruptive to the sugarcane ecosystem. Finally, 21 species of parasitic insects imported from around the world have been released in south Texas for control of the rice borer. However, recent surveys indicate that the dominant parasites in the region are 2 species already indigenous to south Texas: *Chelonus sonorensis* Cameron (Hymenoptera: Braconidae) and *Digonogastra solitaria* Wharton & Quicke (Braconidae). The Jalisco fly from Mexico, *Lydella jalisco* Woodley (Diptera: Tachinidae), the subject of a new joint research effort between the USDA Subtropical Agricultural Research Center and the Texas A&M University, provides the best opportunity to date for biological control of the rice borer by an exotic parasite.

RESUMEN

En los finales de la década de los 70's y los principios de los 80's la industria de la caña de azúcar en la parte baja del Valle del Río Grande en Texas fue afectada dramáticamente por 3 eventos: 1) la disminución de la importancia del barrenador de la caña de azúcar *Diatraea saccharalis* (F.)(Lepidotpera: Pyralidae) que pasó de ser una plaga clave a una de importancia menor; 2) la intensificación de la importancia del barrenador mexicano del arroz, *Eoreuma loftini* (Dyar) (Pyralidae) que pasó de ser una especie no reportada a ser una especie clave; 3) el establecimiento de *Cotesia flavipes* (Cameron) (Hymenoptera: Braconidae) como agente de control del barrenador de la caña de azúcar. Es interesante especular sobre el grado en que los 3 eventos pueden haber estado causalmente relacionados. En la actualidad, el barrenador mexicano del arroz abarca cerca del 95% de los barrenadores de tallo, causando un daño que va del 20 a 30 % de internodos perforados. Esto representa una pérdida anual mayor de 10 millones. Varias lineas de investigación están siendo exploradas para controlar al barrenador del arroz. Formulaciones biopesticidas de *Beauveria bassiana* (Bals.) Vuill. (Deuteromycotina: Hyphomycetes) y de *Steinernema riobravis* Cab. Poin. & Raul. (Rhabditida: Steinernematidae) muestran altos niveles de virulencia en el laboratorio pero pueden no ser tan efectivas en el campo. Mejoramiento para la producción de especies resistentes de caña de azúcar, y el desarrollo de variedades transgénicas resistentes a insectos siguen siendo estimulantes lineas de investigación. Se evaluó el efecto perturbador de una feromona sintética sobre el apareamiento, pero el daño en la caña de azúcar en las plantaciones tratadas fue casi idéntico al observado en las plantaciones testigo. El uso de agentes químicos tales como reguladores de crecimiento está siendo probado en contra de los barrenadores de tallo y sus parásitos para encontrar aquellos menos dañinos al ecosistema de la caña de azúcar. Finalmente, 21 especies de insectos parásitos importados de diferentes partes del mundo se han liberado en el sur de Texas para el control del barrenador del arroz. Sin embargo, muestreos recientes indican que los parásitos dominantes en la región son dos especies ya indígenas en el sur de Texas: *Chelonus sonorensis* Cameron (Hymenoptera: Braconidae) y *Digonogastra solitaria* Wharton & Quicke (Braconidae). La mosca de Jalisco proveniente de México, *Lydella jalisco* Woodley (Diptera: Tachinidae), que es el tema de un nuevo proyecto de investigación conjunto entre el Centro de Investigación Agrícola Subtropical del USDA y Texas A&M University, ofrece en la actualidad la mejor oportunidad para el control biológico del barrenador del arroz por un parásito exótico.

[1]This article presents the results of research only. Mention of a commercial or proprietary product does not constitute an endorsement or recommendation for its use by the USDA.

[2]USDA-ARS-MSA, P.O. Box 225, Stoneville, MS 38776-0225

The sugarcane industry is an essential component of the agriculture and economy of the Lower Rio Grande Valley (LRGV) of Texas, comprising approximately 10% of agriculture in the region over a growing area of 18,200 ha (45,000 acres) in 1996. The LRGV produces all the commercial sugarcane grown in Texas and is the 4th largest source of domestic sugar in the US. In the 1994-95 growing season, gross cane harvest exceeded 1.5 million tons, with a value of almost $64 million. Since the early 1970s, larvae of stalk boring moths have been the most serious pests of sugarcane in the LRGV. The primary pest today is the Mexican rice borer (MRB), *Eoreuma* (=*Acigona* = *Chilo*) *loftini* (Dyar) (Lepidoptera: Pyralidae), an exotic pest from Mexico, first detected in the LRGV in 1980 (Johnson 1984). Since its initial entry from Mexico, MRB has displaced another stalkboring pyralid, the sugarcane borer (SCB), *Diatraea saccharalis* (F.), as the dominant pest of sugarcane in the Valley. From 1989 to the present, damage due to MRB has averaged between 20-30% bored internodes, resulting in estimated losses of over $575 per hectare (Meagher et al. 1994). Total loss to the sugarcane industry in the LRGV is currently between $10 to $20 million annually (Legaspi et al. 1997). Chemical control of the rice borer has had limited success because of high plant density and the tunneling behavior of the borer, which restrict contact with pesticides. Furthermore, pesticides have provided only temporary control because of the continuous activity of the rice borer throughout the cropping season. As a result, many sugarcane growers in the LRGV resigned themselves to accepting the annual economic loss due to rice borer damage, and stopped using insecticides altogether. However, the sugarcane system creates an ideal opportunity for applying noninsecticidal control agents for integrated pest management (IPM) strategies because insecticides do not present an economically viable alternative and particular biological agents will not be adversely affected by insecticides. In this paper, we present a historical overview of the MRB in the LRGV, and the different strategies used in its control.

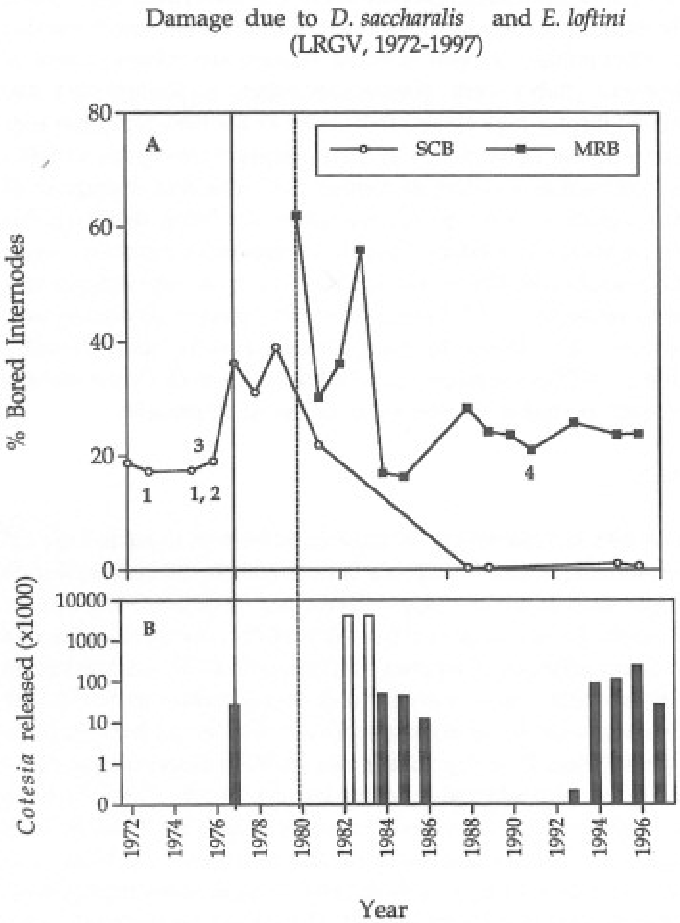

Fig. 1. A) Sugarcane damage in LRGV (1972-1997) as measured in percentage of bored internodes (data collected from various sources). Sugarcane varieties reported: 1=L62-96; 2=CP65-357; 3=CP61-37; 4=TCP81-3058; B) Documented numbers of *Cotesia flavipes* released in LRGV (in thousands, log scale; empty bars indicate conservative estimate of release reported by USDA APHIS PPQ, but not published). The solid line indicated the year *C. flavipes* was first released (1977), the dashed line the year MRB was first reported in the LRGV (1980). In the late 1970s and early 1980s, LRGV sugarcane was marked by: 1) decline of SCB; 2) rise of MRB; 3) releases of *C. flavipes*. It is interesting to speculate on the degree to which the 3 events may be causally related.

The MRB has been an important pest of sugarcane in western Mexico since the 1920s. By the 1970s, the borer had expanded its geographical range to include eastern Mexico, with some reports of incidences in the southernmost parts of Mexico. MRB had also migrated northwards into the US, where it was reported in Arizona on non-cultivated sugarcane and johnsongrass (*Sorghum halepense* (L.) Pers.), and in experimental sugarcane in California. However, because sugarcane was not grown commercially in Arizona and California, MRB was not an economically important pest (Johnson 1984). In contrast, its entry into LRGV sugarcane in 1980 (Johnson and van Leerdam 1981) resulted immediately in yield losses of 50 - 65% (Johnson 1984). As do other borers, MRB damages by tunneling into the stalk and growing points, which causes stunted growth, lodging, reduced juice quality, and "deadhearts" (damage at the growing point producing a dead whorl center). By 1987, the borer had spread northward to include 40 counties in south Texas (Browning et al. 1989). The continued migration of the MRB the northeast, along the Gulf Coast, further threatens sugarcane, and other gramineous crops such as corn, rice, sorghum, wheat and forage grasses throughout the south.

The lifecycle of MRB typically takes about 45 - 50 days in the LRGV, and 4 to 6 generations per year are common. Under laboratory conditions, total generation time was 48.5 days at 27°C, divided according to lifestage as: egg, 6 - 7 days; larvae, 28.5 days; pupae, 9.6 days; and adults, about 7 days. Total fecundity per female ranges from a mean of about 260 eggs at 20°C to more than 400 at 26°C. The maximum oviposition rate of about 188 eggs per female per day occurs at 29°C. The cream-colored eggs are usually deposited in groups of 5 to 100 between layers of dry leaf tissue near the base of the plant. Larvae possess an orange-brown head capsule and 4 parallel purple-red lines along the length of the body. Larvae undergo 5 or 6 molts, and are known to withstand freezing temperatures by entering diapause. Young larvae feed on leaf sheaths and produce a blotched mine with dark red or purple discoloration. Larger larvae enter the stalks, and tunnel both vertically and horizontally, often causing stalk breakage. Tunnels remain packed with feeding debris and excrement, thereby protecting the larvae from both chemical and biological control agents. Mature larvae construct pupation cells and transparent 'emergence windows' near the stalk surface. Adult moths escape through these emergence windows. The MRB adult is distinguished from other stalkborers by a dark spot in the center of each forewing and the absence of other wing markings. Photographs and more detailed information on the rice borer are contained in Legaspi et al. (1997).

A comparative history of sugarcane damage in the LRGV due to MRB and SCB is illustrated as percentage of bored internodes (Fig. 1A) (J. C. Legaspi, unpublished data; Browning and Smith 1988; Johnson 1983, 1985; Meagher and Saldaña 1992; Meagher et al. 1992, 1994; and Pfannenstiel and Meagher 1991). Whenever possible, data relevant to the variety 'NCo 310' were used (other varieties are indicated in the figure). When multiple data sets were found for a given year, the mean was used. During the 1970s, SCB was a key sugarcane pest in the LRGV, small larvae being present on 60% of the stalks examined (Fuchs et al. 1973). The fluctuations in reported percentages of bored internodes are likely due to site specific conditions. Nevertheless, the trend is readily apparent; damage due to SCB declined in the early 1980s which is largely attributed to biological control resulting from the introduction and establishment of the parasitoid *Cotesia flavipes* (Cameron) (Hymenoptera: Braconidae) (Fuchs et al. 1979). The first release of *C. flavipes* in 1977 is indicated by the solid line (Fig. 1), and the first discovery of MRB in the LRGV by the dashed line. In LRGV sugarcane fields, a total of over half a million *C. flavipes* have been recorded as released by Texas Ag. Expt. Sta. scientists since 1977 (Fig. 1B) (empty bars indicate releases reported by USDA APHIS PPQ, but not published). Percentage of bored internodes due to SCB is currently negligible at about 1%. Shortly after the decline of SCB, MRB inflicted heavy damage (50-60% bored internodes), last measured (September 1997) at >20% bored internodes. Counts of borers collected from field sugarcane and reared through in the laboratory similarly show the dominance of MRB (both as direct counts and percentages) relative to SCB (Fig. 2, data from Meagher et al. 1997). Several recent and independent studies have shown that MRB now comprises about 95% of the stalkborer population in LRGV sugarcane (Legaspi et al. 1997, Meagher et al. 1997, Spurgeon et al. 1997). The decline of SCB has been attributed more to the introduction and establishment of *C. flavipes* rather than to competition for ecological resources from MRB (Meagher et al. 1997).

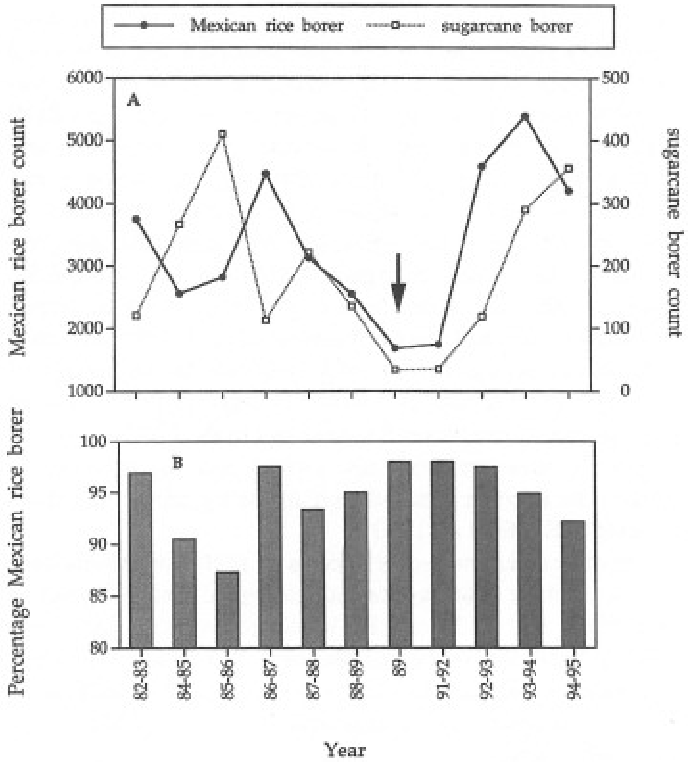

Fig. 2. A) Counts of MRB and SCB reared in the laboratory from sugarcane stalks collected in LRGV fields (note MRB scale is on left axis, SCB scale is on right). Number of MRB collected usually fluctuated between 2000 - 5000 moths, whereas numbers of SCB never exceeded 500 (data from Meagher et al. 1997). The arrow indicates the freeze of 1989 which caused significant reductions in the populations of noth borers. B) Percentage of MRB of all stalkborers collected. With the exception of the 1985-86 season, MRB always comprised greater than 90% of the total stalkborer population sampled (MRB + SCB). Several independent studies confirm that MRB currently (1997) comprises about 95% of SCB in the LRGV (Legaspi et al. 1997, Meagher et al. 1997, Spurgeon et al. 1997).

INTEGRATED PEST MANAGEMENT OF THE MEXICAN RICE BORER

Biological control using introduced parasitic insects.

Since the early 1980s, many species of parasitic insects have been released against MRB. However, none has produced biological control similar to that of *C. flavipes* against SCB. Browning et al. (1985) released 7 species of exotic parasitic Hymenoptera against MRB into fields of sugarcane, sorghum (*Sorghum bicolor* L.), corn (*Zea mays* L.), and johnsongrass in the LRGV. The parasites were released from October 1983 to February 1985, and consisted of *Allorhogas pyralophagus* Marsh (Braconidae) (imported from Mexico), *Rhaconotus roslinensis* Lal (Braconidae) (Pakistan), the pupal parasite *Pediobius furvus* Gahan (Eulophidae) (Kenya), *Trichogramma atopovirilia* Oatman & Platner (Trichogrammatidae) (Mexico), and *T. chilonis* Ishii (Pakistan). *A. pyralophagus* is a 'drill-and-sting' gregarious larval ectoparasite (Smith et al. 1993). Field cage releases were made from September to December 1984 using *Mallochia pyralidis* Wharton (Ichneumonidae) (Mexico) and *Macrocentrus prolificus* Wharton(Braconidae) (Mexico). Releases of about 100,000 *R. roslinensis* and 70,000 *P. furvus* did not result in field recoveries (Browning and Melton 1984). Laboratory studies on *R. roslinensis* indicated that SCB was a more suitable host than the rice borer, and that the parasite was probably unable to survive winter temperatures in the LRGV (Hawkins and Smith 1986). Recoveries of the *Trichogramma* species were hampered by the difficulty in assessing egg parasitism in the field. *P. furvus* parasitized only about 1% of pupae in field cage experiments, because the parasite could not penetrate the closed emergence windows and frass-filled tunnels of the rice borer, or it could not respond to stimuli necessary to locate the host (Pfannenstiel et al. 1992). Smith et al. (1990) found that females of *M. pyralidis* lay an average of >80 eggs per lifetime and live ~47 days at 26°C. Despite evidence that it has become established in the LRGV, reported parasitism rates are very low (<1%) and *M. pyralidis* is unlikely to become a significant mortality factor in LRGV sugarcane (Smith et al. 1990).

Many exotic and native species of trichogammatids have been studied by other workers as biological control agents of both MRB and SCB in LRGV sugarcane (e.g. Fuchs and Harding 1978, Browning and Melton 1987). In laboratory and greenhouse experiments, Greenberg et al. (1996) found that the exotic *T. minutum* Riley parasitized about 50% of MRB eggs on potted sugarcane.

Smith et al. (1987) released over 2 million *A. pyralophagus* and recovered the parasite consistently afterwards, even after December freezes. At 26°C, *A. pyralophagus* averaged 82 eggs per female lifetime, with developmental time from egg to adult of 18 days, and adult lifespan of about 24 days (Melton and Browning 1986). In field cage experiments in Weslaco, Hawkins et al. (1987) reported parasitism rates of about 25%, but concluded that *A. pyralophagus* was probably unable to attain complete control because it could not attack the borers deep in the sugarcane stalks.

Numerous explorations were conducted in Mexico for parasites of stalkborers, including MRB. Among the areas surveyed were: the state of Sinaloa in the west (Melton et al. 1986), Veracruz in the south (Smith et al. 1988), the huastecas area on the eastern coast (Rodriguez-del-Bosque et al. 1989), the southwestern states of Michoacan and Jalisco (Rodriguez-del-Bosque and Smith 1989), and the central states of Puebla and Morelos (Rodriguez-del-Bosque and Smith 1990). The parasites reared from MRB included: *Chelonus sonorensis* Cameron (Braconidae), *M. prolificus*, and the Jalisco fly, *Lydella jalisco* Woodley (Diptera: Tachinidae). *C. sonorensis* is a co-evolved solitary endoparasite that directly attacks the eggs and larvae of MRB (Smith et al. 1993). Field parasitism by the Jalisco fly was almost 50% in late instars of the rice borer. The Jalisco fly was introduced into the US through Texas A&M Entomology Quarantine, and was successfully cultured in the laboratory (Rodriguez-del-Bosque and Smith 1996).

Five exotic parasites were released in LRGV sugarcane fields in 1989 (Pfannenstiel et al. 1990). Parasitic Hymenoptera released were: *Alabagrus stigma* (Brullé) [= *Agathis stigmatera* (Cresson)] (Braconidae) (imported from Bolivia), *Goniozus natalensis* Gordh (Bethylidae) (South Africa), *Macrocentrus prolificus*, *Xanthopimpla stemmator*

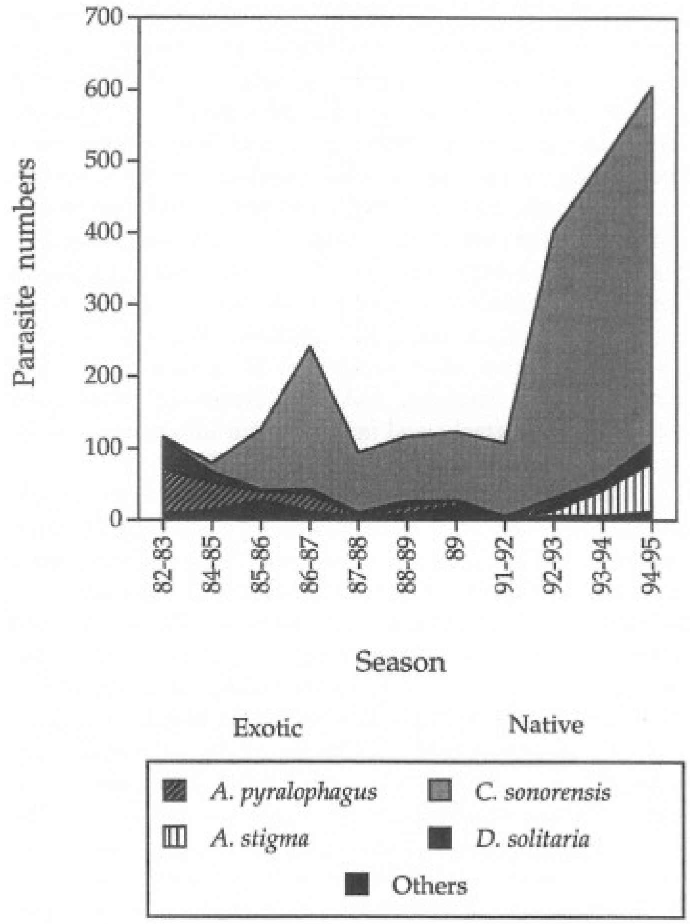

Fig. 3. Parasites reared through in laboratory from field-collected parasitized sugarcane stalkborers (data from Meagher et al. 1997). Since the mid 1980s, the dominant parasite has been the native *Chelonus sonorensis*.

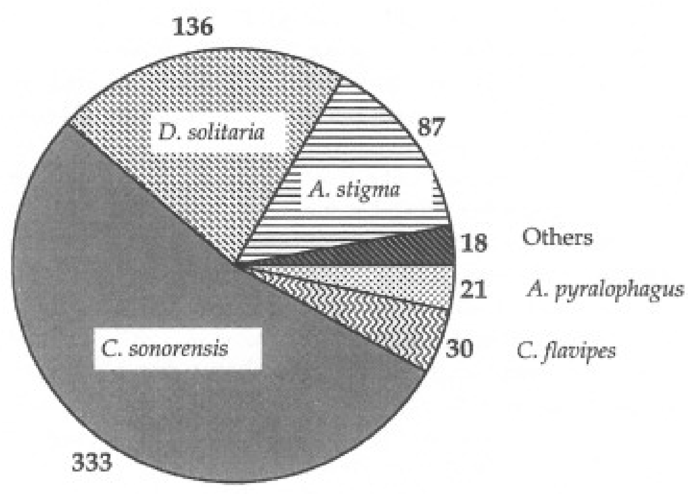

Fig. 4. Most recent parasite recoveries (1995-96). Most recently, the parasites reared through from field-collected parasitized stalkborers shows that the native species *C. sonorensis* and *D. solitaria* have increased in dominance relative to the exotic *A. stigma* and *A. pyralophagus*. The native parasites of MRB now account for 75% of the recorded parasitism.

(Thunberg) (Ichneumonidae) (southeast Asia), and the Jalisco fly. The parasites recovered consisted mostly of 3 species: the native species *Chelonus sonorensis* and *Digonogastra* (=*Iphiaulax*) *solitaria* Wharton & Quicke (Braconidae), and the introduced *A. pyralophagus*. *D. solitaria* is a 'wait-and-sting' larval solitary ectoparasite, while *A. stigma* is a 'probe-and-sting' solitary larval endoparasite (Smith et al. 1993). Of the exotics released, only the Jalisco fly and *M. prolificus* were recovered subsequently, with the Jalisco fly judged to be the most promising of the exotics (Pfannenstiel et al. 1990). *A. pyralophagus* also parasitized over 60% of large MRB larvae in cage experiments performed in flooded rice fields in Hidalgo County (Pfannenstiel and Browning 1995).

In summary, from 1982 to 1997, 21 different species of parasites have been released against MRB in sugarcane fields in the LRGV, the predominant parasite being *A. pyralophagus*. These releases are summarized in Table 1 which shows parasite species, country of origin, stage of host attacked, and numbers released by year (data from 1982 to 1988 taken from Browning and Smith 1988). Of the parasites listed, *D. solitaria, T. pretiosum*, and *C. sonorensis* are indigenous to the LRGV. From 1982 to the present, parasitized MRB larvae have been reared through in the laboratory to evaluate the composition of the indigenous parasite complex. From the mid-80s to the present, the dominant parasite recovered has been *C. sonorensis* (Fig. 3, data from Meagher et al. 1997). 'Others' was due to unidentified species, or minor parasites such as *M. prolificus*, *R. roslinensis* and *P. furvus*. (Fig. 3). The parasites that emerged from stalks collected more recently in 1995-96 were predominantly (75%) the natives *C. sonorensis* and *D. solitaria* (>50%) (Fig. 4). A notable recent trend has been the higher parasitism due to *D. solitaria* (Figs. 3 and 4), further increasing the dominance of the native parasites. The remaining parasitism in 1995-96 was due to the exotics *A. pyralophagus*, *A. stigma* and the SCB control agent, *C. flavipes*. 'Others' consisted of parasitized larvae that did not survive to emergence (Fig. 4).

Other endemic parasites and predators. Fuchs and Harding (1976) conducted surveys for arthropod predators in various habitats of the LRGV. Non-cultivated habitats were found to support higher predator densities than cultivated ones, the dominant predators being spiders (>50% of predators collected) followed by lacewings. In sugarcane fields, spiders and lacewings were also the dominant predators, but predator densities were much higher in mixed grasses [primarily *Pennisetum ciliare* (L.)], sunflowers (*Helianthus* spp.), verbains (*Verbena* spp.) and wild tobacco (*Nicotiana* spp.). Youm et al. (1990) studied natural parasitism of stem borers of corn and sorghum in the LRGV from 1982-1985. Parasites reared from MRB included the following braconids: *Digonogastra* sp., *Orgilus gelechiaevorus* (Cushman), *Bracon* sp., *A. pyralophagus*, *Rhygoplitis aciculatus* (Ashmead), and *C. sonorensis*. Total parasitism was generally low (usually <5%), and parasite activity was not deemed an important factor in the population dynamics of the rice borer. Furthermore, sugarcane stalks artificially infested with MRB and placed in corn and sorghum fields were not parasitized, although parasitism in corresponding treatments using *D. saccaharalis* peaked at 26%. Laboratory studies by Legaspi et al. (1996a) on *Bracon mellitor* Say showed higher parasitism on SCB larvae (100%) than on rice borer larvae (78%), which may support the hypothesis that SCB is the preferred host of *B. mellitor*.

Field sampling of sugarcane fields in Cameron, Hidalgo and Willacy counties in 1990 and 1991 revealed the presence

Table 1A. Parasite releases in LRGV sugarcane 1982-1987; (Browning & Smith 1988)[1] Host stage: E=egg; L=larva; P=pupa;

Parasite Species	Origin	Stage [1]	1982	1983	1984	1985	1986	1987
Allorhogas pyralophagus	Mexico	L	265	899,070	696,400	204,700		
Rhaconotus roslinensis	Pakistan	L		59,402	47,500	42,687		
Pediobius furvus	Kenya	P		3,450	35,300	168,100	132,600	21,950
Mallochia pyralidis	Mexico	L			40	2,479	220	40
Macrocentrus prolificus	Mexico	L			430	18,115	85,337	125,885
Trichogramma atopovirilia	Mexico	E			18,000	394,000	90,000	
Trichogramma chilonis	Pakistan	E				63,000	104,300	
Digonogastra kimballi Kirkland	Mexico	L				421		
Goniozus natalensis	S. Africa	L				3,736	16,571	34,763
Apanteles minator Muesebeck *(Braconidae)*	Bolivia	L					4,340	43,625
Trichogrammatoidea eldanae Viggiani	Ivory Coast	E					83,500	
Palpozenillia diatraeae Townsend (Tachinidae)	Bolivia	L					583	
Trichospilus diatraeae C&M (Eulophidae)	Florida	P						1,236,000
Dentichasmias busseolae Heinrich (Ichn.)	Kenya	P						75
Alabagrus stigma	Bolivia	L						613
Trichogramma pretiosum (Riley)	native	E						
Trichogramma minutum	Canada	E						
Lydella jalisco	Mexico	L						
Xanthopimpla stemmator	Mauritius	P						
Chelonus sonorensis	native	E-L						
Bracon mellitor Say	native	L						

Table 1B. Parasite releases on sugarcane in LRGV (1988-1997) and totals ([z]Data for 1997 only until September 1997)

Parasite Species	1988	1989	1982	1994	1995	1985	1997[z]	Total (1982-1997)
Allorhogas pyralophagus					4,318	7,753	13,365	1,825,871
Rhaconotus roslinensis								149,589
Pediobius furvus								361,400
Mallochia pyralidis								2,779
Macrocentrus prolificus	27,828	28,766						286,361
Trichogramma atopovirilia								502,000
Trichogramma chilonis								167,300
Digonogastra solitaria								421
Goniozus natalensis	3,603	2,629						61,302
Apanteles minator	25,207	4,150						77,322
Trichogrammatoidea eldanae								83,500
Palpozenillia sp.								583
Trichospilus diatraeae								1,263,000
Dentichasmias busseolae								75
Alabagrus stigma	1,126	2,560	74	1,443	330		542	6,668
Trichogramma pretiosum							9,000	9,000
Trichogramma minutum							13,500	13,500
Lydella jalisco	3,011							3,011
Xanthopimpla stemmator	1,672							1,672
Chelonus sonorensis							150	150
Bracon mellitor							600	600

Table 2. Average percent bored internodes of stalks due to MRB, collected from 4 different locations, 95-Series, TX, 1996-1997.

Variety	Annex	Variety	Sugarmill	Variety	Runn	Variety	Santa Ana
NCo 310	19.3a	TCP93-4262	19.4 a	TCP93-4262	37.5 a	NCo 310	39.4 a
TCP93-4262	18.0 ab	TCP93-4238	17.4 ab	TCP93-4260	26.4 b	TCP93-4251	33.8 b
TCP93-4238	16.6 ab	NCo 310	16.0 b	TCP93-4263	26.3 b	TCP93-4262	31.8 bc
TCP93-4263	16.5 ab	TCP93-4291	15.9 b	TCP93-4219	21.6 c	TCP93-4260	31.8 bc
TCP93-4260	16.0 ab	TCP93-4251	14.7 bc	TCP93-4225	21.2 c	TCP93-4263	31.2 bcd
TCP93-4225	15.8 ab	TCP93-4263	14.7 bc	NCo 310	19.9 cd	TCP93-4219	29.9 bcde
TCP93-4219	14.0 bc	TCP93-4260	14.2 bc	TCP93-4238	19.3 cd	TCP93-4291	29.6 bcde
TCP93-3595	12.7 cd	TCP93-4219	12.1 cd	TCP93-4270	18.4 cde	TCP93-4225	29.2 cde
TCP93-4218	11.8 cde	TCP93-4218	10.3 de	TCP93-4291	16.5 def	TCP93-4238	27.1 de
TCP93-4238	11.1 de	TCP93-4225	9.4 def	TCP93-4218	15.1 ef	TCP93-4245	26.2 ef
TCP93-4291	10.5 def	TCP93-3596	9.3 def	TCP93-4283	14.7 efg	TCP93-4252	22.3 fg
TCP93-3596	10.1 def	TCP93-3597	7.9 efg	TCP93-3597	13.6 fgh	TCP93-4270	21.4 gh
CP70-321	9.2 def	TCP93-4270	7.5 efg	TCP93-4264	13.6 fgh	TCP93-3595	20.4 gh
TCP93-3597	8.7 efg	TCP93-4264	7.5 efg	TCP93-4251	13.4 fgh	TCP93-4283	20.0 gh
TCP93-4251	7.7 fgh	CP70-321	7.3 efg	CP70-321	13.4 fgh	TCP93-4264	19.1 ghi
TCP93-4270	7.4 fgh	TCP93-4283	7.2 efgh	TCP93-4252	10.5 ghi	TCP93-4218	18.8 ghi
TCP93-4245	5.9 gh	TCP93-3595	6.2 fgh	TCP93-3595	10.2 hi	CP70-321	17.2 hij
TCP93-4264	5.9 h	TCP93-4245	6.0 fgh	TCP93-4245	9.7 hi	TCP93-3597	14.7 ij
TCP93-4252	5.1 hi	TCP93-3598	4.5 gh	TCP93-3596	9.0 i	TCP93-3598	14.2 j
TCP-3598	4.0 i	TCP93-4252	3.7 h	TCP93-3598	8.0 i	TCP93-3596	13.8 j

Means followed by the same letter within each column are not significantly different (P=0.05).

of 37 species of spiders and 7 species of ants (Hymenoptera: Formicidae) (Breene et al. 1993). The spiders belonged to 18 families, of which 9 were web weaving and 9 were hunting spiders. The most abundant hunting spider was *Phidippus audax* (Hentz) (Araneae: Salticidae); the most abundant ant collected was the tropical fire ant, *Solenopsis geminata* (F.). Many of the spiders and ants collected are generalist predators, some of which have been documented to feed on SCB.

Surveys of egg masses collected from LRGV sugarcane fields revealed the presence of several species of *Trichogramma* attacking eggs of both SCB and MRB (Browning and Melton 1987). In MRB, low levels of parasitism (<5%) were caused by endemic populations of *Trichogramma fuentesi* Torre, *T. retorridum* (Girault), and *T. pretiosum* Riley. *T. pretiosum* accounted for >96% of the parasitism, although van Leerdam et al. (1986) found only *T. retorridum* parasitizing <10% of rice borer eggs collected from LRGV sugarcane fields. No comprehensive studies have been performed on the impact of the native parasites and predators on the MRB populations in LRGV sugarcane.

Microbial control. The entomopathogenic fungus, *Beauveria bassiana* (Balsamo) Vuillemin (Deuteromycotina: Hyphomycetes), is commonly used in the control of many insect pests, and is available in commercial form (Feng et al. 1994). Alves (1986) discussed its use against SCB in Brazil. Legaspi et al. (1996b) compared the pathogenicity of the fungus against MRB and SCB using a commercial formulation of dry conidia (Mycotrol®, Mycotech Corp., Butte, MT) on different stages of larvae in the laboratory. LD_{50} values for 1st- and 2nd-instar rice borers were 8.9 and 10.7 spores/mm^2, respectively. LD_{50} values for 1st and 2nd-instar SCB were 276.2 and 340.8 spores/mm^2, respectively. Mean survival time calculated for 1st- and 2nd-instar rice borers was 3.8 and 3.3 days, respectively. For SCB, the mean survival time of 1st- and 2nd-instars was 4.7 and 4.8 days, respectively. Therefore, the *B. bassiana* formulation displayed greater virulence against the rice borer than SCB. Unfortunately, preliminary results from field tests show that the fungus may not be successful in penetrating the plant tissue protecting the borers inside sugarcane stalks (J. C. Legaspi, unpublished data).

Entomophagous nematodes. Nematodes are several species of unsegmented, cylindrical worms in the phylum Nematoda possessing a variety of relationships with plants and insects. Nematodes belonging to the families Steinernematidae and Heterorhabditidae are entomopathogenic and some species are available as commercial products. In preliminary field trials in Madero, Texas, *Steinernema feltiae* (Filipjev) (Steinernematidae) was applied against the rice borer in sugarcane fields at the rate of 2.3 billion per acre (Pfannenstiel and Browning 1989). Although nematodes were recovered after application, rice borer populations were not affected. In order of decreasing pathogenicity, laboratory bioassays have shown that *Steinernema carpocapsae* (Wieser) 'All', *S. feltiae* 'SN', and *Heterorhabditis bacteriophora* Poinar 'HP88' (Rhabditida: Heterorhabditidae) were all capable of killing MRB larvae (Ring and Browning 1990).

The relatively recent discovery of an entomopathogenic nematode native to the LRGV suggests a promising control agent already acclimated to its subtropical semi-arid environment. *Steinernema riobravis* Cabanillas, Poinar & Raulston was isolated from soil samples from corn fields in Weslaco in 1990 (Cabanillas et al. 1994). The nematode appears to be endemic to the LRGV, where it was found parasitizing prepupae and pupae of the corn earworm [*Helicoverpa zea* (Boddie)] and fall armyworm [*Spodoptera frugiperda* (Smith)] (both Lepidoptera: Noctuidae) (Cabanillas and Raulston 1994). Laboratory studies on the pink bollworm [*Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae)] have also shown that *S. riobravis* is more heat tolerant than *S. carpocapsae* (Henneberry et al. 1996). Preliminary results show that MRB is highly susceptible to *S. riobravis* in the laboratory (J. C. Legaspi, unpublished data). Three days after treatment, all larvae had died. Average juvenile progeny of *S. riobravis* ranged from 2,000 per host larva at the lowest concentration to 4,075 per larva at the highest. Field tests using *S. riobravis* against MRB are on-going since 1997.

Host plant resistance. The degree to which a given genotype of sugarcane can resist attack by insects such as MRB is dependent on several plant characteristics. Resistance to the rice borer may be manifested in 1) unattractiveness as oviposition sites; 2) unfavorability for larval establishment; 3) inhibition or retardation of larval development; 4) plant tolerance (high yield despite high levels of infestation) (Mathes and Charpentier 1969). In laboratory and field studies using LRGV sugarcane, Meagher et al. (1996) suggested the presence of antinutritional components or chemicals in some genotypes. However, oviposition rates on different genotypes in laboratory, greenhouse and field studies were slight, suggesting that attractiveness as oviposition sites is not an important resistance character in this plant-insect system. Comparisons between laboratory and field experiments suggest the action of several mechanisms of resistance.

Pfannenstiel and Meagher (1991) evaluated 5 commercial and 54 non-commercial sugarcane clones for resistance to the rice borer in field experiments performed in the LRGV. The commercial clone 'CP 70-321' was among the most resistant in all tests. Even greater resistance was shown by 'TCP 83-3196' and 'TCP 83-3180'. Texas Ag. Expt. Sta. scientists continue to evaluate sugarcane varieties for resistance to MRB. During the 1996-97 harvest season, 20 varieties were screened at 4 different locations: Sugarmill, Runn, Annex, and Santa Ana. Sampling was done before harvest using 80 stalks per variety tested. Average percent bored internodes for each variety are shown in Table 2 (analyzed by SAS analysis of variance, means separated using Duncan's multiple range test, DMRT). Lowest percentages of bored internodes were found for: 'TCP93-3598', 'TCP93-4252', 'TCP93-4245' and 'TCP93-3596'. In contrast, highest percentages of bored internodes were found for: 'TCP93-4262', 'NCo 310' and 'TCP93-4238'.

Transgenic sugarcane resistant to the Mexican rice borer. The genetic engineering of sugarcane currently under research at the Texas Ag. Expt. Sta. in Weslaco involves the transfer of genes encoding for lectins into the sugarcane genetic code. Lectins are a class of proteins that bind sugars and are found in a diversity of organisms, which include

Table 3. Mean percent bored internodes ± standard error due to Mexican rice borer and sugarcane borer after treatment with 2 rates of Disrupt MRB®. (Manual sampling 1996).

Variety	10 gm/acre Control	10 gm/acre Treatment	20 gm/acre Control	20 gm/acre Treatment
CP70-321	7.8±1.b n=110	16.6±1.2a n=150	15.0±2.2a n=20	24.0±6.0a n=10
NCo 310	38.6±5.2a n=10	10.6±1.6b n=30	22.2±5.0b n=20	32.2±4.0a n=20
CP70-1133	-	23.8±2.4 n=10	-	-
CP72-1210	20.4±1.6b n=95	24.5±1.2a n=143	38.2±3.8a n=20	18.6±3.8b n=10
CP71-1240	4.7±2.3b n=10	14.8±3.0a n=30	-	23.5±5.0 n=10
TCP81-3058	-	27.1+4.1 n=10	-	-
TCP83-3196	-	-	22.9±3.2a n=10	10.8±2.4b n=20
TCP87-3388	13.8±2.1a n=40	17.3±2.0a n=30	-	-

Means followed by different letters between the control and treatment are significantly different (*P*=0.05) under each application rate (n=number of stalks sampled; - = no sample taken) (shaded blocks represent 4 comparisons with a significantly higher percent bored internodes in treated fields compared to control fields, out of 9 possible comparisons)

microorganisms, animals, plants and insects (Sharon and Lis 1990). When consumed by insect pests, lectins may bind to the glycoproteins in the digestive tract and interfere with nutrient absorption, although they are apparently nontoxic to mammals (Pusztai et al. 1996).

To assess the anti-insecticidal activity against the rice borer, preliminary feeding trials were conducted using an artificial diet into which transgenic tobacco extract was incorporated. In all feeding trials, the control was the artificial diet from which the laboratory MRB colony was reared. Treatments included the control diet, diet with nontransgenic or transgenic tobacco. Preliminary results showed significant reduction in larval, pupal and adult weight and length in treatments containing transgenic plants compared to nontransgenic plants and the control. In addition, developmental time of the larvae, pupae and adults of MRB was longer in treatments containing transgenic compared to nontransgenic plants and the control.

The initial sugarcane cultivar transformed was 'CP65-357'. Over 150 herbicide resistant plants have been regenerated and screened for the presence and expression of lectin. Plants expressing various levels of protein have been identified, and a set of highest expressors were tested for resistance against MRB. Results of feeding trials that incorporated nontransgenic and transgenic sugarcane leaf tissues into an artificial diet demonstrated that the lectin affected development of the rice borer. At a concentration of 2.5 % transgenic sugarcane leaf tissue in the artificial diet, larval weight of MRB was significantly lower in treatments containing transgenic sugarcane compared to nontransgenic sugarcane. APHIS permits have been granted for field trials to evaluate the resistance of transgenic sugarcane to MRB.

Pheromones. Pheromones are a class of chemicals secreted by insects into the environment, that influence the behavior or development of others of the same species (Shorey and Gaston 1967). Synthetic pheromones have been used in monitoring the nocturnal activity of MRB in LRGV sugarcane fields (Spurgeon et al. 1996). Spurgeon et al. (1997) evaluated the efficacy of synthetic pheromones as mating disruptants for MRB in LRGV sugarcane fields. The pheromone treatments were not efficacious in disrupting mating of the rice borer and the strategy of mating disruption alone was deemed ineffective without substantial improvements in formulation, application, and monitoring technologies.

Texas Ag. Expt. Sta. scientists recently evaluated the effectiveness of a synthetic mating disruptant pheromone, Disrupt MRB®, to control the MRB in sugarcane in the LRGV. Disrupt MRB was aerially applied at rates of 10 gm/acre (0.4047 ha) over 3,038 acres (1230 ha) and 20 gm/acre over 419 acres (170 ha) to sugarcane fields of several varieties in Hidalgo and Cameron Counties. Wherever possible, each treatment field had a designated control field nearby. Population densities and damage caused by MRB and SCB were compared from September to December 1996. From each field, 50 stalks were sampled prior to harvest: 40 stalks were processed using a stalk splitter, 10 were processed manually to determine percentage of bored internodes, infestation of stalkborers, and parasitization of borer immatures. Taxonomy of the stalkborers was confirmed through independent examination by the USDA Systematics Laboratory (Beltsville, MD).

Results indicate that 98% of the borer population in the LRGV is comprised of MRB. Damage attributed to SCB (0 to 0.5% bored internodes per field), is much lower than that caused by the rice borer (7.5 to 55.6%) (Table 3). Using the manual sampling method, we found that the pheromone-treated fields had a higher infestation of rice borer in 4 out of 9 (44%) field-to-field comparisons made (shaded blocks in

Table 3). Control fields had higher infestation in 3 out of 9 (33%) comparisons while 2 out of 9 comparisons made (22%) did not show any significant difference between the pheromone-treated and control fields. Furthermore, the over-all percentage of bored internodes across all treated fields (20.3%) was almost identical to the over-all percent bored internodes across all control fields (20.4%). Thus, the data from this study does not prove the efficacy of Disrupt MRB as a control agent against MRB in the LRGV.

Insecticidal control. The effectiveness of chemical control against MRB in LRGV sugarcane fields was studied by Johnson (1985) and Meagher et al. (1994). Monocrotophos, azinphosmethyl, and carbofuran reduced percentage of bored internodes of sugarcane relative to untreated checks in San Juan, TX (1981), while fenvalerate did not (Johnson 1985). Large plots which received 17 applications of monocrotophos contained fewer deadhearts and higher levels of sugarcane yield and quality relative to untreated checks. Monetary loss due to rice borer damage was estimated at $287, $431, and $575/ha for 10, 15, and 20% bored internodes, respectively (Meagher et al. 1994). The application of insecticides can result in significant decreases in percentage of bored internodes, but rarely an increase in sugarcane yield or commercially recoverable sugar.

Current research by Texas Ag. Expt. Sta. scientists was performed in collaboration with USDA-ARS and focuses on the evaluation of Baythroid®2 (pyrethroid) and Karate® (lambda-cyhalothrin) and the experimental insect growth regulators 'RH 2485' and 'RH 5992' (tebufenozide), against MRB and selected parasites. Conventional insecticides are also being evaluated for their effects on the target insect, and also on nontargets such as natural enemies of MRB and SCB. We found that MRB larvae were more susceptible to Baythroid compared to SCB larvae 48 hrs after treatment. Furthermore, *C. flavipes* females are apparently more susceptible to the same chemical than males. Cohorts of borer survivors from the treatment and the control were exposed to the parasite, *A. pyralophagus*. Substantial parasitism by *A. pyralophagus* was found on surviving borers that were treated with Baythroid, while percentage emergence of females was higher than males. For surviving *C. flavipes* which were treated with Baythroid, we found that percentage parasitism ranged from 50 - 100% while the next generation of *C. flavipes* showed parasitism ranging from 60 - 95%. Again, percentage emergence of female *C. flavipes* was higher than males (Legaspi and Wolfenbarger, unpubl. data).

In field tests, var. 'TCP81-3058', located in Hidalgo County, near Runn, TX was sprayed 2 - 3 times during the 1996 season to suppress populations of the rice borer. On most of the sampling occasions, the mean percentage of damaged internodes was significantly lower in plots that were treated with Baythroid compared to those treated with RH-5992, RH-2485 and Karate and the untreated check plots. However, on the last sampling date using the Tilby cane splitter, the percentage damage of the internodes was significantly lower in plots treated with RH-5992, Baythroid, RH-2485 and Karate compared to the untreated check plot. The data on the mean number of MRB collected per stalk seemed to follow the same trend as was found on the percentage of damaged internodes. On most sampling occasions, the plots treated with Baythroid had significantly lower numbers of rice borer larvae than those treated with RH-5992, RH-2485 and Karate. In addition, the yield was not significantly different among the different treatments; although the highest yield was collected from plots treated with RH-5992, followed by RH-2485, Karate, Baythroid and the untreated check (J. C. Legaspi, unpubl. data).

In the laboratory *A. pyralophagus* were exposed to the treated and untreated leaves for 24 hr. In general, the parasites exposed to leaves treated with RH-5992, RH-2485, and Karate had significantly lower percentage mortality of the parasites compared to those exposed to Baythroid. All of the results of the insecticidal trials described in this paper will appear in a separate publication currently in preparation (J. C. Legaspi, unpubl. data).

CONCLUSIONS

In the late 1970s and early 1980s, 3 interesting events occurred which greatly impacted the sugarcane industry in the LRGV: 1) incidence and damage due to SCB declined severely; 2) MRB rose from an insect unrecorded in the area to the key pest; 3) *Cotesia flavipes* was released against SCB in 1977. It is interesting to speculate on the degree to which these 3 events are causally related. Had *C. flavipes* not been released against SCB, then the current dominance of MRB may be viewed as an example of displacement by a competitor occupying the same ecological niche. If the suppression of SCB is in fact due to biological control by *C. flavipes*, as many have argued, then the parasite may have influenced the present composition of the stalkborer complex.

Much has been learned about the sugarcane pests in the LRGV, especially MRB and SCB. However, much more research is needed before the insect pest damage to sugarcane in the LRGV is reduced to acceptable levels. Many exciting research avenues are open, utilizing both existing technologies and newer ones still in development. Breeding for insect resistant varieties will always be an important component of sugarcane IPM. The possibilities brought by new genetic engineering technologies add a new dimension to plant breeding because scientists are no longer limited to selecting for genes in existing sugarcane gene pools. New sugarcane varieties may contain genes conferring resistance to insects, as well as endowing the sugarcane plant with the ability to synthesize other chemical compounds of high commercial value. Attempts at the biological control of MRB using exotic natural enemies have not been rewarding. The current parasite complex of the rice borer in the LRGV consists mostly of species described as endemic to the region. Research should be directed towards the endemic species, *Chelonus sonorensis* and *Digonogastra solitaria* -- to discover the reasons for their success, to design effective methods for mass rearing, and perhaps to develop strategies to improve their efficacy in the LRGV. Efforts to mass rear these two native parasites have not been successful to date. The most promising candidate for an exotic control agent appears to be the Jalisco fly, *Lydella* *jalisco*. Its success as a control agent in Mexico, as well as the results of preliminary releases in the LRGV suggest the tachinid fly can control MRB, perhaps to the extent that *Cotesia flavipes* brought about the decline in SCB.

The Jalisco fly is the subject of a new project between the USDA Subtropical Agricultural Research Center, the Texas Agricultural Experiment Station, both in Weslaco, and the Department of Entomology, Texas A&M University, in College Station. Entomology Department personnel will collect material from Mexico, in collaboration with Mexican cooperators. The shipments will be processed and quarantined at the quarantine facility in College Station. The primary responsibility of Experiment Station personnel in Weslaco will be in conducting laboratory and field evaluations of the Jalisco fly against the rice borer. The biology of the fly will also be studied in detail. USDA scientists will develop an artificial diet for the fly, possibly creating avenues for cost-effective mass rearing systems. USDA and Texas Ag. Expt. Sta. scientists will study *in vivo* versus *in vitro* reared parasites to compare their effectiveness as control agents. This joint research effort provides the best opportunity to date for biological control of the Mexican rice borer in the LRGV through the use of an exotic agent.

ACKNOWLEDGEMENTS

We are grateful to N. Rozeff (Rio Grande Valley Sugar Growers, Inc.), J. Irvine (Texas Ag. Expt. Sta.), and 2 anonymous reviewers for helpful comments on the manuscript. R. Meagher (ARS Center for Medical, Agricultural and Veterinary Entomology, Gaineville, FL) and J. W. Smith, Jr. (Dept. of Entomology, Texas A&M Univ.) provided useful insights, especially with regards to historical data. Invaluable technical support was given by M. Garcia, S. Alvarez, J. Huerta, M. Quinn, R. Diaz, C. Cate, and E. Bustamante. We acknowledge funding kindly provided by the Rio Grande Valley Sugar Growers, Inc. under Hatch Project No. 6796. Approved for publication by the Director of the Texas Agricultural Experiment Station.

REFERENCES

Alves, S. B. (ed.) 1986. Controle microbiano de insectos. Editora Manole Ltda. (In Portuguese). Breene, R. G., R. L. Meagher, Jr., and D. A. Dean. 1993. Spiders (Araneae) and ants (Hymenoptera: Formicidae) in Texas sugarcane fields. Fla. Entomol. 76: 645-650.

Browning, H. W., and C. W. Melton. 1984. Parasite rearing and release for biological control of the pyralid borer, *Eoreuma loftini* (Dyar) on sugarcane. Texas Ag. Expt. Sta. PR-4196.

Browning, H. W., and C. W. Melton. 1987. Indigenous and exotic Trichogrammatids (Hymenoptera: Trichogrammatidae) evaluated for biological control of *Eoreuma loftini* (Lepidoptera: Pyralidae) borers on sugarcane. Environ. Entomol. 16: 360-364.

Browning, H. W., J. W. Smith, Jr. 1988. Progress report of the Mexican rice borer research program, 1980-1987. Annual Mexican Rice Borer Research Review, 22 March 1988. Texas Ag. Expt. Sta. 87 pp.

Browning, H. W., C. W. Melton, and R. R. Saldaña. 1985. Release and evaluation of exotic parasites for biological control of the Mexican rice borer on sugarcane in the Lower Rio Grande Valley, 1983-85. Texas Ag. Expt. Sta. PR-4344.

Browning, H. W., M. O. Way., and B. M. Drees. 1989. Managing the Mexican rice borer in Texas. Texas Ag. Ext. Serv. Bull. No. B-1620.

Cabanillas, H. E., and J. R. Raulston. 1994. Evaluation of the spatial pattern of *Steinernema riobravis* in corn plots. J. Nematol. 26: 25-31.

Cabanillas, H. E., G. O. Poinar, Jr., and J. R. Raulston. 1994. *Steinernema riobravis* n. sp. (Rhabditida: Steinernematidae) from Texas. Fundam. Appl. Nematol. 17: 123-131.

Feng, M. G., T. J. Poprawski, and G. G. Khachatourians. 1994. Production, formulation and application of the entomopathogenic fungus *Beauveria bassiana* for insect control: current status. Biocontrol Sci. Tech. 4: 3-34.

Fuchs, T. W., and J. A. Harding. 1976. Seasonal abundance of arthropod predators in various habitats in the Lower Rio Grande Valley of Texas. Environ. Entomol. 5: 288-290.

Fuchs, T. W., and J. A. Harding. 1978. Oviposition patterns, egg parasitism, and spring emergence of the sugarcane borer, *Diatraea saccharalis*. Environ. Entomol. 7: 601-604.

Fuchs, T. W., J. A. Harding, and T. Dupnik. 1973. Sugarcane borer control on sugarcane in the Lower Rio Grande Valley of Texas with aerially applied chemicals. J. Econ. Entomol. 66: 802-803.

Fuchs, T. W., F. R. Huffman, and J. W. Smith, Jr. 1979. Introduction and establishment of *Apanteles flavipes* [Hym.: Braconidae] on *Diatraea saccharalis* [Lep.: Pyralidae] in Texas. Entomophaga. 24: 109-114.

Greenberg, S. M., S. Legaspi, D. A. Nordlund, Z. X. Wu, B. Legaspi, Jr., and R. Saldaña. 1996. Evaluations of *Trichogramma* against sugarcane stalkborers. International Sugar Journal. 98(1173E): 459.

Hawkins, B. A., and J. W. Smith, Jr. 1986. *Rhaconotus roslinensis* (Hymenoptera: Braconidae), a candidate for biological control of stalkboring sugarcane pests (Lepidoptera: Pyralidae): development, life tables, and intraspecific competition. Ann. Entomol. Soc. Am. 79: 905-911.

Hawkins, B. A., H. W. Browning, and J. W. Smith, Jr. 1987. Field evaluation of *Allorhogas pyralophagus* [Hym.: Braconidae], imported into Texas for biological control of the stalkborer *Eoreuma loftini* [Lep.: Pyralidae] in sugar cane. Entomophaga. 32: 483-491.

Henneberry, T. J., L. F. Jech, R. A. Burke, and J. E. Lindegren. 1996. Temperature effects on infection and mortality of *Pectinophora gossypiella* (Lepidoptera: Gelechiidae) larvae by two entomopathogenic nematode species. Environ. Entomol. 25: 179-183.

Johnson, K. J. R. 1983. Field evaluation of insecticides for rice borer control on sugarcane in Texas, 1982-1983. Report to the Lower Rio Grande Valley Sugar Growers, Inc.

Johnson, K. J. R. 1984. Identification of *Eoreuma loftini* (Dyar) (Lepidoptera: Pyralidae) in Texas, 1980: Forerunner for other sugarcane boring pest immigrants from Mexico? Bull. Entomol. Soc. Am. 30: 47-52.

Johnson, K. J. R. 1985. Seasonal occurrence and insecticidal suppression of *Eoreuma loftini* (Lepidoptera: Pyralidae) in sugarcane. J. Econ. Entomol. 78: 960-966.

Johnson, K. J. R., and M. B. van Leerdam. 1981. Range extension of *Acigona loftini* into the Lower Rio Grande Valley of Texas. Sugar Azucar. 76: 34, 119.

Legaspi, J. C., S. Greenberg, B. Legaspi, Jr. and R. Saldaña. 1996a. Laboratory evaluations of *Bracon mellitor* as a parasite for stalk borers (Pyralidae) in Texas. Intl. Sugar J. 98(1173E): 460.

Legaspi, J. C., S. Wraight, and R. Saldaña. 1996b. Pathogenicity of the fungal entomopathogen *Beauveria bassiana* against sugarcane stalkborers (Lepidoptera: Pyralidae). Proc. XX Cong. Entomol. 25-31 August, 1996, Firenza, Italy. p. 692.

Legaspi, J. C., R. Saldaña, and N. Rozeff. 1997. Identification and management of stalkborers on Texas sugarcane. Texas Ag. Expt. Sta. MP-1777.

Mathes, R., and L. J. Charpentier. 1969. Varietal resistance in sugar cane to stalk borer moths, pp. 175-188 In: J. R. Williams, J. R. Metcalfe, R. W. Mungomery, and R. Mathes (eds.). Pests of sugar cane. Elsevier, New York.

Meagher, R. L., Jr., and R. R. Saldaña. 1992. Application techniques study for Mexican rice borer control on sugarcane, 1991. Insect. Acar. Tests. 17: 285-286.

Meagher, R. L., Jr., R. S. Pfannenstiel, and R. R. Saldaña. 1992. Survey and estimated injury of the Mexican rice borer in Texas. J. Am. Soc. Sugarcane Tech. 12: 22-26.

Meagher, R. L., Jr., J. W. Smith, Jr., and K. J. R. Johnson. 1994. Insecticidal management of *Eoreuma loftini* (Lepidoptera: Pyralidae) on Texas sugarcane: a critical review. J. Econ. Entomol. 87: 1332-1344.

Meagher, R. L., Jr., J. E. Irvine, R. G. Breene, R. S. Pfannenstiel, and M. Gallo-Meagher. 1996. Resistance mechanisms of sugarcane to Mexican rice borer (Lepidoptera: Pyralidae). J. Econ. Entomol. 89: 536-543.

Meagher, R. L., Jr., J. W. Smith, Jr., H. W. Browning, and R. S. Saldaña. 1997. Sugarcane stemborers and their parasites in southern Texas. Environ. Entomol. (In review).

Melton, C. W., and H. W. Browning. 1986. Life history and reproductive biology of *Allorhogas pyralophagus* (Hymenoptera: Braconidae), a parasite imported for release against *Eoreuma loftini* (Lepidoptera: Pyralidae). Ann. Entomol. Soc. Am. 79: 402-406.

Melton, C. W., H. W. Browning, J. W. Smith, Jr., and C. W. Agnew. 1986. A search in western Mexico for natural enemies of the Mexican rice borer, *Eoreuma loftini* (Dyar), September, 1984. Texas Ag. Expt. Sta. PR-4355.

Pfannenstiel, R. S., and H. W. Browning. 1989. Preliminary evaluation of the entomophagous nematode *Steinernema feltiae* on the Mexican rice borer in sugarcane, Fall 1986. Texas. Ag. Expt. Sta. PR-4680.

Pfannenstiel, R. S., and H. W. Browning. 1995. Field evaluations of parasitoids of larval stalkborers against *Eoreuma loftini* (Lepidoptera: Pyralidae) in rice. J. Entomol. Sci. 30: 406-414.

Pfannenstiel, R. S., and R. L. Meagher, Jr. 1991. Sugarcane resistance to stalkborers (Lepidoptera: Pyralidae) in south Texas. Fla. Entomol. 74: 300-305.

Pfannenstiel, R. S., J. W. Smith, Jr., and R. L. Meagher. 1990. Field release and recovery of parasites of *Eoreuma loftini* (Lepidoptera: Pyralidae) in sugarcane, 1989. TX. Agric. Exp. Sta. PR-4811.

Pfannenstiel, R. S., H. W. Browning, and J. W. Smith, Jr. 1992. Searching behavior of *Pediobius furvus* (Hymenoptera: Eulophidae) for *Eoreuma loftini* (Lepidoptera: Pyralidae) in sugarcane. J. Econ. Entomol. 85: 384-388.

Pusztai, A., J. Koninkx, H. Hendriks, W. Kok, S. Hulscher, E. J. M. van Damme, W. J. Peumans, G. Grant, and S. Bardocz. 1996. Effect of the insecticidal *Galanthus nivalis* agglutinin on metabolism and the activities of brush border enzymes in the rat small intestine. J. Nutr. Biochem. 7: 677-682.

Ring, D. R., and H. W. Browning. 1990. Evaluation of entomopathogenic nematodes against the Mexican rice borer (Lepidoptera: Pyralidae). J. Nematol. 22: 420-422.

Rodriguez-del-Bosque, L. A., and J. W. Smith, Jr. 1989. Exploration for parasites of sugarcane stalkborers (Lepidoptera: Pyralidae) in Michoacan and Jalisco, Mexico, 1988. Texas Ag. Expt. Sta. PR-4672.

Rodriguez-del-Bosque, L. A., and J. W. Smith, Jr. 1990. Exploration for parasites of sugarcane stalkborers (Lepidoptera: Pyralidae) in Morelos and Puebla, Mexico, May 1989. Texas Ag. Expt. Sta. PR-4686.

Rodriguez-del-Bosque, L. A., and J. W. Smith, Jr. 1996. Rearing and biology of *Lydella jalisco* (Diptera: Tachinidae), a parasite of *Eoreuma loftini* (Lepidoptera: Pyralidae) from Mexico. Ann. Entomol. Soc. Am. 89: 88-95.

Rodriguez-del-Bosque, L. A., J. W. Smith, Jr., and H. W. Browning. 1989. Exploration for parasites of sugarcane and corn stalkborers in the huastecas area of Mexico, May 1985. Texas Ag. Expt. Sta. PR-4595.

Sharon, N. and H. Lis. 1990. Legume lectins - a large family of homologous proteins. The FASEB Journal. 4: 3198-3207.

Shorey, H. H., and L. K. Gaston. 1967. Pheromones. pp. 241-265 In W. W. Kilgore and R. L. Doutt (eds.) Pest control: biological, physical, and selected chemical methods. Acad. Press. NY.

Smith, J. W., Jr., H. W. Browning, and F. D. Bennett. 1987. *Allorhogas pyralophagus* [Hym.: Braconidae], a gregarious external parasite imported into Texas, USA, for biological control of the stalkborer *Eoreuma loftini* [Lep.: Pyralidae] on sugar cane. Entomophaga. 32: 477-482.

Smith, J. W., Jr., C. W. Agnew, and R. Montandon. 1988. Exploration in Veracruz, Mexico for parasites of sugarcane borers. Texas Ag. Expt. Sta. PR-4594.

Smith, J. W., Jr., L. A. Rodriguez-del-Bosque, and C. W. Agnew. 1990. Biology of *Mallochia pyralidis* (Hymenoptera: Ichneumonidae), an ectoparasite of *Eoreuma loftini* (Lepidoptera: Pyralidae) from Mexico. Ann. Entomol. Soc. Am. 83: 961-966.

Smith, J. W., Jr., R. N. Wiedenmann, and W. A. Overholt. 1993. Parasites of lepidopteran stemborers of tropical gramineous plants. ICIPE Science Press, 89 pp.

Spurgeon, D. W., T. N. Shaver, J. R. Raulston, and P. D. Lingren. 1996. Activity patterns of adult Mexican rice borers (Lepidoptera: Pyralidae) in sugarcane. Southwest. Entomol. 21: 23-32.

Spurgeon, D. W., J. R. Raulston, P. D. Lingren, and J. M. Gillespie. 1997. Mating disruption of Mexican rice borers (Lepidoptera: Pyralidae) in Lower Rio Grande Valley sugarcane. J. Econ. Entomol. 90: 223-234.

van Leerdam, M. B., K. J. R. Johnson, and J. W. Smith, Jr. 1986. Ovipositional sites of *Eoreuma loftini* (Lepidoptera: Pyralidae) in sugarcane. Environ. Entomol. 15: 75-78.

Youm, O., F. E. Gilstrap, and H. W. Browning. 1990. Parasitism of stem borers (Lepidoptera: Pyralidae) associated with corn and sorghum in the Lower Rio Grande Valley of Texas. J. Econ. Entomol. 83: 84-88.