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LATIN AMERICAN RESEARCH ON *SPODOPTERA FRUGIPERDA* (LEPIDOPTERA: NOCTUIDAE)

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ABSTRACT

Recent Latin American literature concerning *Spodoptera frugiperda* (J. E. Smith) is reviewed. The pest's distribution, economic importance, seasonal abundance, host plants, life cycle and biology, as well as natural, cultural, genetic and chemical controls are discussed.

RESUMEN

Se revisa la literatura Latinoamericana que trata del gusano cogollero, *Spodoptera frugiperda* (J. E. Smith). Se resume la información disponible sobre su distribución, importancia económica, abundancia estacional, plantas hospederas, ciclo de vida, biología y control.

This literature review is an extension of that which was presented by Andrews (1980) and includes both previously unencountered pre-1980 publications and recent citations. This review includes many published summaries of papers presented at regional professional meetings. Most of these citations are not included in any entomological abstracting service. Brief, preliminary or even superficial, short publications have been included because they are oftentimes the only published information available on a particular subject. Moreover, each provides names and addresses which may help foreign researchers obtain further information through correspondence. For the most part, English-language references easily accessible to North American researchers through abstracting services are not included.

MORPHOLOGY

Angulo & Jana (1982) described the pupae of 4 species of *Spodoptera* encountered in northern Chile.

Intracountry Distribution

In Mexico, *Spodoptera frugiperda* (J. E. Smith) is a more serious pest in the coastal states and territories of Michoacan, Oaxaca, Quintana Roo, and Yucatan. It is also serious in Morelos state. It is of much less importance in highlands areas over 2000 mts in Puebla, Tlaxcala, Hidalgo, Guanajuato, Queretaro, and Mexico states (Sifuentes 1978). The pest is much more important in the coastal plain of Nicaragua than in interior areas. The heavy use of insecticides in cotton in the Pacific plain and subsequent destruction of natural enemies may cause this differential abundance (Van Huis 1981). Alternatively, the difference in populations in these areas may be a result of the higher biotic potential of the species where hot conditions and large monocultures predominate.

Seasonal Abundance

Manrique et al. (1979) conducted a four-year study involving blacklight traps located at two sites in Durango and Chihuahua, Mexico. *S. frugiperda* moths were caught regularly between June and November but few were trapped from December through May. In Tamaulipas, Mexico, a three-year study involving staggered maize plantings from June to November revealed greatest damage in July and October; the least damage occurred in June and August (Alvarado & Carrillo 1981). Peralta (1980) reported little *S. frugiperda* damage in April and May in this same state.

In Rio Grande do Sul, Brazil, no *S. frugiperda* moths were caught in blacklight traps during August, September or October, and moths were most abundant in February, March and April (Silveira et al. 1979). In this state, *S. frugiperda* is most common in maize between December and April (Maia 1978). In Piracicaba, Brazil, Carvahlo et al. (1971) found highest adult populations between October and February; during this period, warm temperatures prevail and maize is growing. Lara et al. (1977) reported that *S. frugiperda* was collected in over 80% of the blacklight samples at 2 sites during 4 years. Lara & Silveira (1977) collected adults during the entire year in Sao Paulo with highest populations recorded between November and March.

Doreste (1975) reported the results of a 10-year study using light traps for collecting *S. frugiperda* in Venezuela. Few moths were caught during the dry season, November to April. Catches increased dramatically in June and July at the onset of the rainy season. Population crashes in August were due to the effects of *Beauvaria* sp. and other natural enemies. In dry years, the population peak was delayed until August. Clavijo (1981b) found similar results using data collected at 5 sites and over 12 years in Venezuela. He related abundance to rainfall. Silvain (1986) reported that highest larval and adult populations tended to occur around January and July in French Guiana.

Hichens & Mendoza (1976) reported that *S. frugiperda* was present in Chilean alfalfa throughout the year. According to van Huis (1981), in Nicaragua, second cycle maize (that which is planted in August or September) is more severely attacked than is maize which is planted in May or June at the beginning of the rainy season. Honduran data (Andrews et al., unpublished) contradict these findings. Adult populations are generally low throughout the second cycle growing season (August to December) and the dry season (January through May). Adult populations are very high during June, July and August. Larval populations are also highest during this period. Larval populations rapidly reach damaging levels in irrigated maize grown during the Central American dry season (Anon. 1984) indicating that lack of larval host plants, rather than mortality agents, normally maintain low adult populations during the dry season. Passoa (1983) collected *S. frugiperda* during every month in Honduras.

Yield Reductions and Economics of *S. frugiperda* Control

Just how important is *S. frugiperda* "south of the border"? Chemical control of *S.*

frugiperda on sorghum in Cuba was uneconomical (Ryder et al. 1968). In hybrid maize grown in Cuba for forage, Ryder (1968a) measured yield increases of 4.6-6.5 metric tons/ha due to whorlworm control and suggested that if 5% of the whorls are infested an application of insecticide might be economically justified.

Sifuentes (1978) reported that in areas in Mexico where the whorlworm is most damaging, yields are normally increased by an insecticide application. When 3 applications are made, yield increases of 2-2.5 metric tons are normal. Silva (1978) working in Oaxaca, Mexico, registered yield increases of 130 to 2000 kg/ha in maize which received 3 insecticide applications. Tello & Diaz (1982) reported yield increases in Sinaloa of 900 kg/ha through chemical control of whorl feeding *S. frugiperda*. These authors did not present compelling evidence that the reported losses were due only to *S. frugiperda* and not a combination of whorl and stem boring insects. Peairs & Saunders (1981) reported studies in Mexico involving a late maturing tropical white dent and an intermediate-maturing tropical yellow flint. They used controlled infestation methods developed in CIMMYT and an insecticide check. Yield reductions were significant only when considered over several growing cycles and averaged 13%. Maximum losses were 30%. Galt and Stanton (1979) reported average losses of 17% due to foliage-feeding insects in trials in Mexico carried out on experiment station grounds and on-farm.

Maize yields in Brazil were unaffected by *S. frugiperda* leaf feeding (Montenegro 1981). The same was true for maize in Venezuela (Clavijo 1984a,b).

In four unpublished theses based on work carried out in maize in Guatemala, whorlworm control was rarely associated with significantly reduced yields and was never justified economically (García de Dacarett 1975, Cabarrus 1977, Teos 1980, Pérez 1982). Dardón et al. (1983) registered yield increases of up to 15% due to control of foliage pests. In the Dominican Republic, Del Rosario et al. (1981) and Del Rosario & Diclo (1981) showed statistically insignificant yield increases of 8% when whorlworms were controlled chemically.

In Nicaragua, van Huis (1981) measured strong interactions between fertilizer use and whorl protection in studies involving a hybrid variety of maize. Use of fertilizer alone increased yields only 6%; use of insecticide increased yields by 24%. Use of both inputs increased yields by 60%. Because of this pronounced synergistic effect, the decision to control *S. frugiperda* and *D. lineolata* should precede a decision to use fertilizer. Ideally, however, credit facilities would enable use of both inputs. In another test, maize grain yields were not significantly less in plots where whorl protection started 7, 15 or 30 days after plant emergence as compared to plots which were always protected. Without whorl protection, yields were about the same for plants subjected to different degrees of water stress. With sufficient soil moisture, whorl protection increased yield by 50%, but under severe water stress, whorl protection did not increase yields. Whorl infestation was highest for maize which was deprived of irrigation for the longest period.

Based on artificial defoliation studies, van Huis (1981) contended that maize plants were more sensitive to late whorl than early whorl damage. Greatest yield reduction occurred after mid-whorl stage. With two open pollinated varieties, yields were reduced linearly as older plants were defoliated. With two hybrids, however, the greatest effect was registered when defoliation occurred immediately after mid-whorl with less effect on subsequent defoliation dates. Severe defoliation before mid-whorl caused moderate yield losses of 20-30%. This author concluded that the commonly recommended action threshold of 20% infested plants generally resulted in higher yields than did an action threshold of 50% and this was always better than an untreated check.

This species can be devastating as a cutworm. Shannon & Navarro (1983) included it as one of the three most serious pests of seedling maize in Panama. They estimated plant stand losses of 30%. León (1978) reported seedling losses of 60% in Sonora, Mexico. Rueda et al. (1985) argued that care must be taken to not attribute damage caused to maize seedlings by *Listronotus dietrichi* (Stockton) to *S. frugiperda*.

In Nicaragua, loss of maize grain yield due to ear feeding is negligible (van Huis 1981, Anon. 1984), but Sifuentes (1978) contended that this damage is important in Jalisco, Mexico.

Guiagossian et al. (1981) reported that yields of susceptible sorghum varieties were reduced 55-80% when subjected to heavy, artifically induced whorlworm attack. Losses in intermediately susceptible varieties were 35-50%. Carvalho et al. (1971) studied yield responses of one sorghum hybrid and found that severe damage resulted in 15% yield loss when compared to undamaged plants. Attacks at 64 days resulted in 34% yield reduction. Other varieties responded similarly, registering losses of 20-30% when serious versus light infestations were compared. In El Salvador, Hueso de Mira & Lainez (1980) found yield losses of 50% in 13- to 22-day old sorghum due to *S. frugiperda* acting as a cutworm. In 30- to 41-day old plantings the same pest population density resulted in 25% yield reductions; between 45 and 55 days, corresponding losses were 15%.

Life Cycle and Behavioral Studies

In Venezuela, Labrador (1967) found that *S. frugiperda* larvae passed through 6 or 7 instars when fed maize, and he presented detailed information regarding head capsule width. Nieto & Llanderal (1982) presented head capsule widths for a population of *S. frugiperda* in Mexico. Loya (1978) studied larval development on maize and sorghum in Mexico. Larval development took as little as 20 days in midsummer and as long as 35 days in September. Reproduction was greater and adults were longer lived when larvae were fed maize leaves. Most larvae passed through 7 instars. Another report from Mexico (Armenta 1971, cited in Sifuentes 1977) reported that larvae developed faster on sorghum than on maize (14 versus 19 days). Pierda (1974) found larval development times to be 17 and 15 days on sorghum and maize, respectively; this difference was not significant. Castro et al. (1987b) found no difference in development times when larvae were reared on these hosts, although adults reared on maize produced more eggs. Peña (1980b) reported that larval development took 13 days on maize and 22 days on an artificial diet. Nieto & Llanderal (1982) reported the larval development period to be 30 days, followed by a pupal period of 11 days; females laid 1,500 eggs. In Surinam, larval development typically is 15 days (van Dinther 1960) and 8-9 generations/year are expected. According to Doposto & Enkerlin (1964) larval and pupal stages are completed in 22 and 9 days, respectively. Estrada (1960, cited in van Huis 1981) reported that on maize, larval development took 9.6 to 20 days, the average being 11.1 days. In Peru (Campos n.d.), larval development on maize at 27°C was 18.9 days. Adults laid an average of over 1,600 eggs, with a mean oviposition period of 9.2 days. Bertels (1970) found that in Brazil egg and larval stages lasted 10 and 21-28 days, respectively. Pupae required 9 (Armenta 1971), 9-10 (van Dinther 1960), 8-9 (Piedra 1974), 8 (Peña 1980b), 10 (Loya 1978) or 10-30 days (Bertels 1970) to complete their development. Castro et al. (1987b) compared *S. frugiperda* development periods and other parameters of a Honduran colony with individuals collected in Mississippi.

Studies by Piedra (1971) in Cuba showed that 24 days were required for development from first instar larva to adult on maize. Corresponding times required on sorghum, *Stizolobium deeringianum* Bert. and *Pennisetum purpureum* Schumach. were 26, 28 and 29 days, respectively. In subsequent studies, she found that larval mortality was higher on *P. purpureum* than on maize, sorghum or *S. deeringianum*. In Colombia, Alvarez & Sánchez (1983) found that larvae fed on sorghum and nutsedge passed through 6-8 instars. Larvae fed on older sorghum leaves grew more slowly and molted more often than did larvae provided with young sorghum foliage.

According to Valerio & Combs (1980), adult *S. frugiperda* oviposit more readily on "callie" bermudagrass than on other varieties of *Cynodon dactylon* (L.) Pers. and the optimum temperatures for adults and larvae are 25 and 30°C, respectively. Sifuentes

(1977), van Huis (1981), and Alvarez & Sánchez (1982) observed that females laid more eggs on maize plants than on interplanted sorghum plants.

Fernandez (1971) caught twice as many *S. frugiperda* females as males in light traps in Venezuela over a 3-year period. Trevino (1980) captured more moths in light traps during new moon phase, at higher temperatures, and when there was less precipitation. Portilla et al. (1984) studied the sexual behavior of normal and allatectomized males.

Carvalho & Silveira (1971) found that in whorl stage sorghum in Brazil, the maximum size for coexisting large *S. frugiperda* larvae was 2.5 cm. However, in 74% of the whorls where they found a larva over 3.0 cm long, they also found small larvae. They often found small and medium sized larvae together in whorls; but, as they grew in size, the number of cohabitating larvae decreased. These authors considered this to be conclusive evidence for cannibalism. In the grain filling stage, 85% of the worms found were located in the basal part of the heads and only 15% in the upper half. Aguilera & Vargas (1970) found an average of 4.6 larvae/whorl but reported that large larvae do not cohabit a whorl.

S. frugiperda larvae collected by van Huis (1981) from *Digitaria* sp. did not show conditioning to that plant, but had a slight feeding preference for maize. The same author made several interesting observations on the biology of *S. frugiperda* on maize. All eggs laid on the early whorl stage were laid on the underside of the leaves, but by the late whorl and tasseling stages between 30-40% were laid on the upper side. Egg mass size increased linearly with maize plant growth; one week after plant emergence, masses averaged 80 eggs while at 50 days the typical mass contained more that 400 eggs. In 3 separate experiments van Huis (1981) measured peaks of oviposition activity in early whorl and tasseling stages; oviposition activity was low at mid-whorl stage (30 days after emergence).

Host Plants

Brunner et al. (1975) listed 17 economically important plants attacked by *S. frugiperda* in Cuba, including peanut, pepper, papaya, garbanzo, gladiolus, rice, guinea grass, para grass, lima bean, verdulaga, sugarcane, Johnson grass, sorghum, maize, kudzu, pigeon pea and *Eucalyptus* sp. Van Huis (1981) reported sorghum, sesame, sugarcane, maize, rice, cotton, tobacco, potato, tomato, cucumber and cabbage as important crop hosts for this pest. Larvae were common on weeds, especially *Digitaria* sp. and *Eleusine indica* (L.) Guertno. Passoa (1983) listed maize, rice, pepper, cabbage, tomato, sorghum, onion, bean, beets, lettuce, garlic and potato as important host plants in Honduras. Labrador (1967) listed 31 host plant species belonging to 21 families in Venezuela. Included in the list are 9 gramineaceous larval hosts and 3 fruit crops upon which eggs are laid. In Ecuador, the species is a problem on maize, cotton, tobacco, tomato, cucumber, rice, sugarcane, beans, soy beans, various grasses and forage legumes (Cevallos 1976).

According to Parasram (1976), larvae cause the most damage in cabbage by boring straight down into the head. In Brazil, De Moraes et al. (1974) reported that *S. frugiperda* caused considerable damage to buds on seedlings of *Eucalyptus urophyla* S. T. Blake. In Chile, of 13 species of Noctuids which cause damage in alfalfa, *S. frugiperda* is the second most important, just behind *S. eridania* (Aguilera et al. 1971). In Brazil, Chandler (1984) and Calil et al. (1985) showed the importance of *S. frugiperda* as a pest of young dry beans. *S. frugiperda* is common on *Digitaria sanguinalis* (L.) Scop., *Digitaria eglumis* Peter, *Setaria geniculata* (Lam.) Beauv. and *S. viridis* Beauv. (Bertels 1970). Howell (1980) stressed the importance of *Digitaria* spp. as a host and source of migrating worms in Honduras. Alvarez & Sánchez (1983) cited *Cyperus rotundus* L. as an excellent, widespread host in hot areas of Colombia. Sinha (1982) reported

S. frugiperda as the key pest of blackeyed peas [*Vigna unguiculata* (L.) Walp.], maize and sorghum in Guyana. *S. frugiperda* is a key pest in soybeans in Columbia; it acts as a cutworm, leaf feeder, terminal borer and pod feeder (Hallman 1983).

Abiotic Control

Van Huis (1981) showed that heavy rainfall a few days after first instar larvae were artificially infested into 8- and 18-day old maize plants resulted in a 20-30% reduction in intensity of damage in injured whorls. Light rains did not, however, kill significant numbers of larvae. The effect of rain was restricted to the early instars.

Natural Enemies

Parasitoids

Some of the parasitoids taken in Latin America and the Caribbean from *S, frugiperda* are listed in Table 1. Ashley (1979) listed others. Other species have been reported and distributions may be considerably wider than the limited information provided here would indicate.

Hexamermis sp. is a commonly reported nematode parasitoid of whorlworm larvae. Nickle (1978) described the life cycle of *Hexamermis*. Honduran data not yet published (M. Castro, H. Pitre, G. Wheeler & K. Andrews) indicate that this species occasions more mortality than any other larval parasitoid.

Van Huis (1981) reported 16 species of parasitoids and 3 entomopathogens which as a group accounted for an average 35% larval mortality. The most commonly recovered parasitoids were *Lespesia archippivora* (Riley) and the nematode *Hexamermis* sp. Other important parasitoids were *Rogas laphygmae* Vier., *Chelonus insularis* Cresson, *Ophion* sp. and *Archytas narmoratus* (Tns.). *Hexamermis* sp. is not common in coastal areas; the use of carbofuran as a soil treatment at planting probably destroys large numbers of this nematode. *L. archippivora* kill approxmately 76% of the larvae recovered from weeds in maize field while larvae taken frn whorls of maize in the same field were attacked at a much lower level. Weeds may be a significant source of this important parasitoid. Parasitism by *L. archippivora* was more important in the late whorl and tasseling stages than in young maize. The reverse was true for *R. laphygmae* which was frequent only in early growth stage maize. Intercropping of maize with beans decreased parasitism of *R. laphygmae*.

Teran (1974) listed 19 species of Diptera as parasitoids of *S. frugiperda* in Venezuela. Notz (1972) provided some biological data on 5 of these species and on 4 species of Hymenoptera. Campos (1965) found only 10% infestation by tachinids in Peru and provided some data on development for 3 species.

A number of *S. frugiperda* studies in Mexico may be cited. Laboratory and limited field tests with *Bracon kirkpatricki* Wilkenson were reported by Peña (1980a) and Moya (1980). Field test results were not impressive. Montoya (1979, 1980) reported that *Trichogramma* sp. and *Euplectrus* sp. caused 45-55% egg and 10-25% larval mortality in different years in Veracruz. In maize in Quintana Roo, average larval parasitism of 41% was caused by *Archytas* sp., *L. archippivora*, *Pristomerus spinator* (F.) and *Chelonus* sp. (Carrillo 1980). Loya (1978) attempted to control *S. frugiperda* with mass releases of an unspecified species of *Trichogramma* without success. Parasitism levels of 0.18% in fields where no liberations were made increased to only 0.56% in treated fields. *Chelonus* sp. parasitized 5% of the eggs. Another attempt to use mass liberations of *Trichogramma* spp. in Tamaulipas resulted in less than 15% average parasitism (Peralta et al. 1981). Castrejón (1981) conducted a laboratory study of oviposition behavior of *Telenomus remus* (Nixon).

TABLE 1. PUBLISHED REPORTS OF PARASITOIDS OF *SPODOPTERA FRUGIPERDA* FROM VARIOUS LATIN AMERICAN AND CARIBBEAN COUNTRIES.

Parasites	Countries	Citation
DIPTERA		
SARCOPHAGIDAE		
Sarcophaga lambens	Lesser Antilles	Fennah 1947
Sarcophaga sp.	Venezuela	Terán 1974
TACHINIDAE		
Acroglossa vetula	Venezuela	Notz 1972
	Venezuela	Terán 1974
Archytas analis	Venezuela	Terán 1974
	Barbados	Alam 1978
Archytas divisus	Venezuela	Terán 1974
Archytas incasana	Chile	Etcheverry 1957
Archytas incertus	Chile	Etcheverry 1957
	Brazil	Lucchini & Almeida 1980
	Brazil	Patel & Habib 1984
Archytas marmoratus	Lesser Antilles	Fennah 1947
(= *A. piliventris*)	Venezuela	Notz 1972
	Venezuela	Terán 1974
	Chile	Valencia & Valdivia 1973
	Cuba	Brunner et al. 1975
	Nicaragua	van Huis 1981
	Barbados	Alam 1978
	Trinidad	Yaseen 1978
Archytas sp.	Mexico	Carrillo 1980
Eucelatoria armigera	Cuba	Brunner et al. 1975
(= *Blondelia armigera*)	Venezuela	Terán 1974
Eucelatoria sp.	Venezuela	Terán 1974
	Barbados	Alam 1978
Euphorocera sp.	Brazil	Goncalvez & Goncalvez 1973
Gonia crassicornis	Lesser Antilles	Fennah 1947
	Brazil	Goncalvez & Goncalvez 1973
	Venezuela	Terán 1974
Gonia texensis	Cuba	Brunner et al. 1975
Lespesia archippivora	Lesser Antilles	Fennah 1947
	Cuba	Ryder & Piedra 1968
	Venezuela	Notz 1972
	Cuba	Brunner et al. 1975
	Venezuela	Terán 1974
	Mexico	Carrillo 1980
	Nicaragua	van Huis 1981
	Brazil	Patel & Habib 1984
Lespesia sp.	Cuba	Ryder & Pulgar 1969
	Venezuela	Notz 1972
	Brazil	Goncalvez & Goncalvez 1973
	Venezuela	Terán 1974
	Brazil	Lucchini & Almeida 1980
	Colombia	Vargas & Sánchez 1983
Linnaemya analis	Venezuela	Terán 1977
Patelloa similis	Brazil	Patel & Habib 1984
Peleteria robusta	Chile	Etcheverry 1957
Pronemorilla mima	Venezuela	Notz 1972

TABLE 1. (Continued)

Parasites	Countries	Citation
	Venezuela	Terán 1974
Pseudokea sp.	Brazil	Costa Lima 1949
Spoggosia calaripennis	Venezuela	Terán 1974
Spoggosia floridensis	Venezuela	Terán 1974
Winthemia quadripustulata	Venezuela	Terán 1974
Withemi reliqua	Chile	Valencia & Valdivia 1973
Withemia roblesi	Chile	Valencia & Valdivia 1973
Winthemia sp.	Lesser Antilles	Fennah 1947
	Chile	Etcheverry 1957
	Venezuela	Terán 1974
	Trinidad	Yaseen 1978
	Colombia	Vargas & Sánchez 1983
	Brazil	Patel & Habib 1984
HYMENOPTERA		
BRACONIDAE		
Apanteles marginiventris	Lesser Antilles	Fennah 1947
	Surinam	van Dinther 1960
	Venezuela	Notz 1972
	Brazil	Lucchini & Almeida 1980
	Nicaragua	van Huis 1981
	Brazil	Patel & Habib 1984
Apanteles sp.	Barbados	Alam 1978
(*glomeratus* group)	Trinidad	Yaseen 1978
Aphanteles sp.	Colombia	Vargas & Sánchez 1983
	Brazil	Patel & Habib 1984
Bracon kirkpatricki	Mexico	Peña 1980
	Mexico	Moya 1980
Chelonus cautus	Nicaragua	van Huis 1981
Chelonus insularis	Lesser Antilles	Fennah 1947
(= *C. antillarum*, *C. texanus*)	Cuba	Ryder & Piedra 1968; Ryder & Pulgar 1969; Brunner et al. 1975
	Venezuela	Notz 1972
	Barbados	Alam 1978
	Trinidad	Yaseen et al. 1981
	Nicaragua	van Huis 1981
	Colombia	Vargas & Sánchez 1983
	Brazil	Patel & Habib 1984
Chelonus sp.	Mexico	Loya 1978
	Mexico	Carrillo 1980
	Brazil	Habib & Patel 1978
Meteorus laphygmae	Surinam	van Dinther 1960
	Venezuela	Notz 1972
	Colombia	Vargas & Sáchez 1983
Palinzele sp.	Trinidad	Yaseen 1978
Rogas caphimal	Nicaragua	Lacayo 1984
Rogas laphygmae	Nicaragua	van Huis 1981
Rogas vaughani	Nicaragua	van Huis 1981
	Honduras	Passoa 1983
Rogas sp.	Cuba	Ryder and Piedra 1968
	Cuba	Ryder & Pulgar 1969
	Honduras	Passoa 1983
Zele sp. prob. *mellea*	Nicaragua	van Huis 1980

TABLE 1. (Continued)

Parasites	Countries	Citation
ICHNEUMONIDAE		
Amblyteles sp.	Brazil	Costa Lima 1949
Campoletis flavicinta	Nicaragua	van Huis 1981
	Uruguay	Yaseen et al. 1981
	Brazil	Patel & Habib 1984
Campoletis groti	Brazil	Lucchini & Almeida 1980
Eiphosoma nr. *annulatum*	Venezuela	Notz 1972
Eiphosoma vitticolle	Nicaragua	van Huis 1981
	Bolivia	Yaseen et al. 1981
	Brazil	Patel & Habib 1984
Eiphosoma sp.	Trinidad	Yaseen et al. 1981
Enicospilus merdarius	Cuba	Brunner et al. 1975
Ophion flavidus	Honduras	Passoa 1983
	Brazil	Patel & Habib 1984
Ophion sp.	Nicaragua	van Huis 1981
Pristomerus spinator	Nicaragua	van Huis 1981
	Brazil	Patel & Habib 1984
Zenillia blanda	Cuba	Brunner et al. 1975
TRICHOGRAMMATIDAE		
Trichogramma exiguum (= *T. fasciata*) (= *T. fasciatum*)	Barbados	Alam 1978
Trichogramma sp.	Mexico	Montoya 1979, 1980
	Nicaragua	van Huis 1981
Trichogramma sp. nov	Guadeloupe	Yaseen et al 1981
EULOPHID		
Euplectrus hircinus	Panama	F. Bennett (pers. comm.)
Euplectrus plathypenae	Lesser Antilles	Fennah 1947
	Venezuela	Marin 1966
	Cuba	Ryder & Piedra 1968; Ryder & Pulgar 1969; Brunner et al. 1975
	Barbados	Alam 1978
	Trinidad	Yaseen 1978
	Colombia	Vargas & Sánchez 1983
Euplectrus nr. *insularis*	Nicaragua	van Huis 1981
Euplectrus sp. nov	Brazil	Lucchini & Almeida 1980
Euplectrus sp.	Mexico	Montoya 1979, 1980
	Nicaragua	van Huis 1981
SCELIONIDAE		
Telenomus heliothidis	Cuba	Brunner et al. 1975
Telenomus minutissimus	Dominican Republic	Yaseen et al. 1981
	Guadeloupe	Yaseen et al. 1981
Telenomus remus	Guadeloupe	Yaseen et al. 1981
	Dominican Republic	Yaseen et al. 1981

López (1981) reported that in Colombia *Meteorus laphygmae* Viereck is perhaps the most frequently encountered parasitoid of *S. frugiperda* and suggested that it is a good candidate for augmentative release. He provided laboratory-derived data on mass rearing and life cycle. In Córdova, Colombia, Cárdenas et al. (1982) and Valderrama & Tordecilla (1982) found low parasitism rates (1%) for *Euplectrus* sp. and *C. insularis* [= *C. texanus* (Cresson)], respectively. Landazabal et al. (1973) studied the effective-

ness of the nematode *Neoaplectana carpocapsae* W. for control of *S. frugiperda* larvae in Colombia. Under humid field conditions, the nematode gave acceptable control when applied at 3000/plant. These authors gave details of rearing procedures and of laboratory studies.

Yaseen et al. (1981) reported that since 1976 the CIBC and cooperating agencies have made several introductions of exotic parasitoids of *S. frugiperda* involving at least 11 species in the Caribbean. Cock (1985) updated the report. *T. remus* exerts adequate control of the whorlworm in Barbados and may prove to be a valuable element in integrated control programs on other islands. This species may have been established in the Cauca Valley of Colombia. Ryder & Pulgar (1969) found that parasitism was low in maize in Cuba and associated phenological stage of the host plant to larval stage and rates of parasitism.

In Sân Paulo, Brazil, Patel & Habib (1984) collected over 2,500 *S. frugiperda* larvae during a 4-year period and found trimestral parasitism rates ranged from 9 to 35%. The most common parasites found were *Campoletis flavicincta* (Ashmead) and *Archytas incertus* (Macquart). Insecticide applications were reported to dramatically reduce levels of parasitism and three hyperparasites of *C. flavicincta* were observed. Fernández & Clavijo (1984) also reported that insecticides reduced effectiveness of certain Venezuelan parasitoids.

Pathogens

Van Huis (1981) concluded, as had previous Nicaraguan entomologists, that *Aspergillus flavus* Link and *Nomuraea rileyi* (Farlow) are both significant pathogens of *S. frugiperda* while *Entomophthora* sp. was unimportant. *Beauvaria* sp. was reported to be of utmost importance in Venezuela as a regulating factor of whorlworm populations (Doreste 1975). Agudelo-Silva (1986) found five pathogens in collections made in Venezuela, including an NPV, a GV, *Erynia radicans* (Brefeld) Hunker, Ben-Ze'ev and Kenneth, and *N. rileyi*. As a comlex, they killed 14% of the larvae collected. *Fusarium roseum* Link was reported by Fassiatiova et al. (1978) from Cuba. A detailed study of the histopathology and toxicology of an NPV was reported by Jiménez & Bustillo (1981). A Venezuelan strain of a nuclear polyhedrosis virus was studied by Agudelo et al. (1983). Garcia et al. (1984) studied a Brazilian NPV in the laboratory. The factors which are responsible for susceptibility of *S. frugiperda* larvae to *Bacillus thuringiensis* were studied by Garcia et al. (1982).

García & Habib (1978) reported that *Aspergillus parasiticus* Speare could kill adult *S. frugiperda*. Patel & Habib (1982) reported that wasp parasites were effective dispersal agents and inoculators of the fungus in larvae.

Predators

Predators must be of considerable importance in the tropics in control of *S. frugiperda* but researchers are only beginning to make the efforts necessary to appreciate their value. They are difficult to study.

Van Huis (1981) found that *Galerita* sp. and *Nerthra fuscipes* (Guérin-Méneville), two probable predators of the larvae, were more abundant in weedy fields than in clean cultivated plots. He identified 7 reduviids and 4 pentatomids as predators. Other general predators, such as *Nabis* sp., *Geocoris* sp. and *Chrysopa* sp., were also important. Loya (1978) also singled out *Chrysopa* as an important egg predator. Van Huis (1981) did not quantify the effect of predators because a methodology for sampling their populations accurately was not available. Labrador (1967) listed 6 species of predators of *S. frugiperda* from Venezuela. Native predators (e.g., *Polistes versicolor* Oliv. and *Col-*

emegilla sp.) were not effective in regulating whorlworm populations in Trinidad (Yaseen et al. 1981).

Van Dinther (1960) mentioned two birds, *Crotophaga ani* and *Pitangas sulphuratus sulphuratus*, as predators. He and van Huis (1981) reported vespid wasps of the genera *Polistes* and *Polybia* as important predators. Guagliumi (1972/1973) cited these same genera as predators of *S. frugiperda* in sugarcane in northeast Brazil. At the Panamerican Agricultural School and elsewhere in Honduras, *Polybia* spp. readily enter the whorls where they attack and kill larvae (Andrews, unpublished). Attempts to manipulate *Polybia* spp. have been unsuccessful. Gómez & Zapateiro (1982) concluded that 500 *Podisus nigrispinus* Dallas nymphs per hectare were capable of suppressing whorlworm larval infestations of up to 15% in maize.

Another predator which merits special attention is *Doru taeniata* (=*taeniatum*) (Dohrn). These earwigs are good fliers and hide deep in the whorl or behind sheath collars. Van Huis (1981) reported that more earwigs were found in maize intercropped with beans and in weedy maize than in monoculture or clean cultivation maize. In petri dish studies, van Huis (1981) showed that eggs and instars 1 through 3 were readily consumed while later instars were rejected. In field studies with one adult earwig per plant, an average of 57% of the whorlworm egg masses put on the plants were consumed. Varying the number of masses from 1-13/30 plants did not affect predation levels. Egg masses were either completely consumed or untouched. In other field cage studies with one adult *D. taenita* per plant, artificial larval infestation of 2 to 4/whorl were reduced by 50% within 6 days. The average damage level of injured plants was also reduced significantly. Earwig population densities are variable, but commonly reach 1 or more per plant by late whorl stage both in Nicaragua and Honduras (van Huis 1981). Unfortunately, the earwig does not usually colonize in high numbers during the first critical few weeks of plant growth. Farmers are rarely aware of the importance of *D. taeniata* and generally consider it to be a pest because it consumes pollen in rice, sorghum and maize. Jones et al. (in press) provided life table information for *D. taenita*.

In studies in Honduras (Andrews, unpublished), the most important egg predators were *D. taeniata*; a mirid, *Creontiades* sp. and 2 species belonging to the genus *Diabrotica*. The latter genus is normally considered to be strictly Phytophagus. During three 48 hour observation periods, 50-95% of the egg masses placed in the field were destroyed by predators.

Sequeira et al. (1986) reported that *Solenopsis* spp. were effective prodators of both *S. frugiperda* and *Diatraea lineolata* (Wlk.) in seedling maize and sorghum. Little effect on yield was observed.

Effects of Cultural and Mechanical Procedures on *S. frugiperda*

A major area of research which has to be addressed by neotropical entomologists is the effect of different cropping systems on pest densities and damage. This is certainly the case with *S. frugiperda*, where a number of experiments have indicated that low or no till agriculture and polycultures are less severely attacked by the pest than monocultures planted using conventional cultivation. One of the earliest tests involved the interplanting of sunflower and maize in Cuba (Ryder 1968b); interplanted maize was less severely attacked and yielded better than monoculture maize. Del Rosario et al. (1981) in the Dominican Republic showed that the use of no till techniques reduced whorlworm infestations by 30-60%. Yields were much higher in no till plots due to a number of factors, not just whorlworm attack. Studies carried out in Costa Rica (Shenk & Saunders 1981, Shenk et al. 1983, Saunders 1985) showed consistently lower whorlworm damage in no till plots as compared to conventional tillage. No tillage plots offer many other agronomic and economic advantages and merit considerably more attention by tropical researchers.

Van Huis (1981) studied several aspects of cultural control. He found significantly greater *S. frugiperda* damage in monoculture maize than in maize interplanted with beans. Damage reduction was generally on the order of 20-30%. The more complicated polycultural systems generally contained more predators, such as *Doru* sp., spiders, predatory ants and tachinids. However, van Huis concluded that the major reason for reduced infestations was less oviposition by moths and less successful dispersal by first instar larvae. More egg masses were found in monoculture maize than in maize intercropped with beans. It is not known if interplanted beans have any olfactory effect on *S. frugiperda* feeding in maize. Unfertilized maize received fewer eggs than fertilized, but whorl injury was not statistically different. No effect on oviposition was seen when distance between rows of maize was varied, nor were percentages of plants infested affected significantly by planting distance. Weeds present between rows of maize increased oviposition on the maize; very few egg masses were found on the weeds. Apparently, most larvae infesting the weeds originated from masses which were laid on maize plants. Farmers often report increased severity of whorlworm attack on maize shortly after they hand weed the crop; this is because many larvae move from the desiccating weeds to the maize. Increased attention to sampling is needed at this time. If weeding is required and chemical control is not possible, the severity of the attack may be reduced by leaving a thin strip of weeds in mid row.

In two experiments, applications of soil directly to the whorls provided no control of larvae in Nicaragua (van Huis 1981). Dardón et al. (1985) found that sand applied to maize whorls in Guatemala reduced larval infestations.

Clavijo (1981a) reported that planting density did not affect the percentage of plants infested by the whorlworm. In Venezuela, rice fields are commonly flooded until the plants are nearly covered in order to drown larvae (Labrador 1967) Castro et al. (1987a) observed no effect of pigeon pea on infestations of interplanted maize and sorghum plants.

Dispersion, Sampling and Action Thresholds

Clavijo (1978a) reported that in Venezuela larval distributions were best described by a Poisson distribution; therefore, a random sampling allocation is appropriate. In a subsequent paper, Clavijo (1978b) estimated that between 122 and 190 plants had to be sampled to estimate the number of larvae/plant with 5% probability of error and precision levels of 20 to 5%. Barbosa & Perecin (1982) found that the number of larvae/10 plant samples was best described using the negative binomial model. The percent of plants infested in 10-plant samples adjusted best to the binomial distribution. Baez et al. (1980) found both aggregated and random dispersion patterns depending upon instar sampled and plant growth stage. Aguilera & Vargas (1970) reported that 0.45 larvae/whorl justified an insecticide application in Chilean maize. According to van Huis (1981), resource scarce farmers should count the number of injured whorls in 20 consecutive plants at 5 randomly selected sites. Carvalho & Silveira (1971) reported higher infestations in the edges of fields than in the center. Andrews (1984) provided detailed sampling recommendations for the pest in several crops grown in Honduras. Andrews et al. (1986) recommended sampling 20 plants in each of 5 sites and use of a 40% infestation rate in Honduran maize.

The use of sex attractant-baited sticky traps for predicting outbreaks of larvae was suggested by Ward et al. (1985). Herrera et al. (1982), Flores and Zapata (1982) and Izquierdo et al. (1983) reported the results of Mexican trials using various attractants and trap locations. Silvain & Hing (1985) and Silvain (1986) reviewed the programs developed in French Guiana to warn pasture managers of impending larval outbreaks on the basis of trap counts of male moths.

Host Plant Resistance

Van Huis (1981) reported that a hybrid maize variety was significantly less severely infested by *S. frugiperda* than was a local variety, Tuza Morada, in the early weeks of development. Silva (1978) reported that 7 of 33 maize lines which he tested in Oaxaca, Mexico, were resistant or moderately resistant to *S. frugiperda*; all were susceptible to *Diatraea* spp. Peairs and Saunders (1981) suggested that yield reductions must be considered the most reliable indicator of resistance; damage estimates did not correlate well with yield reductions. Carvalho et al. (1971) working with maize in Brazil felt that the use of a 5 point foliar damage rating scheme was valuable; yield reductions were well correlated with foliar damage.

Carvalho & Rossetto (1971) tested sorghum varieties for resistance to *S. frugiperda* using the 5 point damage system. Other Brazilian sorghum trials were reported by Lordello et al. (1980) and Mesquita et al. (1980).

Guiragossian et al. (1981) reviewed progress made at CIMMYT on development of whorlworm resistant sorghum cultivars. There is no relationship between HCN content of sorghum and resistance to the pest. The resistance which has been observed must be due to other mechanisms, including tolerance. Tolerance was confirmed to be the principal mechanism involved (Guiragossian & Mihm 1985).

Castro et al. (1987c) reported that a Honduran dwarf sorghum showed antibiosis to *S. frugiperda*. Efficient mass rearing and infestation techniques to screen for host plant resistance to the whorlworm were summarized by Mihm (1983).

Chemical Control

Insecticides are widely used in Latin America for control of *S. frugiperda*. The following remarks supplement Pitre's (1986) review. Despite the recognized value of insecticides only certain farmers are capable of purchasing and applying them. For example, only 12% of Nicaraguan farmers use insecticides in maize; most applications were made against *S. frugiperda* (van Huis et al. 1982).

Soil applications of carbofuran and mefosfolan at planting are increasingly common in Central America. Van Huis (1981) observed that they reduced larval populations significantly for about 15 days, but thereafter whorlworm populations were higher, often significantly so, when compared to check plots; he hypothesized that the insecticides impeded natural enemies, possibly the nematode *Hexamermis* sp. However, soil treatments generally were associated with statistically significant yield increases. In Surinam, Segeren & Sharma (1978) found that carbofuran use resulted in higher yields as compared to check plots even when all known pests were present at very low levels. This compound provided effective control of *S. frugiperda*. Dardón et al. (1985) found that furathiocarb seed treatments protected seedling maize and increased yields in Guatemala. Trabanino et al. (1987) found that it gave better control than any other sorghum seed treatment.

Nakano & Zucchi (1971) cited the advantages of using vermiculite as a carrier in granular insecticides for use against *S. frugiperda*. Diazinon granules were effective in Cuban maize (Ryder 1967). Mixing of insecticides with sawdust and subsequent hand applications to whorls was effective in maize (Segeren & Sharma 1978). Sánchez & Gonzalez (1982) found granuler formulations to be more effective than emulsifiable concentrate formulations of the same active ingredients. Cruz et al. (1983) described a tractor mounted apparatus used to apply granular insecticides directly to maize and sorghum whorls. A similar, hand-operated machine was reported by Cruz et al. (1984). Reyes et al. (1983) described a hand-held applicator for granular insecticides which can be made with local materials. Cevallos (1976) illustrated 5 application methods for granular formulations.

In Nicaragua, the selective application of granules only to those plants showing symptoms of whorlworm damage resulted in the same post-treatment infestation levels as with general applications. However, yields were higher in plots receiving the latter treatment. Savings in active ingredients on the order of 2/3 make selective applications attractive to resource limited farmer. The hand application of a chlorpyrifos and sawdust mixture can reduce use of active ingredients by 80% without sacrificing control (van Huis 1981). Selective applications were not effective in El Salvador (Reyes et al. 1983).

Several Brazilian references may be cited. Davidson (1966) reported that *S. frugiperda* was susceptible to carbaryl, but appeared to be resistant to certain organochlorines. Batagello & Monteiro (1970), Carvalho et al. (1971) and Gomes de Lima and Cola (1976) confirmed that carbaryl was effective in Brazil. In tests conducted in the same state, Waquil et al. (1982) found that diazinon worked well, but carbaryl was largely ineffective. However, Cruz et al. (1983) found that carbaryl controlled the pest well in Mato Grosso. Cruz and Pereira (1984) reported that trichlorfon and three other compounds gave adequate control in maize. According to Caetano & Schweder (1983) carbaryl and trichlorfon were recommended in Rio Grande do Sul, but they presented no efficacy data.

Few recent references from Andean countries were available. Casanova (1966) found that carbaryl granules gave adequate, but not excellent, control in Peru. Díaz & Flores (1969) found that carbaryl provided some protection to ears of maize against *S. frugiperda* and *Heliothis zea*; trichlorfon did not. Carbaryl was effective in Peru for whorl protection (Peña 1974). Carbaryl was recommended in Ecuador (Cevallos 1976). Campos (1982) provided toxicological data for larvae collected in Chilean alfalfa. Trichlorfon did not effectively kill larvae in the 1977 study reported by Clavijo (1984a), but diazinon functioned well in 1979 (Clavijo 1984b).

The work of Alvarado (1976) indicated that neither carbaryl nor trichlorfon was effective in Quintana Roo, Mexico. However, Sifuentes (1977) still recommended carbaryl for use in Mexican sorghum. This insecticide gave superior control in 1976 tests in Sonora (León 1978). López & León (1980) found carbaryl to be moderately effective in laboratory tests using larvae collected in northeast Mexico. In Tamaulipas, both carbaryl and trichlorfon were effective in suppression of *S. frugiperda* in maize (Charles et al. 1980). Tello & Díaz (1982) reported that in Sinaloa, use of carbaryl did not decrease foliar damage caused by *S. frugiperda* but did increase yields.

Based upon limited experimental data and considerable knowledge of pesticide use patterns, the following generalizations may be made regarding physiological resistance in *S. frugiperda* in Central America. Carbaryl is not effective and diazinon and trichlorfon are not reliable. Standard dosages of most pyrethroids give only sporadic control. Methyl parathion was not effective in the laboratory against third instar larvae from Honduras, but subsequent field tests against first instar larvae did not indicate resistence (Pitre 1987). Methomyl, chlorpyrifos and phoxim are the products of choice. Carbaryl was recommended in Nicaragua by Sequiera et al. (1979), but we have determined that it is of no value in the field in either El Salvador or Honduras (Andrews and Marenco, unpublished). Young (pers. comm.) reported that the Salvadorean strain he tested showed 400-fold resistance to carbaryl. Trichlorfon did not give satisfactory control under Nicaraguan conditions (van Huis 1981).

Hellpod & Mercado (1984) found that larval infestations and damage to maize in Nicaragua were reduced by application of a 0.2% neem extract to the whorls. Lagunes and coworkers (e.g., Lagunes et al. 1982) are actively screening extracts of Mexican plants for activity against *S. frugiperda*. Llanderal and Nieto (1982) reported results of laboratory studies of the effect of diflubenzuron on egg hatch and larval ecdysis. Cerecer et al. (1983) found triflumuron to be slow acting but selective in Mexican maize and sorghum.

Concluding Remarks

A sizable body of information concerning *S. frugiperda* in the neotropics has been developed by expatriate and Latin American scientists. Many comprehensive, careful studies were encountered; others were preliminary and of uneven quality. Seemingly contradictory findings may occasionally result from inadequate study or improper methods. More importantly, however, they reflect the geographic, ecological and agronomic heterogeneity of Latin America. Rather than trying to characterize the species throughout its nearly continental range, we should seek to study it in limited subregions. Moreover, the work of Pashley et al. (1985) compels us to rethink assumptions regarding the genetic homogeneity of the species.

It is ironic that most of the well financed research involving full-time, experienced, professional entomologists has been conducted in temperate zones (both the US and the southern cone of South America) where the pest's forays are seasonal. Many studies would be best carried out in the tropics where the species evolved and persists permanently. Long-term collaborative research projects located in the tropics can be expected to provide insights and information which are otherwise unattainable.

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