BIOLOGICAL CONTROL OF HELIOTHIS SPP. EMPHASIZING THE PRESENT AND POTENTIAL ROLE OF MICROPLITIS CROCEIPES[1/]

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ABSTRACT

Parasitoids in the genus Microplitis (Foerster) are important biological agents for controlling Heliothis spp. There is worldwide interest in Microplitis croceipes (Cresson) as indicated by the collaboration between the USDA, ARS Southern Field Crop Insect Management Laboratory, Stoneville, Mississippi, U.S.A. and scientists in Australia, India, People's Republic of China, New Zealand, and southern Europe. This review reflects the commitment toward exploiting the potential of M. croceipes as a control agent of Heliothis spp. in the U.S.

INTRODUCTION

In this publication, the genus name Heliothis spp. will be used in the broad sense, including species in Hardwick's (1965) corn earworm complex (Helicoverpa spp.), and in the virescens complex.

The distribution and economic importance of Heliothis spp. nationally and internationally justifies the magnitude of research effort directed toward this insect species (Table 1). Heliothis armigera Fabricius and Heliothis zea (Boddie) are major pests of field crops in the Old and New Worlds, respectively, ranging between 45°N and 45°S latitudes (Hardwick 1965). Other pest species are more restricted in

TABLE 1. Economically Important Heliothis spp.[a/].

Region	armigera	punctigera	zea	virescens
New World			+++	+++
Southern Europe	++			
Egypt	+			
Southern Asia	+++			
Southern/ Eastern Africa	+++			
Australia	+++	+++		

[a/] + = occasional pest, ++ = annual pest causing moderate damage, and +++ = annually causes severe damage.

[1/]Hymenoptera: Braconidae

distribution. For example, Heliothis punctigera (Wallengren) is restricted to Australia, where it is a major pest of cotton. Heliothis gelotopoeon (Dyar) is restricted to South America, and Heliothis viriplaca (Hufnagel) is found only in southern Europe. Heliothis assulta (Guenee) is a pest of solanaceous plants in southern Asia, Africa, and Australia, while Heliothis peltigera (Denis and Schiffermuller) is restricted to southern Asia, and the species Heliothis nubigera Herrich-Schaffer and Heliothis fletcheri (Hardwick) occur in Africa (Hardwick 1965, Hariri 1982). Heliothis virescens, along with H. zea, are major pests of a wide range of crops in the Americas and the Caribbean (Kogan et al. 1988). Heliothis armigera, H. punctigera, H. zea, and H. virescens together have been recorded as feeding on over 100 different plant species including corn, cotton, sorghum, soybean, vegetables, pulses, wheat, and tobacco (Reed and Pawar 1982, Stadelbacher et al. 1986, Zalucki et al. 1986).

DISCUSSION

Heliothis spp. as Pests. Damage estimates and costs for control of Heliothis spp. approach $200 million each year in cotton in the U.S. (Proc. Beltwide Cotton Production Research Conference 1981-86). Estimates that include other crops in the U.S. as well as cotton exceed $1 billion annually (Table 2), despite insecticide applications estimated

TABLE 2. Estimated Yield and Revenue Losses in the U.S. Attributable to Heliothis spp.

Commodity	Yield Loss (Percent)	Annual Revenue Loss ($ million)
Snap Beans	6.0	6.6
Corn	16.2	632.1
Cotton	12.0	453.2
Lettuce	2.3	17.5
Peanut	0.4	3.9
Peppers	0.5	N/A
Sorghum	4.1	79.6
Soybean	0.6	75.0
Tobacco	1.3	41.9
Tomato	4.5	50.4
Total		$1,260.4

to be as high as $0.25 billion/year (Agriculture Research Service 1976). Damage estimates to chickpea and pigeonpea in India exceed $300 million per year (Reed and Pawar 1982). Costs related to Heliothis spp. damage and control in Queensland, Australia alone were estimated at $25 million each year (Twine 1988).

Synthetic insecticides obviously cannot be relied upon solely to suppress Heliothis spp. populations. Heliothis armigera, H. zea, and H. virescens rapidly develop resistance to insecticides (Georgheiou 1986, Wolfenbarger et al. 1981). Moreover, chemical pesticides raise other concerns such as environmental safety, production efficiency, pest resurgence due to natural enemy mortality, outbreak of secondary pests (aphids, mites, etc.) and energy conservation. All available management methods (i.e., integrated pest management IPM), should be used to control Heliothis spp. worldwide. The conservation and maximum use of biological control agents (natural enemies) is a basic component of the IPM strategy.

Heliothis spp. possess many attributes that contribute to their pest status: polyphagous, fruit-feeding, voracious, highly mobile, highly fecund, multivoltine with facultative diapause, and possessing a propensity to develop resistance to insecticides. These same attributes also help explain why biological control agents often do not maintain Heliothis spp. populations below economic thresholds. For example, fruit-feeding insects such as Heliothis spp. compete directly with us for what is usually the most desirable part of the plant. Consequently, the insect damage tolerated is so low that biological control agents often cannot be used as the sole means of control. Moreover, once a Heliothis sp. enters the fruit, it is hidden from visually oriented natural enemies and should be subject to reduced mortality. In fact, field corn serves as a reservoir for the corn earworm because of ineffective control of larvae once they enter the ear. The relatively low economic value of field corn precludes chemical control. Because of the polyphagous nature of Heliothis spp., populations can build up on a succession of host plants over space and time (Stadelbacher 1979, 1981); and because of its vagility, Heliothis spp. can rapidly exploit host crops even in advance of natural enemies (Knipling and Stadelbacher 1983). The likelihood that Heliothis spp. populations will be treated with insecticides also greatly limits the potential of biological control. Often, these chemicals are more toxic to the predators and parasitoids than to Heliothis spp.; moreover, without hosts, biological control agents must either leave the field or die.

In fact, most state insect control guides, except for control of H. zea in sweet corn, recognize that natural enemies have a value; but explicit guidelines for quantifying their numbers and/or combinations of species are seldom given. Natural enemy conservation efforts typically consist of delaying treatments for Heliothis spp. and avoiding treatments for other insect species. One Texas guideline for control of Heliothis spp. in cotton recommends no action when the predator:prey ratio for Heliothis spp. is 1:1. However, no guidelines are available for using parasitoid numbers in making decisions for control of Heliothis spp. Recommendations relative to biocontrol of Heliothis spp. listed in Table 3 provide an example.

Incidence of Parasitism. Table 4 lists some of the principal parasitoids of Heliothis spp. that have been reported in the literature for the U.S. Microplitis croceipes has often been cited as the most prevalent parasitoid of Heliothis spp., particularly in cotton. As related by Powell and Elzen (this supplement), M. croceipes is a specific parasitoid for the genus Heliothis; it attacks most of the instars, but prefers 3rd and 4th instars. This parasitoid often attacks Heliothis spp. larvae that infest early spring hosts (Stadelbacher et al. 1984), and later parasitizes Heliothis spp. larvae that infest cotton, sorghum, and alfalfa, but not parasitizing those that infest tobacco, or corn in the ear stage. Microplitis croceipes historically has been the predominant parasitoid of Heliothis spp. within cotton, sorghum, and alfalfa plantings. The few reports prior to the use of the organochlorines reflect high rates of parasitism, with M. croceipes as the predominant parasitoid (Table 5).

Beginning in the 1960's, a sharp increase in research on natural enemies of Heliothis spp., in general, was reflected in the papers reporting larval parasitism (Table 6). Undoubtedly, this increased interest in biological control came about via the desire to develop alternative management strategies because of the failure of many of the organochlorine, organophosphate, and carbamate compounds to control

Heliothis spp. and other insect pests. Parasitization rates recorded were reduced due to insecticide use, particularly in cotton, but M. croceipes continued to be among the parasitoids most often recorded.

Several important studies were conducted in the 1970's (Table 7), with basically the same results as in the 1960's. Interestingly, during this period, the tobacco budworm became the predominant Heliothis sp. on both early-season wild hosts and on cotton (Stadelbacher 1979, Pfrimmer et al. 1981); and until use of the pyrethroids in 1979, none of the available insecticides provided fully satisfactory control of this pest.

TABLE 3. Recommendations Relative to Biological Control Agents of Heliothis spp.

Crop	Recommendation
Cotton	Use higher Heliothis spp. thresholds in untreated fields
	Practice management that delays or eliminates other insect pest treatments
	Delay insecticide applications until pest threshold levels reached
	Apply selective insecticides at minimum effective rates
Corn	Insecticide applications not warranted in field corn
	Insecticide applications at 24-48 h intervals for sweet corn
Sorghum	NPV more effective and persistent in sorghum than cotton
Tobacco	Thresholds for flue-cured tobacco may range from 2.5 TO 25% infested buds, depending on geographical location and incidence of natural enemies

TABLE 4. Principal Parasitoids of Heliothis spp. in the U.S.

BRACONIDAE

- Microplitis croceipes (Cresson)
- Chelonus insularis (Cresson)
- Cotesia marginiventris (Cresson)
- Cardiochiles nigriceps Viereck

ICHNEUMONIDAE

- Pristomerus spinator (Fabricius)
- Campoletis spp.
- Hyposoter exiguae (Viereck)

TRICHOGRAMMATIDAE

- Trichogramma spp.

SCELIONIDAE

- Telenomus heliothidis Ashmead

TACHINIDAE

- Archytus marmoratus (Townsend)
- Eucelatoria bryani Sabrosky

TABLE 5. Prevalence of *Microplitis croceipes* (Early 1900's).

Researcher and Survey	Year	State	Host Plant	Total % Parasitism	Percentage *M. croceipes*
Quaintance and Brues (1905)	1904	Texas	Cotton	34	100
		Mississippi	Cotton	69	100
Bibby (1942)	1929	Texas	Sorghum	10	100
Winburn and Painter (1932)	1930	Kansas	Alfalfa	58	93
			Sorghum	70	100

TABLE 6. Prevalence of *Microplitis croceipes* (1960's).

Researcher and Survey	Year	State	Host Plant	Total % Parasitism	Percentage *M. croceipes*
Lewis and Brazzel (1968)	1964-66	Mississippi	Various	21	54
			Cotton	18	-
			Clover	18	-
			Cranesbill	46	-
Snow et al. (1966)	1964-65	Georgia	Whorl Corn	-	Most Common
Watson et al. (1966)	1965	Alabama	Various	-	Recorded
Bottrell et al. (1968)	1965-66	Oklahoma	Cotton	8	Most Common
			Alfalfa	16	Most Common

Microplitis croceipes was commonly found parasitizing *Heliothis* spp. in cotton and other host plants, but its position as the predominant parasitoid often was shared with *Cardiochiles nigriceps* Viereck, a braconid selective for *H. virescens*.

A dramatic increase in rates of parasitism of *Heliothis* spp. larvae infesting early spring hosts, and particularly cotton, has occurred during the 1980's (Table 8). Often, over half the larvae have been parasitized, with *M. croceipes* often constituting over 90% of the parasitoid population. Another occurring phenomenon has been replacement of the budworm by the bollworm, *H. zea*, as the predominant *Heliothis* sp. in cotton over the last 7 yr. This apparently has resulted in a decline in the *C. nigriceps* population, if for no other reason, because of a lack of suitable hosts. Apparently, the pyrethroids killed the bollworm and budworm at an equal rate; whereas, in the 1960's and 1970's, the budworm often had a selective advantage due to its higher tolerance of the available insecticides (Stadelbacher 1979, Pfrimmer et al. 1981).

TABLE 7. Prevalence of *Microplitis croceipes* (1970's).

Researcher and Survey	Year	State	Host Plant	Total % Parasitism	Percentage *M. croceipes*
Shepard and Sterling (1972)	1969-70	Texas	Cotton	7	<5
Graham et al. (1972)	1970	Texas	Wild hosts	27-47	<20
			Tomato	26	27
			Cotton	11	31-63
Young and Price (1975)	1971	Oklahoma	Sorghum	4-7	Most Common
			Cotton		
			Alfalfa	>50	Most Common
Pair et al. (1982)	1971-4	Mississippi	Cotton	12	32
Smith et al. (1976)	1972-4	Mississippi	Various	6	Most Common
Burleigh and Farmer (1978)	1974-6	Arkansas	Cotton	10-23	95

TABLE 8. Prevalence of *Microplitis croceipes* (1980's).

Researcher and Survey	Year	State	Host Plant	Total % Parasitism	Percentage *M. croceipes*
Eger et al. (1982)	1979-80	Texas	Paintbrush Bluebonnets	-	Most Common in 1979
Stadelbacher et al. (1984)	1981	Mississippi	Cranesbill	69-80	98
			Clover	43-60	100
			Cotton	8-45	80-93
			Soybean	10	100
Puterka et al. (1985)	1981-82	Texas	Various	29-60	13-62
			Cotton	29	48
Mueller and Phillips (1983)	1981	Arkansas	Cranesbill	31	100
			Clover	79	100
King et al. (1985)	1981-82	Arkansas	Cotton	30-50	>90
	1983	North Carolina	Cotton	35	57

Potential of M. croceipes. Recognition of the present and potential importance of *M. croceipes* in suppression of *Heliothis* spp. populations has sparked a renewed interest in *M. croceipes* both within and outside the U.S. Short-term efforts are toward conserving and using indigenous *M. croceipes* populations more effectively, but longer-range plans include augmenting populations via propagation and release. Researchers are attempting to establish M. croceipes in Australia, New Zealand, China, and India where it is not native. This review reflects this broad interest.

Microplitis croceipes is well-endowed with the attributes necessary for making it successful, including a broad geographic range, and prevalence in much of the Southeast, Midsouth, and Southwest where Heliothis spp. are normally pests. Elsewhere in this review, the high search rate, host and stage preference, and synchronization of M. croceipes will be addressed. Particularly impressive has been the wasp's tolerance of selected insecticides (See Bull et al. this supplement, Elzen et al. 1987, Elzen et al. In Press).

Ultimately, we hope to augment populations of M. croceipes. Presently, economical mass propagation of the parasitoid is a major constraint of this strategy. We already have developed a large-scale in vivo rearing system for Heliothis spp. hosts, and extensive field research has been conducted on laboratory-reared M. croceipes.

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