SEASONAL INCIDENCE OF FALL ARMYWORM (LEPIDOPTERA: NOCTUIDAE) PUPAL PARASITISM IN CORN BY *DIAPETIMORPHA INTROITA* AND *CRYPTUS ALBITARSIS*[1] (HYMENOPTERA: ICHNEUMONIDAE)

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ABSTRACT

Diapetimorpha introita (Cresson) occurred from May to November and was the primary parasitoid of fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), pupae in corn fields at Tifton, GA, from 1983 to 1985. Another previously unreported pupal parasitoid of FAW, *Cryptus albitarsis* (Cresson), occurred only during a single sample conducted in November 1984. Rates of parasitism averaged 5.2% (range 0-23.7%) and 8.4% (range 0-50.0%), respectively, during 1983 and 1984, with the highest rate occurring in September to November of each year. In a limited study conducted in September and October 1985, total pupal parasitism averaged 33.3% (range 0-44.4%). Predation was the primary mortality factor, averaging 44.7, 37.8, and 95.8%, respectively, during 1983, 1984, and 1985. Predators found either in FAW pupation tunnels or feeding directly upon pupae were earwigs, *Labidura riparia* (Pallas); nonidentified carabid beetles; wireworms, *Conoderus* sp.; and the imported fire ant, *Solenopsis invicta* Buren. These studies indicate parasitoids and predators of FAW pupae play a primary role in regulating FAW populations following their development in corn and likely significantly reduce the numbers that subsequently disperse into new habitats for oviposition on other crops.

Key Words: *Spodoptera frugiperda,* pupal parasitoids, predation, corn, *Diapetimorpha introita, Cryptus albitarsis,* Noctuidae, Ichneumonidae, Fall armyworm.

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INTRODUCTION

Mortality agents of fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), pupae have hardly been described, despite their potential impact upon resultant adult abundance. Luginbill (1929) reported several insect species as predators of FAW pupae. Pair and Gross (1984) first reported the existence of a parasitoid, *Diapetimorpha introita* (Cresson), attacking FAW pupae in late-season corn in Georgia. They also reported that predation of FAW pupae averaged 73.3%.

Scant information exists regarding the host range and biology of *D. introita* or of other species of ichneumonids belonging to the subfamily Cryptinae. Pair and Gross (1984) reported that female *D. introita* usually deposit a single egg within the FAW pupal cell. Upon hatching, the larva feeds as an ectoparasitoid and usually consumes the entire contents of the host before pupation. Female *D. introita* apparently use a series of chemical and physical cues in the detection and

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acceptance of host pupae for oviposition (S. D. Pair et al., unpublished). Studies were conducted at Tifton, Ga., to determine its seasonal abundance and to identify other species of parasitoids that also may impact pupal populations of the FAW.

MATERIALS AND METHODS

The studies were conducted in an 0.25-ha plot of sweet corn ('Silver Queen') located near Tifton, Ga., during 1983-1985. Weekly sampling occurred from 11 May-29 November 1983, 8 May-26 November 1984, and 24 September-21 October 1985. The techniques we used to determine rates of FAW pupal predation and parasitism were the same as those described by Pair and Gross (1984). Each week, late 6th instar FAW larvae (ready for pupation) were selected from a laboratory colony maintained at the Insect Biology and Population Management Research Laboratory (Perkins 1979). Larvae were caged between corn plants within rows by inverting a 29.6-ml clear plastic cup over the larvae and firmly pushing the cup rim into the soil to minimize escape. Prior to each introduction, ca. 2 cm of water was applied by sprinkler irrigation to enhance larval success in burrowing into the soil. When the larvae had burrowed into the soil (usually within 1 to 3 days, depending upon temperature), the cups were removed and pushed into the soil adjacent to the site, to serve as a marker. Two hundred and 288 larvae were caged per each weekly introduction, in 1983-84 and in 1985, respectively. In each introduction, larvae were divided into four equal lots of 50 (1983-84) or 72 (1985), and distributed equally among four 0.06 ha and contiguous quadrants within the sweet corn plot. Within each quadrant, the larvae were placed at 2-m intervals within five different rows of corn, each of which was separated by at least one row of corn.

Sampling of all cohorts within an introduction was intiated after 5-10 days of exposure (depending on the soil temperature), and each site was carefully excavated using a hand trowel to uncover pupal cells. Live FAW pupae and larval or pupal stages of the parasitoids recovered from the sites were placed in labelled plastic cups and transported to the laboratory for rearing to the adult stage. Since the rate of development of FAW is temperature-dependent, FAW pupae were exposed for shorter periods of time during the summer than during the cooler fall months. Parasitized FAW pupae were detected more readily, and parasitoid survival after collection was higher when the parasitoids were in the advanced larval stages or had pupated. Collected adult parasitoids were compared with identified specimens and submitted to the USDA Systematic Laboratory for identification. Values used to calculate percent parasitism were adjusted to reflect only the number of live FAW pupae available for parasitism and therefore FAW pupae that were removed by predators were not considered in determining rates of parasitism. Rates of parasitism were calculated as follows: % parasitized = number parasitized ÷ number parasitized + number nonparasitized pupae × 100.

Larvae that escaped or were removed from cages by predators before burrowing into the soil were not used in calculating mortality rates. Death of FAW prepupae or pupae in cells not attributed to arthropods or to their feeding was assumed to have been pathogen-related. Empty cells were recorded as FAW having been preyed upon. Thus, rates of predation were based on the number of pupae initially exposed and did not include mortality factors identified as having been caused by parasitism or infection. All parasitism and predation data were transformed via arcsin $\sqrt{x}$ and subjected to ANOV (SAS, 1982) for differences among years.

RESULTS AND DISCUSSION

Diapetimorpha introita was first recovered from pupal samples during mid- and late May in 1983 and 1984, respectively (Fig. 1). FAW larvae were not introduced earlier than 8 May of either year, nor were natural FAW populations available, so it is not known if *D. introita* had emerged from diapause prior to initiation of our sampling. During May-July of both years, *D. introita* was recovered from samples at ca. 20-day intervals, indicating a generational effect. Although populations of *D. introita* were not detected during the period from mid-July through late August, generations appeared to have overlapped beginning in September until the termination of sampling in late November. Rates of parasitism averaged less than 10.0% during May-July, with the highest percentage of parasitism occurring in September and October of each year. Parasitism did not differ significantly ($P > 0.05$) among years and averaged 5.2 (range 0-23.7) and 8.4% (range 0-50.0%), respectively, during 1983 and 1984. During the three introductions of FAW made in the fall of 1985, parasitism averaged 33.3%, and ranged from 0-44.4%. Only three samples were collected from 24 September-21 October 1985 to confirm pupal parasitism, so the 1985 data were not shown in Fig. 1.

Almost all parsitism of FAW pupae in 1983 and 1984 was due to *D. introita. Cryptus albitarsis* (Cresson) was detected only from a single sample from larvae placed in the field on 2 November 1984. *Cryptus albitrarsis* was recovered from five (31.5%) of the 16 parasitized FAW pupae found in the excavations on November 2. Our report is a new host record for *C. albitarsis* on FAW although it has been found on five other lepidopteran hosts, including *Heliothis zea* (Boddie) (Carlson 1979). *Diapetimorpha introita* and *C. albitarsis* were the only species reared from FAW pupae in our study, but other parasitoid species have occurred sporadically. Two ichneumonid specimens recovered from FAW in earlier field studies (1982) were recently identified as *Vulgichneumon brevicintor* (Say). Besides FAW, 10 other species of Lepidoptera are known to serve as hosts for *V. brevicintor* (Carlson 1979).

Predation was the predominant mortality factor of FAW pupae during the 3-year study. Percent predation averaged 44.5, 37.8, and 95.8% during 1983, 1984, and the fall of 1985, respectively. Predation of FAW pupae in 1983 was significantly greater ($P < 0.05$) than that observed in 1984. The seasonal incidence of predation in 1983 and 1984 was variable, with the highest rates of predatory events observed in May and June of each year (Fig. 2). In both years, and particularly in 1984, predation declined markedly by August and steadily increased, peaking again in October. Predatory events were rarely observed directly; thus the identity of the organisms involved was based largely upon circumstantial evidence. In most cases, small mammals and/or birds preyed on the pupae whose remains were found around the disturbed site. Also, pupae often were simply dug out of the cell and removed. FAW pupae removed by mammals or birds comprised 77.8, 63.9, and 98.4% of the total FAW pupal mortality attributed to predation during 1983, 1984, and 1985, respectively. In a few introductions, up to 90% of the newly caged FAW larvae, visible through the cup cage, were removed by predators prior to their burrowing into the soil. Also, after a larva had burrowed into the soil, removal of its cage sometimes disturbed the immediate area surrounding the site. These circumstances suggested that vertebrates learned to associate the cup cage and perhaps the disturbed site with the presence of food, resulting in higher rates of

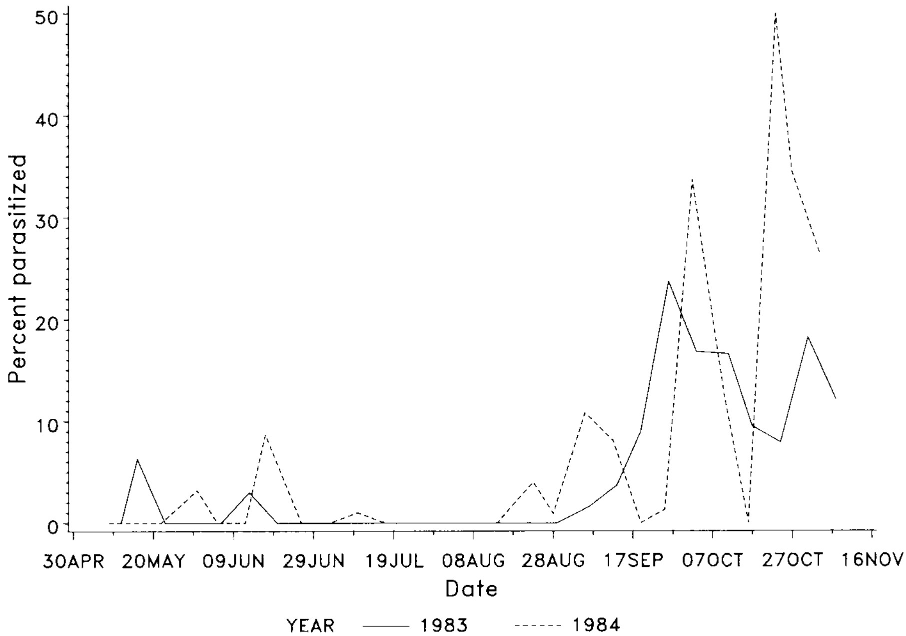

Fig. 1. Incidence of fall armyworm pupal parasitism in corn fields at Tifton, GA, 1983-84.

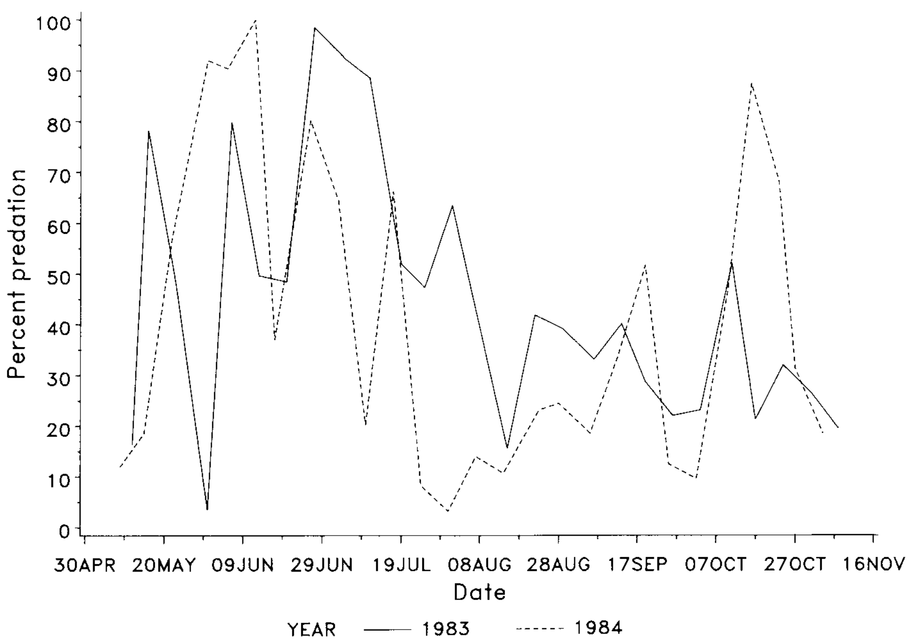

Fig. 2. Incidence of predation on fall armyworm pupae in corn fields at Tifton, GA, 1983-84.

predation than expected under normal field conditions. Predation of corn earworm, *H. zea,* pupae by mammals in Texas corn fields under natural conditions was estimated to be 25% (Pair et al. 1987). Other mortality agents that either had been found feeding on FAW pupae or had invaded the pupation cell included the striped earwig, *Labidura riparia* (Pallas), small carabid beetles, wireworms, *Conoderus* sp., and the imported fire ant, *Solenopsis invicta* Buren. Mortality of prepupae and pupae attributed to pathogens amounted to 8.9 and 12.9% during 1983 and 1984, respectively. No diseased FAW were observed during the fall of 1985.

This study showed that *D. introita* likely occurred in south Georgia at low densities during the summer of 1983 and 1984, at least as early as May of each year. Subsequently, *D. introita* populations increased progressively during the summer and fall as available hosts (probably *Spodoptera* spp.) appeared in higher densities. Colonies of both *D. introita* and *C. albitarsis* have now been established in our laboratory, and preliminary studies indicate that *Spodoptera* spp. and *H. virescens* (F.) are the preferred hosts of *D. introita* and *C. albitarsis*, respectively (S. D. Pair, unpublished).

Gross and Pair (1986) suggested that the search for more effective biological agents should emphasize the K strategists which attack the latter larval instars and/or pupal stages of the target organism. Both *D. introita* and *C. albitarsis*, which employ an ovipositional strategy directed at the pupal stage of their host, could be effective mortality agents of pests such as the FAW if mass propagated and released against incipient seasonal populations. Perhaps of equal or more importance is the need to more completely identify and manage the predator(s) that inflict the heaviest mortality upon FAW pupae. In any case, suppression of highly mobile lepidopteran pests prior to their emergence and dispersal is a more desirable and effective management strategy than are conventional methods directed at subsequent, sometimes widespread, damaging populations of the larvae.

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LITERATURE CITED

Carlson, Robert W. 1979. Ichneumonidae. *In* Krombein et al., Catalog of Hymenoptera in America north of Mexico. 1: 315-741. Smithsonian Institution Press, Washington.

Gross, H. R., Jr., and S. D. Pair. 1986. The fall armyworm: status and expectations of biological control with parasitoids and predators. Fla. Entomol. 69: 502-15.

Luginbill, P. 1928. The fall armyworm. USDA Tech Bull. No. 34.

Pair, S. D., and H. R. Gross. 1984. Field mortality of pupae of the fall armyworm, *Spodoptera frugiperda* (J. E. Smith), by predators and a newly discovered parasitoid, *Diapetimorpha introita.* J. GA. Entomol. Soc. 19: 22-6.

Pair, S. D., J. R. Raulston, D. R. Rummel, J. K. Westbrook, W. W. Wolf, A. N. Sparks, and M. F. Shuster. 1987. Development and production of corn earworm and fall armyworm in the Texas High Plains: evidence for reverse fall migration. Southwest. Entomol. 12: 89-91.

Perkins, W. Deryck. 1979. Laboratory rearing of the fall armyworm. Fla. Entomol. 62: 87-91.

SAS Institute, Inc. 1982. SAS user's guide: statistics, 1982 ed. Cary, NC. 584 pp.