Suppression of Mexican Bean Beetle[1] on Soybeans with Annual Inoculative Releases of *Pediobius foveolatus*[2,3]

L. M. STEVENS,[4] A. L. STEINHAUER,[4] AND J. R. COULSON[5]

ABSTRACT

Pediobius foveolatus (Crawford) was released annually in soybeans during 1972 and 1973 in preliminary attempts to suppress *Epilachna varivestis* Mulsant. The results led to an area-wide suppression during 1974, utilizing nurse crops of snap beans for early inoculation of *E. varivestis* larval populations, and widespread releases of *P. foveolatus* directly into soybean fields. The results indicate a promising means of biological control for areas where *E. varivestis* is economically important.

The Mexican bean beetle, *Epilachna varivestis* Mulsant, is a chronically important pest on snap and lima beans in Maryland. Overwintering beetles begin searching for host material in mid-May and tend to search out snap and lima beans, but by late June they begin ovipositing in soybeans. Large populations develop in soybeans and inflict serious economic damage, particularly in September and October. Two complete generations a year are common in soybeans and frequently a partial 3rd generation is achieved, particularly when 2nd generation Mexican bean beetles move from snap or lima bean fields into soybean. The problem has steadily worsened in Maryland during recent years, and, with the increasing cash value of soybeans, there is a greater tendency for growers to treat with chemicals for Mexican bean beetle control. The danger of becoming locked into a chemical control cycle on soybeans is real, considering the large number of potential pests that exist (Lincoln et al. 1975). These conditions precipitated our search for a suitable non-chemical suppression method for Mexican bean beetle.

Pediobius foveolatus (Crawford), a eulophid parasite of epilachnines from India (Angalet et al. 1968) was previously introduced along the eastern U.S. seaboard by personnel of the USDA Beneficial Insects Research Laboratory, Moorestown, NJ.[6] It effectively parasitized Mexican bean beetle larvae during the season, but failed to overwinter for lack of diapause capability and/or available host material (Reece Sailer, pers. comm.).[7] A study in India by Lall (1961) indicated that the parasite has a sufficiently short life cycle (10–30 days depending on temperatures) so that it can pass through several generations during a season and has the potential of attaining high levels of parasitism within a single season. We therefore began preliminary field studies in 1972 and 1973, and in 1974 attempted area-wide suppression of the Mexican bean beetle in Maryland.

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[4] Dept. of Entomol., Univ. of Maryland, College Park, MD 20742.
[5] USDA-ARS, Beneficial Insect Introduction Lab., Beltsville, MD 20705.
[6] Presently located at Newark, Delaware.
[7] Dr. Reece Sailer, Dept. of Entomol. and Nematology, Univ. of Florida, Gainesville, FL. Formerly Chairman of the USDA-ARS Insect Identification and Beneficial Insect Introduction Inst.

Materials and Methods

Parasite Stock

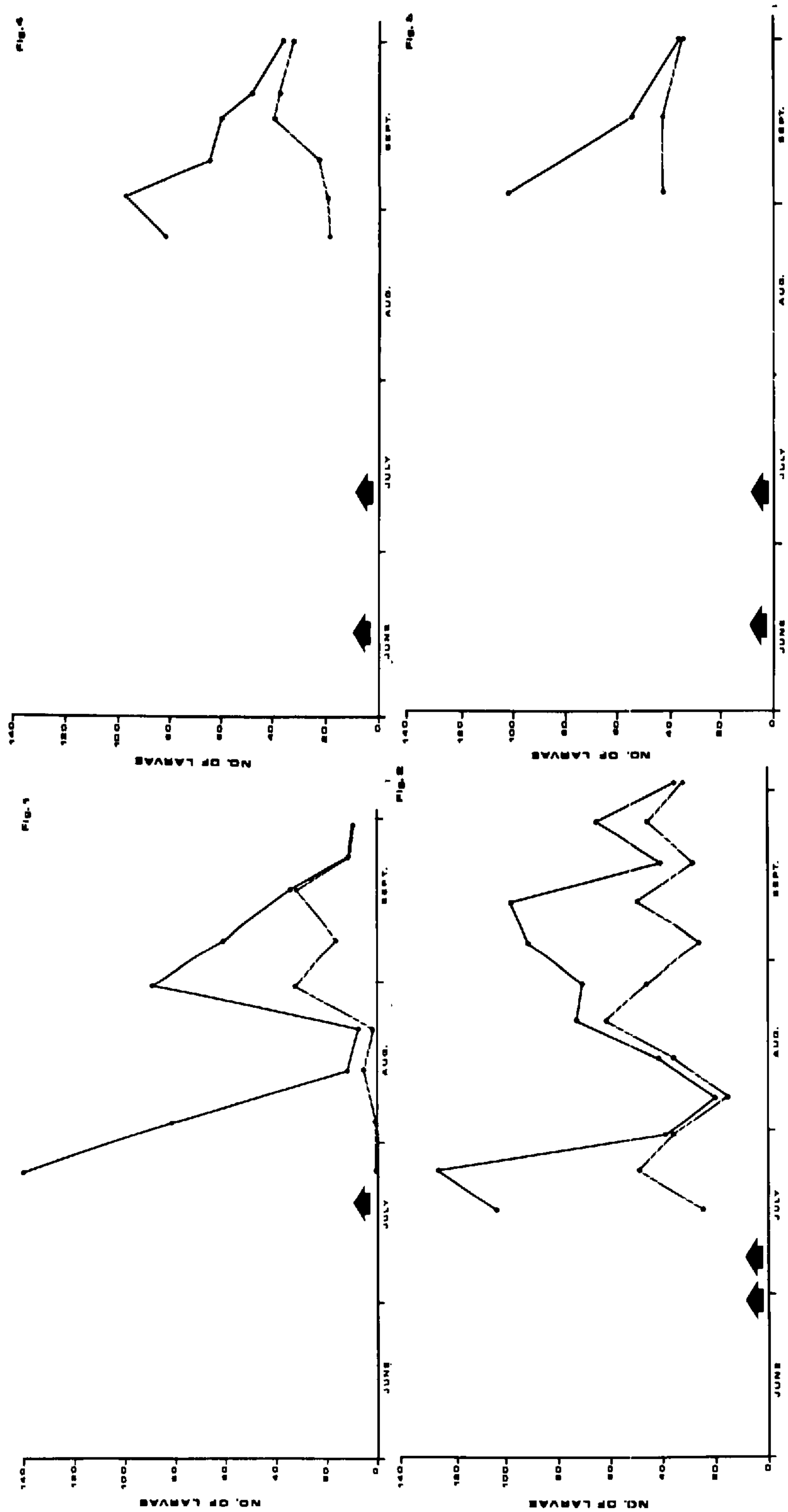
The original stock of *Pediobius foveolatus* was obtained from the Commonwealth Institute of Biological Control in India from specimens reared on *Henosepilachna sparsa* (Herbst), a pest of potato and eggplant. The original material was quarantined and sent to us through the USDA Laboratory at Moorestown, NJ. We maintained the colony on *E. varivestis*, both parasite and host being reared according to Stevens et al. (1975).

Field Releases—1972

On July 19, 1972, parasites were released in 2 soybean fields ca. 2 mi apart in Somerset Co., MD. The fields were ca. 20 acres (8 ha) in size. Approximately 1470 parasites were released in Field 1 and 1880 in Field 2. The parasites were all less than 1 wk old on the release date. They were taken from laboratory storage at 13°C and transported to the field in pt ice cream cartons with a drop of honey on the inside of the lid. The cartons were kept in styrofoam boxes until the time of release. Release was accomplished by walking between the rows of soybeans and stopping every 50 paces and tapping a number of parasites onto the leaves of the soybean plants until all the parasites were distributed. There were abundant host larvae present at the time of release. At approximately weekly intervals thereafter (Fig. 1), larvae were collected (3rd and 4th instars, prepupae, and mummies) and returned to the laboratory where they were held at 22°C to determine the number parasitized. Parasitism was confirmed by emergence of parasites from mummies or by dissection. The collection method consisted of 2 people gathering larvae from the leaves during a 30-min period. Although a confidence interval about the mean number of larvae cannot be calculated with this method, it provided an indication of relative abundance of hosts at each collection date. It was also the only reasonable method of obtaining a sample of host larvae to determine percent parasitism. From these samples a confidence interval for the percent parasitism can be calculated. Larval mummies were separated from non-mummies in the field so as to avoid parasitization of larvae should parasites have emerged in transit to the laboratory.

Field Releases—1973

On June 29 and July 7, 1973, 3000 parasites were



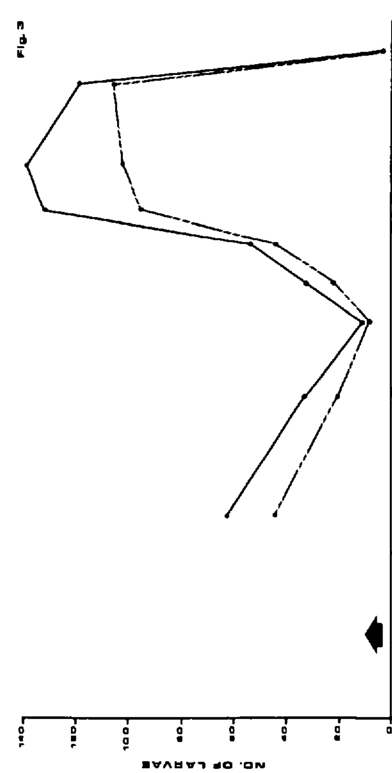


FIG. 1–5.—Average number of Mexican bean beetle larvae collected on each sampling date (solid line) and the proportion parasitized by *P. foveolatus* (broken line). The arrows indicate release dates. Fig. 1.—From 3 fields during 1972. Fig. 2.—From 2 fields during 1973. Fig. 3.—From 3 fields during 1974. Fig. 4.—From area-wide survey for parasitism, 1974. Arrows indicate 1st and last release date. Fig. 5.—From survey for parasitism in Wicomico Co., 1974. Arrows indicate 1st and last release dates.

released in each of 6 fields located in 6 different counties in Maryland (Fig. 6). Each field was a 2-acre (0.8 ha) portion of larger fields from 15–40 acres (6–16 ha) in size. The parasites were released in the 2-acre plots in the same manner as the 1972 releases. At weekly intervals following the 2nd release, larvae were collected from 5 of the fields in the same manner as in 1972 except that 2 people collected for 15 min each rather than 30 min. The larvae and mummies were returned to the laboratory where the level of parasitism was determined as in 1972. From Oct. 4–14, 1973, a systematic survey of the Maryland soybean growing area was conducted to determine the presence of parasitized larvae in non-release fields. This survey was accomplished by selecting a predetermined route through each county, stopping at the 1st soybean field encountered and collecting larvae for 15 min or until the 1st larval mummy was encountered, whichever came first. At that point, the surveyor drove for 15 min and stopped at the next soybean field encountered where the larval collection procedure was repeated. Larvae collected during this survey were returned to the laboratory and reared to determine parasitism.

Mexican Bean Beetle Suppression Attempt—1974

Release Procedures.—The objective for 1974 was to make as many and as early parasite releases as possible to suppress Mexican bean beetles in soybeans throughout the Maryland soybean area. Because of their preference for snap beans, beetle populations in snap beans generally preceded those in soybeans by about 2 weeks. We attempted to establish from 3–5 small snap-bean plots in each of 11 counties and release parasites in these to inoculate each county as early as possible. Working through County Extension Agents, snap bean seed was distributed and growers were enlisted to plant nurse plots adjacent to soybeans. The size and shape of plots was left to the judgment of individual cooperators. As a result, nurse plots varied from a single row along the edge of a soybean field to a 1-acre block. As soon as 2nd instar bean beetles appeared on the snap beans, from 200–2000 parasites were released in each nurse plot. This generally occurred about June 15–20. These plots were allowed to develop as inoculation foci for the surrounding area and as sources of parasitized larvae that could be collected and distributed to soybean fields as larvae appeared.

In addition, laboratory-reared parasites were released in ca. 360 soybean fields as soon as larvae began appearing between July 1 and 15 (Fig. 7). No attempt was made to disperse parasites throughout a field, but rather a single pt carton containing from 200–1000 parasites was placed ca. 50 m into each field. The parasites rapidly flew out of the container and dispersed. Rearing, feeding, and transport of the parasites to the field were the same as in 1972 and 1973.

A greenhouse with ca. 600 ft^2 of planting bed was located in Wicomico Co. at the University of Maryland Research Farm. On April 1, 1974, the bed was seeded with lima beans which were infested with ca. 200 Mexican bean beetles on May 10. On June 10, 2000 parasites were released. By July 9, all the bean plants had many mummified larvae adhering to the leaves and stems. These plants were cut at ground level, loaded into the back of a pickup truck, and disseminated into ca. 40 fields throughout the county. We estimated that ca. 250,000 parasites were released in this manner. The minimum temperature in the greenhouse was 23°C, but the maximum frequently climbed over 40°C on sunny days. These conditions did not seem to adversely affect either host or parasite. A summary of parasite releases by county appears in Table 1.

Parasitism Survey.—No attempt was made to monitor parasitism within fields in which releases had been made. However, using a systematic sample as previously described, a county by county survey of randomly selected fields was conducted from Aug. 1 through Oct. 4. The procedure for selecting fields to survey consisted of stopping to sample a field shortly after entering a county and driving along a predetermined route for ca. 15 min before stopping at the next field, and so on, until at least 5 fields/county were surveyed. The predetermined route through each county was varied from week to week and very seldom was the same field sampled twice. The chosen route was designed to cover as much of the county as possible.

The sampling method consisted of the surveyor entering the field and proceeding until he saw evidence of fresh larval feeding. He then searched plants for larvae, collecting 3rd and 4th instars, prepupae, and mummies for a period of 15 min, beginning when he first entered the field. The insects were collected in pt cartons. On leaving the field, the mummies were removed from the carton and a number of leaves placed into the carton as food for the larvae. The larvae and mummies were stored in a styrofoam box and returned to the laboratory, where the remaining larvae were fed until they pupated or mummified. The mummies were individually placed into 1-oz media cups and held for emergence of adult parasites. Mummies from which no parasites emerged were dissected to verify parasitization. The survey was intended to cover each county weekly but this was not always possible. During the critical period from Aug. 26 through Oct. 4, we surveyed an avg 4.5 fields/county/week. In addition to the overall survey, 3 fields in Charles Co. were sampled throughout the season to provide a comparison to the fields monitored in 1972 and 1973.

Results

Field Releases—1972

Fig. 1 shows the avg numbers of larvae and the proportion parasitized in the 2 fields in which parasites were released on July 19, 1972. The larval numbers have been halved to make the figure comparable to Fig. 2 where the sampling period employed was only ½ as long. Obviously, the parasite release was late in terms of larval abundance, falling

Table 1.—Average percent parasitism of Mexican bean beetle larvae by *Pediobius foveolatus* in soybean fields of Maryland counties during 3 grouped sampling periods, 1974.

			Grouped sampling periods								
			Aug. 26–Sept. 9			Sept. 10–Sept. 24			Sept. 25–Oct. 4		
County	No. *P. foveolatus* released	1974 soybean acreage	No. fields sampled	Avg no. larvae per field	% parasitism	No. fields sampled	Avg no. larvae per field	% parasitism	No. fields sampled	Avg no. larvae per field	% parasitism
Queen Anne	7,150	32,000	4	27	23	6	9	36	3	0	0
Talbot	31,336	26,000	12	45	9	14	37	43	13	25	83
Caroline	30,375	40,500	6	41	4	8	36	17	9	28	70
Wicomico	282,405	31,000	12	50	42	18	27	77	18	18	97
Dorchester	31,063	36,000	8	65	10	10	32	37	12	13	78
Somerset	33,322	20,500	5	57	24	13	36	57	11	24	69
Worcester	18,148	30,000	7	59	33	12	30	61	13	17	77
Charles	39,881	5,000	13	49	24	7	40	61	15	36	98
Saint Mary's	7,693	8,000	7	42	25	11	45	29	8	28	67
Calvert	3,978	700	9	24	35	5	11	28	7	6	98
Anne Arundel	1,150	500	8	35	12	5	25	21	5	6	79
Prince Georges	2,400	2,400	3	24	21	7	24	56	—	—	—
Area totals	488,901	232,600	94	45	22	116	31	48	114	21	84

at or near the mid-July host peak, rather than preceding it. As a result, parasitism was just increasing when larval numbers were lowest between Aug. 14 and 22. As larvae once more increased in abundance, the parasites responded and attained 99–100% parasitism on the last 3 sampling dates in September. After this initial preliminary study, we felt that the parasite needed to be released as soon as larvae appeared in soybeans in order to allow maximum time for natural increase. During July and August, daily mean temperatures in Maryland are close to 25°C, which should permit a generation of *Pediobius foveolatus* every 10–14 days (Lall 1961, Stevens et al. 1975).

Field Releases—1973

Figure 2 shows the avg numbers of larvae and the proportion parasitized in the 5 release fields that were sampled weekly during 1973. The earlier introduction of parasites in 1973 in relation to the peak of the host larval generation of Mexican bean beetles allowed the parasites to attain high levels of parasitism that were sustained well into the 2nd peak of host larvae. Average parasitism at the end of the host larval 2nd peak reached 90%. In all but one of the fields studied, overall levels of feeding did not exceed recommended thresholds. However, one of the cooperating growers felt the necessity of spraying his field. This field had sustained high levels of parasitism throughout the season. Although we did not record adult beetle numbers, we observed a tremendous increase in adult activity shortly before the field was sprayed. A nearby soybean field (½ mi away) had been completely defoliated by Mexican bean beetle earlier and we believe that influx from this field had added sufficient pressure to precipitate the need to spray.

The results of the 1973 survey of soybean fields in Maryland are presented in Fig. 6. It was obvious that *P. foveolatus* was capable of significant dispersal during a single season. Recoveries as far as 40 mi from the nearest release point were recorded. The survey did not demonstrate maximum dispersal, but reflected the extent of the survey. No soybean fields outside the shaded area in Fig. 6 were sampled.

Mexican Bean Beetle Suppression Attempt—1974

Fig. 3 shows the avg numbers of larvae and the proportion parasitized in the 3 fields that were monitored in Charles County throughout the 1974 season. These fields were each adjacent to snap bean nurse plots in which parasites were released on June 15–20. By July 11, avg parasitism in the 3 soybean fields was 70% and remained between 60 and 90% throughout the year. Fig. 4 shows the results of the overall state survey for 1974, and Fig. 5 for 3 sampling periods in Wicomico., where additional parasite releases were made from the greenhouse rearing operation. The numbers of larvae recorded for each sample have been doubled to make Fig. 3–5 comparable to Fig. 2, where the time spent collecting each sample was twice as long. A county-by-county summary of the 1974 suppression attempt is presented in Table 1.

Discussion

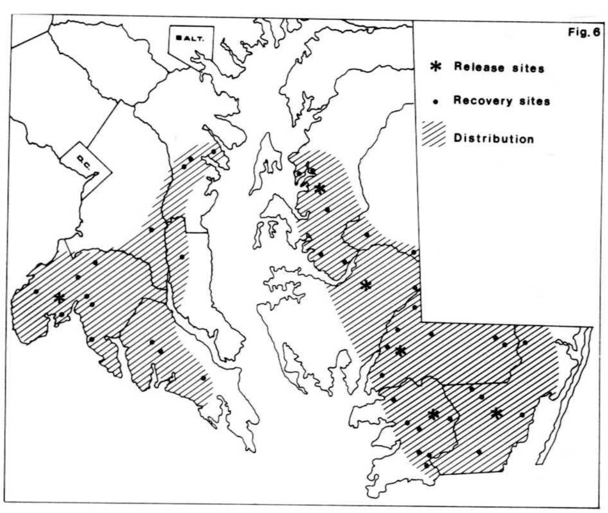
The program was most successful in Wicomico Co., where all snap bean nurse plots were planted in blocks and the highest parasite release rate was employed. In the 2 yr. prior, ca. 50% of the soybean acreage in Wicomico Co. had been sprayed for Mexican bean beetle between Aug. 15 and Sept. 30. In 1974, ca. 13% of the acreage was sprayed. These estimates are based on a survey of licensed airplane applicators who do almost 100% of soybean spraying at this time of year. In Charles Co., where both nurse plots and parasite release rate were comparable to Wicomico, successful suppression was achieved. There was virtually no spraying of soybeans in Charles Co. 1974.

In Caroline, Talbot, and Dorchester Counties, results were less encouraging. However, in these 3 counties, a great deal of double cropping occurs, where soybeans are planted after a winter small-grain crop. These late-planted soybeans were essentially without Mexican bean beetle larvae at the time releases were being made. This resulted in poor establishment of inoculative releases, with the result that parasites were still dispersing in these counties well into September. Of the 94 fields sampled during the Aug. 26 to Sept. 9 period, 91 had beetle larvae and 83 had the parasite present (91%). Five of the 8 fields without the parasite were located in the 3 counties where double cropping is present. After Sept. 10, *P. foveolatus* was present in 100% of all fields sampled. The relatively low levels of parasitism in St. Mary's Co. are due to the fact that releases were made only in the northern half of the county and dispersal to the southern portion was entirely a result of natural movement. This delayed the attainment of high levels of parasitism.

Fig. 1–3 illustrate the effect of timing the inoculative release. In 1972, the initial release was late and had relatively little effect on the 1st host larval peak on soybeans. In 1973, the release into soybean fields was earlier and resulted in a portion of this 1st larval peak being parasitized. However, a low level of host material during August probably resulted in dispersal out of the fields of significant numbers of parasites. In 1974, when nurse plots of snap beans adjacent to soybean fields permitted still earlier inoculation of the host population, the parasitism in the soybean fields closely parallels the 2 host larval peaks, resulting in sustained high levels of parasitism throughout the entire season. This early release in snap beans allows for ca. 2 parasite generations prior to the appearance of suitably sized host larvae in soybeans and magnifies the effect of the inoculum considerably. Assuming a 50-fold increase each generation, given the fecundity, sex rato, and mortality expected (Stevens et al. 1975), the inoculum could have increased 2500-fold by mid-July. By mid-August, when host larvae are once again building up, there would have been time for 2 additional generations, plus significant dispersal of the parasite when host larvae are scarcest in early August. It appears, from Fig. 3, that the dispersal that occurred either did not deplete the in-field parasite population enough to result in lowered parasitism, or was counterbalanced by dispersal into the field of parasites from adjacent areas. In the area of the 3 fields represented by Fig. 3, the parasite was present in all fields examined by late July.

The type of host-parasite association demonstrated in Fig. 3 illustrates what we believe is attainable with this system on a regional basis. Early inoculation of bean beetle infested snap bean nurse plots, followed by natural spread from these plots plus additional release into surrounding soybean fields, results in rapid parasite buildup and considerable biological control through both larval peaks on soybeans. Fig. 4 shows that our state-wide suppression attempt did not attain this level, but reflected an effect on the late larval generation somewhat similar to the 1972 results (Fig. 1). The results in Wicomico Co. (Fig. 5) appear intermediate to the results obtained in 1972 and 1973 (Fig. 1 and 2) for parasitism of the 2nd larval peak. It is apparent that additional progress is possible.

In areas where successful snap bean nurse plots were located, suppression of bean beetle was superior. One of the problems with these nurse plots during 1974 was that inoculations were not always success-



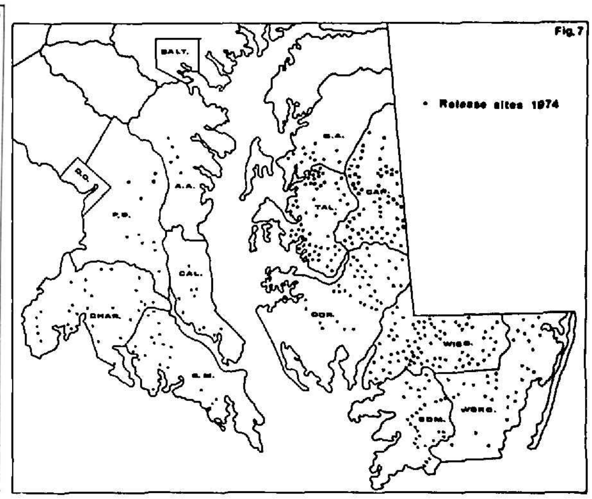


FIG. 6.—Sites where *P. foveolatus* were released June 29 and July 7, 1973 (asterisks) and fields where the parasite was recovered Oct. 4–14, 1975 (solid dots). Shaded area represents probable minimum area of dispersion of the parasite during the season. FIG. 7.—*P. foveolatus* release points, June 15 to July 10, 1974.

ful. Because the size and shape of the nurse plots were left to the individual cooperating growers, many simply planted a single row of snap beans along the edge of the soybean field. Retention of the inoculative release in these single-row plots was poor. On the contrary, plots planted in blocks retained the inoculative release and eventually resulted in the parasitism of large numbers of bean beetle larvae with excellent dissemination of parasites to surrounding soybean fields as soon as suitable larval populations were available.

Turnipseed (1972) and Shepard et al. (1974) reported on insect predators in soybean fields in South Carolina. The complex of predatory insects is essentially the same in Maryland. We have not attempted to quantify their effect on Mexican bean beetle populations. Judged from observations in the field, egg predation by predaceous coccinellids appears to be the most common predatory activity. Egg predation by Mexican bean beetle adults has also been observed. Of the several hundred thousand field-collected larvae that have been reared in the laboratory for determination of parasitism, only 2 larvae have been found that were parasitized by something other than *P. foveolatus*. In both cases this parasite was an ichneumonid. It appears that *P. foveolatus* has virtually no competition from any endemic parasites. This may account for the higher levels of parasitism we observed than have been recorded for this insect in India (Ladd 1961, Lal 1946, Appanna 1948).

Another benefit that we have been unable to measure so far is the effect of parasitism on the size of the overwintering population of adult Mexican bean beetles. In 1974, the avg parasitism for the entire 2nd larval peak approached 80% (Fig. 3). A maximum effect of this sort would result in a similar reduction in the numbers of adult beetles entering their winter hibernacula. In the past 2 yr, collections of Mexican bean beetle adults from overwintering sites (pine-needle litter in groves of trees bordering soybean fields) in March and April indicate that there is very little overwintering mortality due to climatic factors. Almost 100% of the beetles recovered from these sites were viable. There is evidence of predation by rodents, but we have no idea as to the level of mortality inflicted. It appears that reduced numbers of adult beetles entering the winter as a result of parasitism may be additive to what overwintering mortality does occur.

In conclusion, our results indicate that annual inoculative releases of *P. foveolatus*, if conducted early enough and in conjunction with establishment of nurse plot areas of snap beans in a widespread manner, are capable of suppression of the Mexican bean beetle on soybeans in Maryland. A similar program in other areas where the Mexican bean beetle is a problem on soybeans may be desirable.

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