BIOLOGICAL CONTROL AGENTS OF SOYBEAN INSECT PESTS

IN THE TIDEWATER AREA OF VIRGINIA

by

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INTRODUCTION

The use of biological control agents to suppress populations of insect pests has been attempted with many crops. In many successful programs, the degree of control usually is not complete, rather, the pest population is reduced to a point nearer or below the economic injury threshold. Soybeans are a crop with which biological controls are well suited, as the plants are able to sustain a low level of defoliation without a subsequent decrease in yield. This study was intended as a preliminary survey and assessment of the relative values of biological control agents of soybean pests, and was motivated by the increasing importance of the crop in Virginia and the lack of information concerning biological agents.

REVIEW OF LITERATURE

Numerous papers concerning many different insects are pertinent to this study. Due to their diversity, the literature will be organized by sections, each pertaining to one of the insects or groups of major importance on soybeans grown in Virginia. The major insect pests covered in this study were the following:

Mexican bean beetle	*Epilachna varivestis* Mulsant
green stinkbug	*Acrosternum hilare* (Say)
brown stinkbug	*Euschistus servus* (Say)
corn earworm	*Heliothis zea* (Boddie)
green cloverworm	*Plathypena scabra* (F.)

Mexican Bean Beetle

The Mexican bean beetle, *Epilachna varivestis*, a defoliator of beans in North America, is native to Mexico. In 1918 it spread from the southwest, where it had been known since about 1860, to the eastern United States and first appeared in Virginia in 1922. By 1928, all of Virginia was infested, and by 1930, most of the eastern United States was also infested. Much of the biological control work on this insect was begun after the beetle extended its range to the eastern states.

There is a wealth of information available on the biology, life history, and control of this coccinellid (Nichols and Kogan 1972).

Howard and English (1924) mentioned several minor predators of the beetle and one parasite, Phorocera claripennis Macq. (Tachinidae). They reported that the most important entomophagus insect was Stiretrus anchorago F., a pentatomid. The spined soldier bug, Podisus maculiventris Say (Pentatomidae), was considered to be of lesser value as it occurred later in the season. Thomas (1924) also reported S. anchorago as the most important native enemy of the Mexican bean beetle.

Eddy and McAllister (1927) reported the spined soldier bug to be an effective predator of the beetle in South Carolina. Chapman and Gould (1928) observed it feeding on the Mexican bean beetle in Virginia. Howard (1930) and Friend and Turner (1931) reported the aforementioned insects and a second parasite, Helicobia helicis Townsend (Sarcophagidae).

As a valuable predator of Lepidoptera and certain Coleoptera, the spined soldier bug has been studied by several workers. Morrill (1906) recorded observations on the biology of this predator, which he reared on a diet of elm leaf beetle larvae and caterpillars. Morris (1963) studied the effects of predator age and prey defense on the functional response of P. maculiventris to larvae of the fall webworm, Hyphantria cunea Drury. He concluded that both significantly affected the functional response. Mukerji and LeRoux (1965) described the laboratory rearing of P. maculiventris, and made an excellent review of the species. The same authors (1969) also studied the effect of predator age on the functional response of the spined soldier bug to the greater wax moth, Galleria mellonella (L.). In the same year (1969a) they reported on a quantitative study of food consumption and growth of the insect. Iwao and Wellington (1970) studied the effects of prey behavior, with tent caterpillar larvae as prey. Warren and Wallis (1971) studied the biology of P. maculiventris.

Oetting and Yonke (1971) made detailed descriptions of the immature stages and studied the biology of Podisus placidus Uhler and Stiretrus fimbriatus (Say).

Plummer and Landis (1932) studied predators of the Mexican bean beetle in Mexico, and reported ten pentatomids, four coreids, one calosoma beetle and one clerid beetle which fed on Epilachna spp.

Stehr and Farrel (1936) noted two previously unreported Heteroptera which fed on the bean beetle in Ohio -- Perillus circumcinctus Stal and the wheel bug, Arilus cristatus (L.).

Landis and Howard (1940) made an extensive study of Paradexodes epilachnae Aldrich, a tachinid parasite of the Mexican bean beetle in Mexico. Attempts to establish this fly in the United States were made in the 1920's; however, the parasite would not diapause and thus failed to overwinter.

Angalet et al. (1968) studied potential parasites of the Mexican bean beetle from India, Tetrastichus ovulorum Ferriere, a solitary egg parasite, and Pediobius foveolatus (Crawford). P. foveolatus, a gregarious larval parasite, was released "in some eastern states in 1967". Further work with P. foveolatus was performed in Maryland, and releases were made in Virginia in 1974 by the U. S. D. A.

Howard and Landis (1936) listed two bacteria as natural enemies of the Mexican bean beetle: Coccobacillus sp. and Streptococcus sp.

Also listed were the fungi Beauveria globulifera, Cephalothecium sp. (reported from eggs), Cordyceps militaris (L.) and Isaria sp.

A complete list of natural enemies of the Mexican bean beetle was included in a paper by Howard and Landis (1936).

Pentatomids

A complex of at least three phytophagus stinkbugs is found on soybeans in Virginia, and there are several less important pentatomids. The green stinkbug, Acrosternum hilare, is the most abundant species, while Euschistus servus, the brown stinkbug, and E. tristigmus (Say) are less numerous. The presence of the southern green stinkbug, Nezara viridula (L.), in Virginia still requires confirmation (Hoffman 1971), however this species is included in this review because of its similarity to A. hilare, their common natural enemy(s), and its importance in other soybean growing areas.

A description of the life history and control of phytophagus stinkbugs on soybeans was written by Miner (1966). Nettles et al. (1967), Turnipseed (1967), and Roberts and Smith (1971) also discussed the control of stinkbugs on soybeans.

Stinkbugs are pod feeders, and prefer the tender young pods before seed maturation. Pod feeding by stinkbugs has been shown to reduce yield and oil content of the beans (Daugherty et al. 1964). As damage increases, oil content decreases and protein content increases. Jensen and Newsom (1972) found that damaged beans differed significantly in emergence and yield from undamaged beans.

Daugherty (1967) studied pentatomids as vectors of the yeast spot disease of soybeans, and demonstrated that E. servus, the green stinkbug, and four other pentatomids are capable of transmitting the causal organism, Nematospora coryli Peglion. Clarke and Wilde (1970, 1970a, 1971) investigated several aspects of the association of A. hilare with the organism, including transmission, isolation of the organism, and effect on seed quality.

Todd and Turnipseed (1974) studied the effects of N. viridula damage on yield and quality of soybeans. They found that population levels of one or more stinkbugs per row-foot significantly increased damage and reduced the quality of the seed.

Laboratory rearing of phytophagus stinkbugs has been achieved by several workers. Wilde (1968) reported on the laboratory rearing of the green stinkbug, while McPherson (1971) reported a similar method for rearing E. tristigmus tristigmus. Both workers used fresh green beans as food. Jensen and Gibbens (1973) successfully reared N. viridula on an artificial diet which was modified from a corn earworm diet.

Biological control of stinkbugs on soybeans has received little attention, although control of N. viridula has been extensively studied on many crops throughout much of its range. In the United States, successful introductions for the control of N. viridula were made in 1963 in Hawaii (Davis and Krauss 1963). The introduced insects included four egg parasites and one adult parasite, Trichopoda pennipes F. (Tachinidae). The egg parasites were Telenomus basalis Wollaston (Scelionidae) and three encyrtids, Ooencyrtus submetallicus (Howard),

O. trinidadensis Crawford, and Xenoencyrtus niger Riek. The former and X. niger were introduced from Australia, while the remaining two encyrtids were introduced from Trinidad. T. pennipes originated from Trinidad and Florida. Davis described the rearing procedures for these parasites in 1964.

Beard (1940) made a detailed study of the squash bug, Anasa tristis DeGeer, and its parasite, T. pennipes. Investigations on the morphology, life history, bionomics, and behavior were included in the work. In addition to A. tristis, he reported as hosts Acrosternum hilare, A. pennsylvanicum DeGeer, the onespot stinkbug, Euschistus variolarius P. deB., N. viridula, and several other Heteroptera. N. viridula was reported to be the most important host of the fly "in the south".

Messenger and van den Bosch (1971) reported that T. pennipes existed in three strains in North America. An eastern strain primarily attacked the squash bug, a southeastern strain attacked pentatomids, and a western strain attacked a plant bug, Euryophthalmus cinctus californicus Van Duzee.

Dietrick and van den Bosch (1957) reported rearing T. pennipes in the laboratory. The strain involved (eastern) was to be introduced to California, to attack the squash bug, which was not parasitized by the native western strain.

Shahjahan (1968) studied the effects of superparasitization on the fly and its host, the southern green stinkbug. He noted that a slight amount of superparasitization increased the chances of a fly emerging from the host, as not all of the eggs produced larvae which successfully penetrated the host cuticle. The effect on fecundity of the host was not significant. Shahjahan also studied the effect of diet on adults of T. pennipes (1968a). It was found that a raisin diet gave optimum results with respect to fecundity and longevity.

Mitchell and Mau (1971) studied the response of the parasite to male southern green stinkbug pheromones and found it more attracted to caged males than to females.

An excellent review of the literature on N. viridula was made by DeWitt and Godfrey (1972).

Corn Earworm

The corn earworm, Heliothis zea, is the most important pod feeding pest of soybeans in Virginia. The larva feeds directly on the tender young pods, causing them to die and fall from the plant. Infestations (one generation only) occur in late August and September. Because of the direct damage done to the crop, chemicals have been the most useful control agents for the insect. Smith and Bass (1972) presented data which indicated that three larvae per row-foot would justify control measures under average moisture conditions. Plants grown under stress would have a lower economic threshold. The general papers on soybean insect control mentioned in previous sections include the corn earworm.

The use of biological insecticides, such as sprays containing Bacillus thuringiensis Berliner or viruses of the corn earworm has resulted in varied degrees of success. Tanada and Reiner (1962) were able to achieve control comparable to that of standard chemicals with sprays of B. thuringiensis and a nuclear polyhedrosis virus on sweet corn. Young and Hamm (1966) achieved similar results with a nuclear polyhedrosis virus at a rate of 100 - 250 larval equivalents per acre (on sweet corn). Woodall and Dittman (1967) controlled the insect on lima beans at an application rate of 100 larval equivalents per acre. The virus did not control the larvae well at lower rates of application. Ignoffo et al. (1974) studied the stability of B. thuringiensis and Baculovirus heliothis on soybeans and found the half life of the bacteria to be less than 24 hours, while that of the virus was between two and three days.

There are few papers which report fungi that attack the corn earworm. One such paper, Smith and Bass (1972), makes brief mention of Spicaria rileyi (Farlow) as a pathogen of this insect.

Among the parasitic insects reported to attack the corn earworm are at least 19 Hymenoptera and 13 Diptera. Blanchard and Conger (1932) reported six hymenopterous and four dipterous parasites of H. zea. Bibby (1942) reported nine Hymenoptera and five Diptera which attacked the earworm in Texas.

Snow et al. (1966) collected H. zea larvae on weeds and noted parasitism by Microplitis croceipes (Cress.) and Hyposoter sp. (Hymenoptera).

Bottrell et al. studied parasites of Heliothis spp. in Oklahoma, and reared a total of fifteen species from the larvae. Of these, five tachinids, two braconids, and two ichneumonids were reared from larvae identified as H. zea. None of the larvae were collected from soybeans.

Laboratory studies of an important tachinid parasite of H. zea, *Lespesia archippivora* (Riley) were made by Bryan *et al*. (1968). Jackson *et al*. (1969) made similar studies of another tachinid, *Eucelatoria armigera* (Coq.).

Lewis (1970) studied hosts of *Microplitis croceipes*, a braconid parasite of *H. zea*. A preference for third instar larvae was observed, and *H. virescens* (F.) and *H. subflexa* (Guenee) were also found to be suitable hosts.

Gonzales *et al*. (1970) performed field cage studies with *Trichogramma pretiosum* Riley as parasites of *H. zea* eggs.

A summary of the parasites of *H. zea* reported by the above workers appears in Appendix Table 1.

Green Cloverworm

The green cloverworm, *Plathypena scabra*, (generally found east of the Rocky Mountains in the United States and Canada) is a widespread defoliator of leguminous plants. In Virginia it is of relatively minor importance on soybeans, and causes little economic damage, except perhaps during outbreaks. A detailed study of the biology of this species was made by Pedigo *et al*. (1973).

Stone and Pedigo first calculated an economic injury level for this pest (number of larvae per row-foot) on soybeans in 1972. The economic threshold is also gauged by the degree of defoliation of the plants.

Chemical control of this species on soybeans was first recorded by Sherman (1920), when lead arsenate was used in North Carolina. Brannon (1945) found cryolite dust a most effective insecticide for the insect in Virginia. Recent chemical control recommendations have emphasized systemic granules (Turnipseed 1967, Smith 1969) and foliar sprays (Roberts and Smith 1971, Turnipseed et al. 1974).

Beegle et al. (1973) compared the efficacy of the granulosis virus of the green cloverworm with Bacillus thuringiensis and chemical insecticidal sprays. Further work with B. thuringiensis on soybeans has been carried out by Ignoffo et al. (1974).

A number of workers have noted fungal diseases of P. scabra (Sherman 1920, Ratcliffe 1960, Pedigo et al. 1973 and others), and among the causal pathogens reported are Beauveria bassiana (Balsamo) and Metarrhizium sp.

Chittenden reported two natural enemies of the green cloverworm in 1901, a tachinid and a chalcid. Sherman listed seven larval parasites and one egg parasite in North Carolina, and indicated that the egg parasite was very important. He also reported predation of the larvae by Polistes wasps. Whiteside et al. (1967) studied parasites of the green cloverworm (larvae) in Delaware, and reported ca. 20% parasitization, due to 11 species of parasites. Barry (1970) found ten parasite species in Missouri, which included two hyperparasites. The insects parasitized 12-15% of the P. scabra larvae collected. Lentz and Pedigo (1972) discovered seven parasites and three hyperparasites in Iowa. They reported approximately 30% parasitization from June 17 to August 31. The life histories of the two most important parasites of P. scabra in Iowa, Rogas nolophanae Ashmead (Braconidae) and Winthemia sinuata Rein (Tachinidae), were reported in 1974 by Lentz and Pedigo. Pedigo et al. (1972) demonstrated the importance of predators of eggs and young larvae of P. scabra.

A summary of the entomophagus species reported to attack the green cloverworm appears in Appendix Table 2.

Minor Defoliators

A number of defoliators of minor importance on soybeans in Virginia are included in this review because of their importance in other soybean growing areas, and their natural control agents which are common to other pests of more significance.

The salt marsh caterpillar, Estigmene acrea (Drury) is present on soybeans in Tidewater in very low numbers throughout the growing season. In other geographical areas, and on other crops, it is an important defoliator. Taylor (1954) studied parasites of this insect in Arizona and reported six tachinids, one ichneumonid, one braconid, and one trichogrammatid (T. minutum) from the literature as attacking E. acrea. He was able to rear four tachinids and one ichneumonid from specimens collected in Arizona. Butler (1958), also in Arizona, reported one tachinid, Lespesia archippivora from this host. Young and Sifuentes (1959) listed a coccinellid and a malachiid as egg predators, two reduviids as predators of young larvae, and a fungus, Entomophthora aulicae as a pathogen of larvae. Bryan et al. (1968) reported on lab studies with L. archippivora, a parasite of the larvae.

The soybean looper, Pseudoplusia includens (Walker), found occasionally in Virginia soybeans, is of greater importance on soybeans in other southern states. Burleigh (1971) reported three braconids, one ichneumonid, one chalcid (Brachymeria ovata (Say)), one encyrtid and one tachinid (*L. aletiae*), as parasites of this insect. In a later paper (1972), *Spicaria rileyi* and *Massospora sp*. were included as pathogens. *S. rileyi* was also reported as a pathogen of the velvet-bean caterpillar, *Anticarsia gemmatilis* Hubn., by Allen *et al*. (1971).

MATERIALS AND METHODS

I. Collection and Parasitization Studies

In the first and second years of this study (1972-3) collections of phytophagus insects were made to determine the extent of parasitization and the species involved. These were made on all life stages of phytophagus insects of major importance except for the corn earworm, which did not occur in abundance at any of the test sites. Collections were made at four to ten day intervals, in several fields in Suffolk, Virginia. Supplementary collections were made in Isle of Wight, Lancaster, Middlesex, Southampton and Westmoreland Counties. Sweeping was rejected as a collection method, due to injury sustained by some larvae in preliminary collecting, and because of crop injury from continued sampling of the same fields. Specimens were henceforth hand collected at random sites in each field.

Specimens were held in the laboratory in 100 X 15 mm petri dishes, with one to five individuals, depending on size, per dish. The containers were checked daily, and fresh lima bean or soybean foliage was provided for the defoliators, while fresh soybean pods were provided for the pentatomids. Moisture was provided in squares of absorbent paper, and replenished when needed. Parasites were removed upon emergence of the adult, and were sent to the U. S. National Museum for identification.

Due to high mortality of stinkbugs so reared, the methods were altered to conform more closely to those of Wilde (1968) and McPherson

(1971). Larger rearing containers (3" X 5" X 12") were later used in an effort to further reduce the still high mortality rates. An artificial diet (Jensen and Gibbens 1972) slanted in the bottom of 100 X 15 mm petri dishes was tried in 1973. When this was not accepted by the insects, the use of live plants was tried, with limited success.

II. Effects of Insecticides on Parasites and Predators

In an effort to determine the effects of chemical controls on the pests and their natural enemies, plots were established at the Tidewater Research and Continuing Education Center (TRACEC) in Suffolk during 1972-4, and in Lancaster, Middlesex and Westmoreland Counties in 1973 and 1974. Plots at Suffolk were planted in a conventional tillage system while those at the latter sites were planted in a minimum tillage system after small grain. Tests at Suffolk included systemic (granular) insecticides, and sprays of azinphosmethyl, carbaryl, carbofuran, carbophenothion, diazinon, dimethoate, disulfoton, Dursban® (O, O-diethyl O-(3,5,6-trichloro-2-pyridyl) phosphorothioate), methomyl, monocrotophos, Orthene® (O,S-dimethyl N-acetyl phosphoramidothioate), and Sevimol® (carbaryl + molasses). Identical tests including granular and spray treatments were made in Lancaster, Middlesex, and Westmoreland Counties. All tests were of randomized complete block design.

Preplant granular applications of carbofuran and disulfoton were placed in premarked open seed furrows with a Gandy Model 901-2 granular applicator, while such applications on minimum tillage plots were dropped in front of the press-wheel of a minumum tillage planter.

Layby applications of systemic granules at all sites were dropped over the rows with a tractor mounted Ezee Flow granular applicator. Spray applications at all sites were made with a CO_2 pressure regulated back pack sprayer, at a rate of 15 gals/acre, with the exception of the 1973 spray test at TRACEC. Those treatments were applied with a Solo mist blower, at a rate of 50 gals/acre.

Insect counts were made each year on the spray tests before and/or after treatment. Those made on systemic insecticide tests, begun in 1972, were consistently too low to be meaningful, and were discontinued. Subsequently, periodic observations of insect populations were made on these plots. Population counts and observations at Lancaster, Middlesex and Westmoreland Counties were made at two to four week intervals. Both sweeping and direct observation of insects on a row-foot basis were used. In 1974, sweeping and the shake cloth method described by Allen (1972) were used. Sweeping samples consisted of ten 180^{o} sweeps, made across the center two rows of each plot.

In 1973 and 1974, plots at TRACEC were interplanted with rows of snap beans, to aid in the buildup of Mexican bean beetles. After defoliating the preferred snap beans, the beetles moved to the adjacent soybean plots.

III. Studies on *Trichopoda pennipes* and Predaceous Stinkbugs

In 1973 and 1974, intensive investigations were conducted on three important natural control agents, *Trichopoda pennipes*, a parasite of stinkbugs, and two predaceous pentatomids, *Podisus maculiventris* and *Stiretrus anchorago*.

Observations of T. pennipes, begun in 1972, were continued in 1973 and 1974 at TRACEC. Investigations on soybeans were extended to other crops, weeds, and shrubs to determine alternate hosts and habitats.

Host preference tests with T. pennipes were made in the laboratory in 1973 and 1974. One or more adult female parasites were placed in a 3" X 5" X 12" plastic box with a fabric screen top, with the offered hosts, water and sugar cubes. The box was placed under "grow-lux" lights and checked after 24 hours. The hosts were not starved.

Tests to determine olfactory response of T. pennipes to hosts were performed in 1974. The test apparatus in shown in Figure 3. Both insect hosts and the plants on which they are found were tested with the apparatus. During the testing, an attempt was made to uniformly illuminate the chamber with incandescent bulbs.

Colonies of the spined soldier bug, P. maculiventris, and S. anchorago were established in the laboratory from field collected adults in 1974. The insects were placed on snap bean and soybean plants grown in pots and covered with 8" X 10 1/2" glass lamp globes. The open tops were covered with cheesecloth. The predators were also raised in 100 X 15 mm petri dishes, with moistened absorbent paper. Food, consisting of larvae and adults of the Mexican bean beetle, larvae of the Colorado potato beetle, Leptinotarsa decemlineata (Say), larvae of the green cloverworm, corn earworm, and cabbage looper, Trichoplusia ni (Hubner), was presented daily. Care was taken to separate individuals of different size, to reduce cannibalism.

Prey acceptance tests were made with both predators in 100 X 15 mm petri dishes. One or more specimens of the prey species to be tested were placed with a predator which had not been fed for 24 hours. Predators were given at least 24 hours to consume the prey offered, and were frequently checked during that period.

Small scale field testing of S. anchorago was also done in 1974. Two plots of four thirty foot rows were isolated from a 1/3 acre soybean field by creating a 10 foot bare strip around the plots. Population levels of both predator and prey species were then measured by the shake cloth method, and laboratory reared third to fifth instar nymphs of the anchor bug were introduced at a rate of one per three row feet in one plot, and one per six row feet in the second plot. Shake cloth counts of the insect populations were again made 13 days after release in the first plot and seven days after release in the second plot.

IV. Topical Insecticide Application Tests

Laboratory tests were conducted in 1974 to determine the toxicity of an insecticide commonly used on soybeans to the Mexican bean beetle and its two important predators, P. maculiventris and S. anchorago. Tests on the predators were limited by availability of specimens, and were made as pilot tests, while those on the bean beetle (adults) were well replicated. A stock solution of insecticide was first made by adding 1.00 gram (actual insecticide) of technical insecticide to 100 ml of acetone, to make a 1% solution by volume. Subsequent dilutions yielded test solutions of 1/32%, 1/64%, 1/128%, 1/256%, and 1/512%. Acetone only was applied to individuals in the control cohorts. These solutions were then applied topically to the ventral surface of the insects with a 2 μl needle. Survivors were counted after 24 hours, with the criterion for death being failure of an insect to right itself within five minutes after being turned over.

V. Fungal Pathogen Identification

In late August 1974, recurrence of fungal disease seen among Lepidoptera in previous years prompted the use of a more exact identification procedure for the causal organism than had previously been used. Besides identification, Koch's postulates were followed. Specimens of *P. scabra* showing symptoms of a white muscardine fungus disease were used for identification. Two methods were used to obtain cultures of the fungus: crushing the insect on an agar medium, or rinsing the uncrushed insect with distilled sterile water onto an agar medium. The media were then incubated and the cultures identified. A suspension of spores from one of the cultures was then made with distilled water and sprayed on three healthy *P. scabra* larvae, which were placed on fresh soybean leaves in a petri dish. A second dish held three healthy larvae on suspension-sprayed foliage, while a control dish contained three healthy larvae on unsprayed foliage. Dishes were checked daily for diseased larvae, and the symptoms were recorded before final recovery and identification (by these methods) of the pathogen.

RESULTS

COLLECTIONS

Mexican Bean Beetle

Populations of E. varivestis were very low in the Tidewater area throughout 1972. Of 173 larvae and pupae collected at the Tidewater Research and Continuing Education Center (TRACEC) from July 20 through August 23, two individuals (1.15%) carried eggs of unknown tachinid flies. Neither survived to pupariate. A single small collection in Isle of Wight County on September 9 yielded nine parasitized larvae out of 29 collected. None of the larvae bore eggs on their bodies, and several atypical, small adults of Lespesia aletiae emerged from the larvae.

Eighteen egg masses of the bean beetle were reared in 1972, and four of these showed evidence of predation. No parasitized eggs were found. Observed larval predators included Orius insidiosus Say and Nabis sp. Arilus cristatus was observed feeding on adults, and was primarily seen in fields bordered by woods. The data from the collections appear in Table 1.

In 1973, five collections of larvae and pupae in Suffolk, totalling 371 specimens, yielded three larvae bearing tachinid eggs. As in the previous year, no adult parasites emerged. Four collections in Isle of Wight County (121 specimens) yielded two parasitized larvae, both in early September. Two small, atypical adults of L. aletiae emerged from puparia from these hosts. Three collections in Westmoreland

County (225 specimens) yielded one small adult of L. aletiae. One small collection from Middlesex County also yielded a small adult of L. aletiae.

Thirty two egg masses from Suffolk were reared in 1973, and none showed evidence of predation or parasitization. Counts of egg masses at TRACEC in mid-June showed seven of 33 egg masses partially damaged by unknown predators. At the time, high numbers of adult Mexican bean beetles and adult convergent lady beetles, Hippodamia convergens Guer. (both reported egg predators) were in the field.

Summation of the 1972 and 1973 data revealed 2.5% parasitization of Mexican bean beetle larvae and pupae by Diptera. Most of this (1.8%) was attributed to Lespesia aletiae, with the rest due to unknown Diptera. No other parasites of the larvae were reared, and no parasites of the eggs or adults were found.

Observations made while collecting indicated two pentatomids, Podisus maculiventris and Stiretrus anchorago, to be important natural enemies of the bean beetle in the Tidewater area. Beginning in early July, P. maculiventris was found in six out of seven fields regularly sampled in 1973. S. anchorago was found later in the season (August) and was not as well distributed, as it occurred in only one field. Larvae and pupae were both readily attacked, and were often incompletely consumed. Partially consumed prey quickly turned brown and fell to lower foliage or to the ground.

Observations of these predators were continued at TRACEC in 1974. The first specimens of Podisus were seen on May 22, on mixed weeds, while the first specimens on soybeans were observed on July 1. Population

Table 1. -- Parasitization of Mexican bean beetles collected in the Tidewater area of Virginia, 1972-3.

Collection date(s)	Number collected: Adult	Larvae	Pupae	Egg masses	Number parasitized	Parasites reared
			1972 TRACEC			
Jul 20-25	0	88	11	0	2 larvae	0
Aug 8-9	0	25	6	0	0	0
Aug 21-23	0	20	23	0	0	0
Jul 20- Aug 22	0	0	0	18	0	0
			1972 Isle of Wight County			
Sept 9	0	29	0	0	9 larvae	3
			1973 TRACEC			
June 21-25	38	106	0	0	0	0
Jul 9	0	90	5	0	0	0
Jul 13	0	50	0	0	3 larvae	0
Jul 31	0	18	0	0	0	0
Aug 24	0	64	0	0	0	0
Jun 21- Aug 28	0	0	0	32	0	0
			1973 Westmoreland County			
June 28	91	0	0	0	0	0
Aug 1	0	25	30	0	0	0
Aug 9	0	56	23	0	1 larva	1
			1973 Middlesex County			
Sept 6	0	6	13	0	1 larva	1
			1973 Isle of Wight County			
June 26	59	0	0	0	0	0
Jul 2	21	0	0	0	0	0
Sept 7	0	20	5	0	1 pupa	1
Sept 12	0	10	6	0	1 larva	1
TOTAL	209 Adults	729 Larvae and Pupae		50 Egg masses	17 larvae 1 pupa	7 *Lespesia aletiae*

levels generally followed the availability of prey (various caterpillars were also attacked). The highest population was recorded in a heavily infested field in early September, and approximated one stinkbug per six feet of row. This insect was commonly found in five out of six infested fields observed throughout the summer. S. anchorago occurred in lower numbers and was found in only two of the six fields. Stiretrus was found later in the season, and the first specimens were seen on soybeans on July 31.

Stinkbugs

The rearing of collected stinkbugs was continually plagued by high mortality in the laboratory. Various alterations in diet, humidity, type of rearing chambers and temperature were made in attempts to correct the situation, which remained a serious problem throughout the study. For this reason, relatively few of the parasites were successfully reared to maturity. Most of the stinkbugs which died in the laboratory were dissected to check for parasites. Other than Tachinidae, none were found.

In 1971. populations of stinkbugs at TRACEC remained very low until July 27-8 when large numbers of green stinkbugs and a few brown stinkbugs appeared in blooming soybeans. The first parasitized stinkbugs were found on the first collection date, July 29. Populations in the sampled fields remained stable throughout the rest of the growing season. At no time during the year did the population cross the economic injury level of one per three row-feet (as suggested by Roberts and Smith, 1971).

Four collections of adult green and brown stinkbugs were made in

1972, and 49% of the green stinkbugs collected bore oval, cream colored eggs of a tachinid parasite(s). Six specimens of Trichopoda pennipes were reared to adults from these hosts. Twenty four per cent of the brown stinkbugs collected bore elongate, brown tachinid eggs on their bodies, markedly different from those found on green stinkbugs. Two of these yielded adults of Euthera tentatrix Lw. Adults of this fly were not found in the field.

Adults of T. pennipes, first seen in the field on July 31, were commonly found in greater numbers later in the season. With this higher population of parasites, and the stable population of hosts, superparasitism increased dramatically. The last collection of the summer (August 17-24) showed an average of 3.36 eggs per parasitized green stinkbug, and 83% parasitization of adults.

Populations of stinkbugs at TRACEC in 1973 were lower than the previous year, and there was no sudden migration into soybeans as was witnessed in 1972. Insects first appeared in late July, and their numbers increased slowly until mid-August, after which the population remained stable. Populations of the green stinkbug nearly approached the economic injury level at one site (Middlesex County), however, populations were low at all other collection sites.

Five collections of adult green stinkbugs at TRACEC in 1973 revealed an overall parasitization rate of 47%. The parasitization rate of nymphs was much lower, between five and ten per cent. Collections in Isle of Wight and Westmoreland Counties yielded no parasitized stinkbugs. Collections at one well infested field in Middlesex County showed less than 1% parasitization. A single adult green stinkbug was parasitized by *T. pennipes* at this site.

Superparasitization of *A. hilare* was commonly observed at TRACEC, and 14 eggs were seen on one field collected adult.

Seven *T. pennipes* adults were reared from all of the collections in 1973.

Few brown stinkbugs were collected at TRACEC in 1973, and 14% were parasitized (probably by *Euthera tentatrix*). Parasitization of this species at other locations was not seen. One specimen of *E. tentatrix*, captured on flowers in late June, was induced to oviposit in the laboratory, and produced the elongate, dark tan eggs seen on the brown stinkbug in 1972 and 1973. Placement of the eggs by *E. tentatrix* was more selective than by *T. pennipes*. Most were placed on the wings of the host.

One specimen each of the green and the brown stinkbug were found during 1973 with both types of eggs, probably those of *T. pennipes* and *E. tentatrix*. Parasites did not emerge from either specimen.

Although many egg masses were checked for parasitization in the field, no parasitized eggs were seen at any location. A larval cantharid was observed feeding on pentatomid eggs in Middlesex County in 1973.

Data from all stinkbug collections are presented in Tables 2 and 3.

Green Cloverworm

Plathypena scabra was present in low numbers at TRACEC in 1972, and was found from early July until early September. Although it was

Table 2. -- Parasitism of stinkbugs collected at the Tidewater Research and Continuing Education Center, Suffolk, Virginia, 1972-3.

Collection date(s)	Number collected Adult	Nymph	Species†	Number bearing parasite eggs	Average no. eggs per parasitized stinkbug	Adult parasites reared
			1972			
Jul 29-31	39	0	GSB	11	1.4	2*
Aug 2-4	11	0	GSB	3	1.7	0
Aug 8-10	7	0	GSB	4	1.5	0
Aug 8	0	27	GSB	0	---	0
Aug 17-24	30	0	GSB	25	3.4	4*
Aug 24	0	18	GSB	0	---	0
Jul 29- Aug 17	25	0	BSB	6	not counted	2**
TOTAL			87 GSB adults, 43 parasitized (49%) 25 BSB adults, 6 parasitized (24%) 45 GSB nymphs, 0 parasitized			
			1973			
Aug 3	20	0	GSB	10	2.2	2*
Aug 6	5	0	GSB	3	2.3	0
Aug 10	8	0	GSB	3	2.7	1*
Aug 13	9	0	GSB	5	3.4	1*
Aug 23	16	0	GSB	6	2.2	2*
Aug 23	0	30	GSB	2	1.0	0
Jun 25- Aug 23	14	0	BSB	2	not counted	0
TOTAL			58 GSB adults, 27 parasitized (47%) 30 GSB nymphs, 2 parasitized (7%) 14 BSB adults, 2 parasitized (14%)			

† GSB -- Green stinkbug, *Acrosternum hilare*
BSB -- Brown stinkbug, *Euschistus servus*

* *Trichopoda pennipes*

** *Euthera tentatrix*

Table 3. -- Parasitism of stinkbugs collected in the Tidewater area of Virginia, 1973.

Collection date(s)	Number collected Adult	Number collected Nymph	Species†	Number bearing parasite eggs	Average no. eggs per parasitized stinkbug	Adult parasites reared
			Isle of Wight County			
Aug 7	8	0	GSB	0	---	0
Aug 7	6	0	BSB	0	---	0
Aug 23	22	0	GSB	0	---	0
			Middlesex County			
Aug 1	34	14	GSB	0	---	0
Aug 28	30	0	GSB	0	---	0
Sept 6	37	0	GSB	1	1.0	1*
			Westmoreland County			
Aug 1	10	0	BSB	0	---	0
Aug 28	14	0	GSB	0	---	0

† GSB -- Green stinkbug, *Acrosternum hilare*
BSB -- Brown stinkbug, *Euschistus servus*

* *Trichopoda pennipes*

the most numerous defoliator of soybeans in that year, it incurred no economic damage to the plants. A fungal disease, first seen in mid-August, became more widespread and precipitated a population decline in late August.

Three small collections of larvae totalling 126 specimens showed an overall parasitization rate of 19% at TRACEC in 1972. Tachinidae were responsible for 11%, while Ichneumonidae and Braconidae accounted for 8%. Chaetophlepsis sp., Lespesia sp., L. aletiae, and Winthemia sinuata Rein. were the species of Tachinidae reared, while Campoletis flavicincta (Ash.) and Venturia nigriscapus (Vier.) (Ichneumonidae) were also found. A single braconid, Protomicroplitis facetosa (Weed) was reared. Collections of green cloverworm eggs or pupae were not made in 1972.

Specimens of Nabis were frequently observed preying upon young larvae of the green cloverworm, as were specimens of Geocoris and Orius insidiosus. Several species of Polistes wasps were observed preying upon late instar larvae. A white muscardine fungus (previously mentioned) was the sole pathogen discovered. The fungus was not identified.

Populations of P. scabra at TRACEC in 1973 were very low, and slowly increased until late August, when a warm, rainy period brought an epidemic of fungal disease among Lepidoptera. One small collection at TRACEC showed 29% parasitization and 34% were killed by fungal disease. The fungus was identified as Beauveria sp. Two parasites were recovered from pupae, Brachymeria ovata (Say) (Chalicididae) and Coccygomimus aequalis (Prov.) (Ichneumonidae). Two cocoons of a hyperparasitic chalcid, *Ceratosmicra meteori* Burks, were found in a field where the green cloverworm was the only phytophagus insect present.

One small collection in Isle of Wight County (September 7) showed 16% parasitization of larvae, by *L. aletiae* (Tachinidae) and *Mesochorus discitergus* (Say) (Ichneumonidae).

In addition to predators observed in 1972, *Podisus maculiventris* and, to a lesser extent, *Stiretrus anchorago* were observed preying on larvae of *P. scabra*.

Viral disease of the green cloverworm was observed in Isle of Wight and Greensville Counties in 1973, but the virus was not characterized.

Data from the green cloverworm collections are presented in Table 4. A summary of the parasites reared from the green cloverworm in this study follows the table.

Minor or Infrequently Occurring Lepidoptera

Specimens of minor defoliators on soybeans were occasionally noted during field work of this study, and those which showed signs of parasitism were collected for observation in the laboratory. Also, several specimens of the corn earworm were found with parasite eggs and reared in the laboratory. All of these minor pests were subject to attack by fungal disease. A summary by species follows:

Corn Earworm

Six specimens of parasitized *H. zea* larvae were found in Greensville, Southampton, and Isle of Wight Counties in September 1973.

Table 4. -- Parasitism of green cloverworms collected in the Tidewater area of Virginia, 1972-3.

Collection date(s)	Total no. collected	Number parasitized H*	Number parasitized D*	Number killed by fungus	Species and number of parasites reared†
			1972 TRACEC		
Jul 7-12	30 larvae	2	3	0	2 *Campoletis flavicincta* 2 *Lespesia aletiae* 1 *Winthemia sinuata*
Jul 31-Aug 9	37 larvae	2	4	0	2 unknown Hymenoptera 1 *Lespesia sp.*, 1 *L. aletiae* 1 *W. sinuata*
Aug 25-31	59 larvae	6	7	8	1 unknown Hymenoptera 1 *C. flavicincta* 2 *Venturia nigriscapus* 2 *Protomicroplitis facetosa* 2 *L. aletiae*, 4 *W. sinuata* 1 unknown Diptera
TOTAL	126 larvae	24 (19%)		8 (6%)	
			1973 TRACEC		
Aug 21-24	35 larvae	1	9	12	1 unknown Hymenoptera 3 unknown Diptera 2 *L. aletiae*, 4 *W. sinuata*
Aug 21-24	10 pupae	2	0	0	1 *Brachymeria ovata* 1 *Coccygomimus aequalis*
			1973 Isle of Wight County		
Sept 7	18 larvae	1	2	2	1 *Mesochorus discitergus* 2 *L. aletiae*

* H -- Hymenoptera
D -- Diptera

† "Unknown" specimens did not emerge from pupal stage.

Parasites Reared From *Plathypena scabra*

TACHINIDAE

Chaetophlepsis sp. -- solitary internal larval parasite, pupates in soil

Lespesia aletiae (Riley) -- solitary internal larval parasite, pupates in the soil

Winthemia sinuata Rein. -- solitary internal larval parasite, pupates in the soil

ICHNEUMONIDAE

Campoletis flavicincta (Ashm.) -- solitary internal parasite of young larvae, pupates in cocoon spun on leaf surface

Coccygomimus aequalis (Prov.) -- solitary internal pupal or larval-pupal parasite, pupates within host pupa

Mesochorus discitergus (Say) -- Hyperparasite or solitary internal parasite of young larvae, pupates in cocoon on leaf surface

Venturia nigriscapus (Vier.) -- solitary internal larval parasite, pupates within host

BRACONIDAE

Protomicroplitis facetosa (Weed) -- solitary internal parasite of young larvae, pupates in cocoon on leaf surface

CHALCIDIDAE

Brachymeria ovata (Say) -- solitary internal pupal or larval-pupal parasite, pupates within host pupa

Dipterous parasites emerged from all of these, and two adult Winthemia rufopicta (Big.) emerged.

Salt Marsh Caterpillar

Three parasitized specimens of Estigmene acrea were collected at TRACEC in September 1972 and reared in the laboratory. Adults of Lespesia aletiae emerged from two specimens, while specimens of Apanteles diacrisiae Gahan (Braconidae), a gregarious internal parasite, emerged from the third. Cocoons of the latter were spun in a single mass externally on the host, which remained lethargic but alive for three days after pupation of the parasites.

Yellow Striped Armyworm

Three parasitized specimens of Prodenia ornithogalli (Guenee) were collected form Isle of Wight County and TRACEC from July through September. Adults of L. aletiae emerged from two larvae, while an ichneumonid, Campoletis flavicincta, emerged from a very young larva.

Other Lepidoptera seen in the field included Trichoplusia ni, Pseudoplusia includens, and Vanessa cardui (L.). No parasitized specimens of any of these insects were found.

PLOT WORK RESULTS

During 1972, populations of soybean insects, both phytophagus and entomophagus, were very low. Due to their small numbers, many planned treatments were not applied. Sampling of plots treated with preplant systemic insecticides failed to show differences in populations of beneficial insects. Predators occurred at very low levels in all plots and included nabids, geocorids and Orius insidiosis. The wheel bug, the convergent lady beetle, and _Ceratomegilla maculata_ DeG. were also seen.

In 1973, the population of _E. varivestis_ at TRACEC increased on snap beans before moving into soybean plots. By early August, populations on soybeans exceeded the economic threshold. Periodic observations of systemic insecticide plots failed to show significant differences in beneficial insect populations between treated and untreated plots. Sampling of sprayed plots yielded more meaningful data, which are given in Table 5. Several sprays reduced beneficial insect populations. Azinphosmethyl, carbophenothion, and monocrotophos were in this category. Application of the powdered formulation of methomyl at the one pound rate significantly reduced predator populations, while applications of the liquid formulation did not. Beneficial insect populations in other plots did not differ greatly from the control.

Observations were made on plots in Westmoreland County on August 1, and these showed numbers of green cloverworms near the economic threshold. At this time, nabids and coccinellids were also present in the field. The population of _E. varivestis_ was very low. Few insects were present in plots treated at planting time (June 8) with carbofuran. Populations in plots treated with disulfoton at planting time appeared the same as those in untreated plots. Layby treatments with these two chemicals were made on August 1. Observations of these treated plots on August 9 and 28 indicated lower populations of phytophagus insects, but populations of beneficial insects appeared to be the same as those in untreated plots.

At plot sites in Lancaster and Middlesex Counties, insect pest

Table 5. -- Number of insects per 10 sweeps across two center rows of plots treated with insecticide sprays at TRACEC, September 1973.

Treatment	Formulation	Rate lb AI/A	Mexican bean beetles	Total	
				Phytophagus**	Entomophagus*
Azinphosmethyl	2E	0.5	5.2 ± 1.2	7.2 ± 2.6	0.0
Carbaryl	80W	1.0	1.5 ± 1.7	2.0 ± 1.8	1.2 ± 1.5
Carbophenothion	8E	0.5	4.0 ± 2.2	5.0 ± 2.6	1.0 ± 0.8
Dimethoate	267E	0.3	5.5 ± 1.3	6.0 ± 1.4	1.7 ± 2.2
Dimethoate	267E	0.5	3.2 ± 1.2	4.7 ± 1.5	1.0 ± 0.8
Dursban[a]	4EC	0.5	17.0 ± 3.2	18.5 ± 4.0	0.5 ± 1.0
Dursban[a]	4EC	1.0	7.2 ± 4.6	10.2 ± 4.5	0.5 ± 0.6
Methomyl	1.8E	1.0	1.7 ± 1.7	1.7 ± 1.7	1.2 ± 1.5
Methomyl	90SP	1.0	3.5 ± 4.0	3.5 ± 4.0	0.5 ± 0.6
Monocrotophos	5E	0.5	3.2 ± 3.2	3.2 ± 3.2	0.0
Monocrotophos	5E	1.0	1.2 ± 0.9	1.5 ± 1.3	0.0
Sevimol[a] (Carbaryl-molasses)	4F	1.0	2.7 ± 2.5	3.0 ± 2.0	2.3 ± 2.5
Untreated	--	---	79.7 ± 24.0	81.7 ± 24.8	1.5 ± 0.6

Average of four replications, made 48 hours after treatment. (Treated with mist blower.)

* Includes geocorids, nabids, spiders, and P. maculiventris

** Includes Mexican bean beetles, stinkbugs, and loopers populations were also low. None of the pest species were ever present in numbers sufficient to warrant control measures. No differences were seen in the numbers of beneficial insects between treated (systemic) and untreated plots. Common beneficial insects included nabids, coccinellids, and tachinids. Populations of Odonata were especially high at the Middlesex County site, and these may have kept down the numbers of alate insects in the plots.

Populations of E. varivestis at TRACEC again built up on snap beans in 1974. The economic threshold was reached when the insects moved to the adjacent soybean plots in early August. By mid-September, the high population had defoliated all untreated plots. Populations of all other phytophagus insects were low.

Sprayed plots were sampled by sweeping and by using the shake cloth. Results appear in Tables 6 and 7. Shake cloth samples showed an increase in numbers of entomophagus insects in three of the four treatments evaluated by this method. The exception was monocrotophos. Sweeping counts from these plots showed that monocrotophos reduced beneficial insect populations. Sweep counts also showed that a high population of beneficial insects was present in plots sprayed with two 1/4 lb applications of methomyl. Plots receiving one application of this material at the 1/2 lb rate were low in beneficial insects.

No insects were present in significant numbers in plots in Lancaster, Middlesex and Westmoreland Counties. Mexican bean beetles were not found in plots at the two former sites. Data on the effects of systemic applications on beneficial insects were insufficient for

Table 6. -- Number of insects per shake cloth sample (three row-feet) in plots treated with insecticide sprays at TRACEC on August 27, 1974.

Sampling time	Number of insects per sample: Phytophagus*	Number of insects per sample: Entomophagus**
	Carbaryl 80W 0.50 lb AI/Acre	
Before treatment	48.8 ± 9.2	2.0 ± 2.1
After treatment	7.4 ± 4.6	3.8 ± 2.2
	Monocrotophos 3.2E 0.25 lb AI/Acre	
Before treatment	22.8 ± 10.3	2.7 ± 0.8
After treatment	4.8 ± 2.2	1.5 ± 1.2
	Methomyl 1.8E 0.25 lb AI/Acre	
Before treatment	47.0 ± 5.8	2.2 ± 1.5
After treatment	9.6 ± 3.3	2.3 ± 0.8

Pre-treatment counts made on August 27, post-treatment counts made on August 29. Mean of six samples (2 plots).

* Includes Mexican bean beetles, green cloverworms, corn earworms and stinkbugs

** Includes nabids, geocorids, coccinellid larvae, and _P. maculiventris_

Table 7. -- Number of insects per 10 sweeps across two center rows of plots treated* with insecticide sprays at TRACEC, 1974.

Treatment	Formu-lation	Rate lb AI/Acre	Phytophagus	Entomophagus
Carbaryl	80W	1/2 X 2	1.7 ± 2.1	2.5 ± 0.9
Lannate® (methomyl)	1.8E	1/4 X 2	3.5 ± 3.3	3.0 ± 2.7
Monocrotophos	3.2E	1/2 X 2	3.0 ± 2.8	0.0
Carbaryl	80W	1.0	2.0 ± 0.8	1.2 ± 1.9
Carbophenothion	8E	0.5	2.2 ± 1.5	2.0 ± 1.4
Dimethoate	267E	0.5	7.5 ± 5.5	1.7 ± 1.5
Lannate® (methomyl)	1.8E	0.5	3.7 ± 2.2	1.0 ± 0.8
Monocrotophos	3.2E	1.0	2.5 ± 1.3	0.2 ± 0.5
Nudrin® (methomyl)	1.8E	0.4	5.2 ± 3.4	1.7 ± 1.7
Nudrin® (methomyl)	1.8E	0.9	2.0 ± 0.8	1.7 ± 1.2
Orthene®	75S	1.0	3.7 ± 2.1	2.7 ± 0.9
Sevimol® (carbaryl-molasses)	4F	1.0	2.5 ± 2.1	1.2 ± 1.5
Untreated	--	---	71.2 ± 23.4	2.5 ± 1.3
Untreated	--	---	49.0 ± 18.0	2.7 ± 2.9

* First treatment, plots 1-3 made August 27. Second treatment, plots 1-3 and remaining treatments made September 9. Evaluated September 12, average of 4 replications.

analysis.

STUDIES ON Trichopoda pennipes

Observations of Trichopoda pennipes in soybean fields in 1972 and 1973 were followed by more intensive investigations as to alternate hosts and habitats of the fly. In 1972, adults were seen in soybeans (TRACEC) during the periods of July 31 - August 8 and August 18 - 25.

In 1973, adults were seen in a watermelon field which was well infested with the horned squash bug, Anasa armigera Say. Females were actively searching the vines for A. armigera. Oviposition of the fly on the host was very fast, and not easily observed. The flies were commonly seen on weed flowers bordering the field, especially wild carrot. Adults were numerous in soybeans during two periods in August.

In 1974, the flies were observed in several different habitats in Suffolk. The periods of their occurrence are shown in Table 8. Flies were also seen in Isle of Wight, Southampton and Sussex Counties in 1974. They were not observed in fields of peanuts or corn.

Preferences as to egg placement on the host were studied during 1973. Oviposition on the green stinkbug seemed to be random. Eggs were usually placed on the body of the host, and occasionally on the antennae or legs. The placement of 63 eggs from field collected green stinkbugs is diagrammed in Fig. 1. A preference for the anterior ventral surface of this host was observed. A very limited number of parasitized horned squash bugs were observed in 1973, and oviposition on this host seemed to be random.

Table 3. -- Sightings of *Trichopoda pennipes* adults at TRACEC, 1972-4. (Summary of daily observations.)

Habitat	Dates	Host
	1972	
Soybean field	July 31 - August 8	Green stinkbug
Soybean field	August 18 - 25	Green stinkbug
	1973	
Watermelon field	July 19 - 24	Horned squash bug
Watermelon field	August 10 - 14	Horned squash bug
Soybean field	August 3 - 8	Green stinkbug
Soybean field	August 13 - 18	Green stinkbug
	1974	
Vegetable garden*	June 6, June 12	Unknown
Field border (weeds and *Prunus* sp.)*	June 28, July 1	Green stinkbug
Watermelon field	July 1 - 16	Horned squash bug
Soybean field	July 23 - August 1	Green stinkbug
Soybean field	August 19 - 26	Green stinkbug

* Observations at these sites made at approximately weekly intervals. Flies were observed only on the dates indicated.

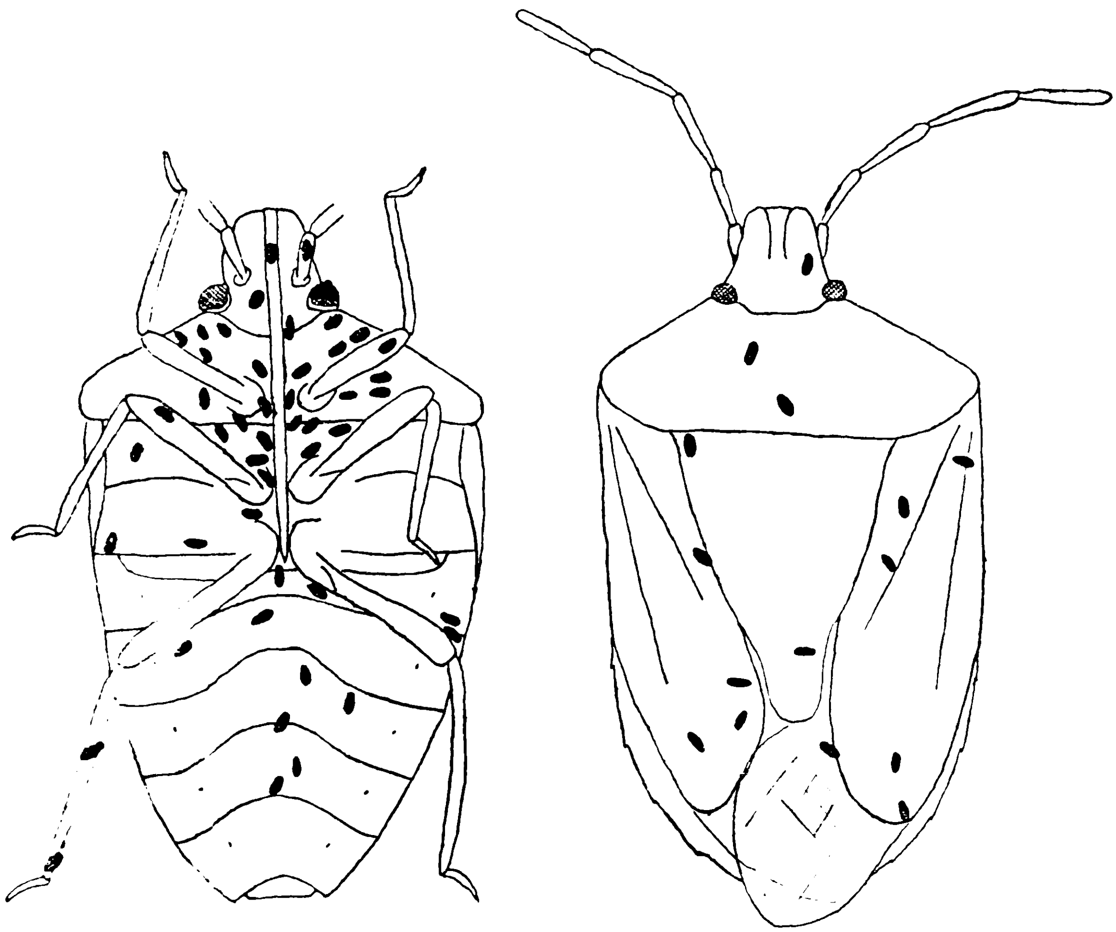

Fig. 1. Placement of 63 eggs of Trichopoda pennipes on 55 adults of Acrosternum hilare collected at TRACEC in 1973. Eggs not drawn to scale.

Table 9. -- Oviposition preference of adult female Trichopoda pennipes in the laboratory at TRACEC, 1973-4.

Test date	Parasites: No. used	Parasites: Source	Introduced hosts*: Species	Introduced hosts*: No. & stage	Test duration (hours)	Results*
			1973			
Aug 10	2	Soybean field	HSB	4 A	72	No oviposition
Aug 13	(same parasites)		HSB	4 A 2 N	36	1 GSB with 18 eggs 1 GSB with 20 eggs 1 HSB A with 1 egg
			GSB	2 A		
Aug 22	3	Watermelon field	HSB	5 A 6 N	24	1 A with 0 eggs 1 A with 4 eggs 1 A with 1 egg 2 A with 2 eggs 3 N with 1 egg 2 N with 2 eggs 1 N with 3 eggs
Aug 23	(same parasites)		HSB	5 A 6 N	24	No oviposition parasites dead
			GSB	5 A 6 N		
Aug 27	2	Watermelon field	HSB	3 A 2 N	48	No oviposition on GSB 1 HSB N with 1 egg
			GSB	2 A 3 N		
			1974			
July 2	1	*Prunus* sp.	HSB	1 A	72	1 GSB with 36 eggs
			GSB	1 A		1 HSB with 1 egg
			Coreid	1 A		1 coreid with 0 eggs

* HSB -- *Anasa armigera*, the horned squash bug
GSB -- *Acrosternum hilare*, the green stinkbug
Coreid was unidentified
A -- Adult
N -- Nymph

In 1974, six other Hemiptera were observed bearing eggs similar to those of T. pennipes. Four of these were pentatomids, and two were coreids. The pentatomids were Euschistus servus, Podisus maculiventris, Proxys punctulatus Beauv., and Solubea pugnax Fab. One coreid was not identified, while the other was Leptoglossus oppositus Say. Parasites did not survive to the adult stage from any of these specimens except P. maculiventris. Of these six species, only L. oppositus was listed as an alternate host of T. pennipes (Beard, 1940). Specimens of L. oppositus were found in a watermelon field, at a time of high adult parasite population and low horned squash bug population. The other insects were collected from soybeans during periods when adult T. pennipes were present. Egg placement on L. oppositus was very uniform. Of the four specimens collected, three bore eggs on the median dorsal surface of the head. Egg placement on the other hosts was not uniform.

Adult parasites successfully emerged from puparia from two of the specimens of P. maculiventris. These were identified as Hemyda aurata R. D.

Laboratory tests to determine the olfactory response of T. pennipes were made with the horned squash bug, the green stinkbug, soybean foliage, and watermelon foliage. Although the tests were run for up to 10 minutes, no response was noted. The flies were positively phototropic.

Results of the tests conducted on T. pennipes appear in Tables 8 and 9.

STUDIES ON PREDACEOUS STINKBUGS

Prey acceptance data indicate that immatures of the Mexican bean beetle were preferred over all other prey tested. Caterpillars of all sizes were also readily attacked. The data are shown in Table 10.

Data from the field release test with S. anchorago are shown in Table 11. The population of immature Mexican bean beetles was significantly reduced after introduction of the predators. The population of green cloverworms was reduced in all plots, primarily due to fungal disease.

The topical insecticide application test (Table 12) showed that the LD_{50} of the spined soldier bug (to carbaryl) was close to that of Mexican bean beetle adults, which was 0.39 μg/gram. The LD_{50} for S. anchorago was lower, 0.22 μg/gram. The data on the Mexican bean beetle is graphed in Fig. 2.

FUNGAL PATHOGEN ISOLATION

Utilizing Koch's postulates as the procedure for isolation of a fungal pathogen of Lepidoptera, pure cultures of a fungus, Penicillium notatum Westling, were obtained by the crushed host technique. A spore suspension from these cultures was used to infect healthy larvae. The material was sprayed on September 3, 1974. Results of the test appear in Table 14. The diseased larvae in dishes 1 and 2 displayed the same symptoms of infection as those from the field. Culturing the fungus from the laboratory infected specimens yielded pure cultures of P. notatum.

Table 10. -- Prey acceptance rating of 25 adults and nymphs of *Podisus maculiventris* and *Stiretrus anchorago* in the laboratory, 1974.

Prey tested	Host tested†	
	P. maculiventris	*S. anchorago*
E. varivestis larva	5	5
E. varivestis pupa	4	4
E. varivestis adult	2	1
P. scabra larva	3	3
P. scabra pupa	1	1
Leptinotarsa decemlineata (Say) larva*	3	2
Trichoplusia ni (Hubn.) larva*	3	3
young *H. zea* larva	3	3
late instar *H. zea* larva*	3	3
young *Hyphantria cunea* larva	3	3

Approximately 100 specimens of each prey species were tested.

* Between 10 and 40 individuals of these hosts were tested.

† Ratings are as follows:
- 5 -- very readily accepted
- 4 -- readily accepted
- 3 -- accepted
- 2 -- rarely accepted
- 1 -- not accepted

Table 11. -- Number of insects per shake cloth sample (3 row-feet) in plots artificially infested with late instar nymphs of *Stiretrus anchorago*, TRACEC, 1974.

Mexican bean beetles				Green clover-worms	Total Entomophagus
Larvae	Pupae	Adults	Total		
Release rate of 1 per 3 feet					
Before release					
45.5	0.5	1.2	47.2 ± 7.2	10.5	2.7 ± 0.5
After release					
18.0	4.0	16.2	38.2 ± 9.2	2.5	2.5 ± 1.7
Release rate of 1 per 6 feet					
Before release					
39.2	2.0	1.2	42.5 ± 3.1	5.2	2.0 ± 2.2
After release					
12.7	4.0	19.7	36.5 ± 8.7	2.0	5.5 ± 2.4
Control					
22.2	11.2	17.0	50.5 ± 20.9	2.2	4.0 ± 0.8

Average of four samples. Insects released in plot 1 at a rate of 1 per 3 feet on August 28. Insects released in plot 2 at a rate of 1 per 6 feet on September 3. Pre-release counts made on same dates as release. Post-release and control counts made September 10.

Table 12. -- Results of topical insecticide application to adults of *E. varivestis*, TRACEC, 1974.

Insecticide dose μg/g	Number tested	Per cent mortality
	METHOMYL	
1.19	60	90.0
0.59	60	56.0
0.30	60	6.6
0.15	60	1.6
0.07	60	0.0
0.00	60	0.0
	CARBARYL	
4.76	40	100.0
2.38	80	97.5
1.19	80	88.7
0.59	80	62.5
0.30	80	43.7
0.15	40	2.5
0.00	80	2.5

Average weight of (field collected) beetles: 0.026g.

Table 13. -- Results of topical application of carbaryl to adults of *Podisus maculiventris* and *Stiretrus anchorago*, TRACEC, 1974.

Insecticide dose μg g	Number tested	Per cent mortality
	Podisus maculiventris	
1.92	3	100
0.96	3	100
0.48	3	100
0.24	2	0
0.12	2	0
0.06	2	0
0.00	5	0
	Stiretrus anchorago	
1.76	2	100
0.88	2	100
0.44	6	83
0.22	6	50
0.11	5	0
0.05	2	0
0.00	7	0

Field collected and laboratory reared specimens included. Average weight of *Podisus* tested: 0.065g. Average weight of *Stiretrus* tested: 0.071g.

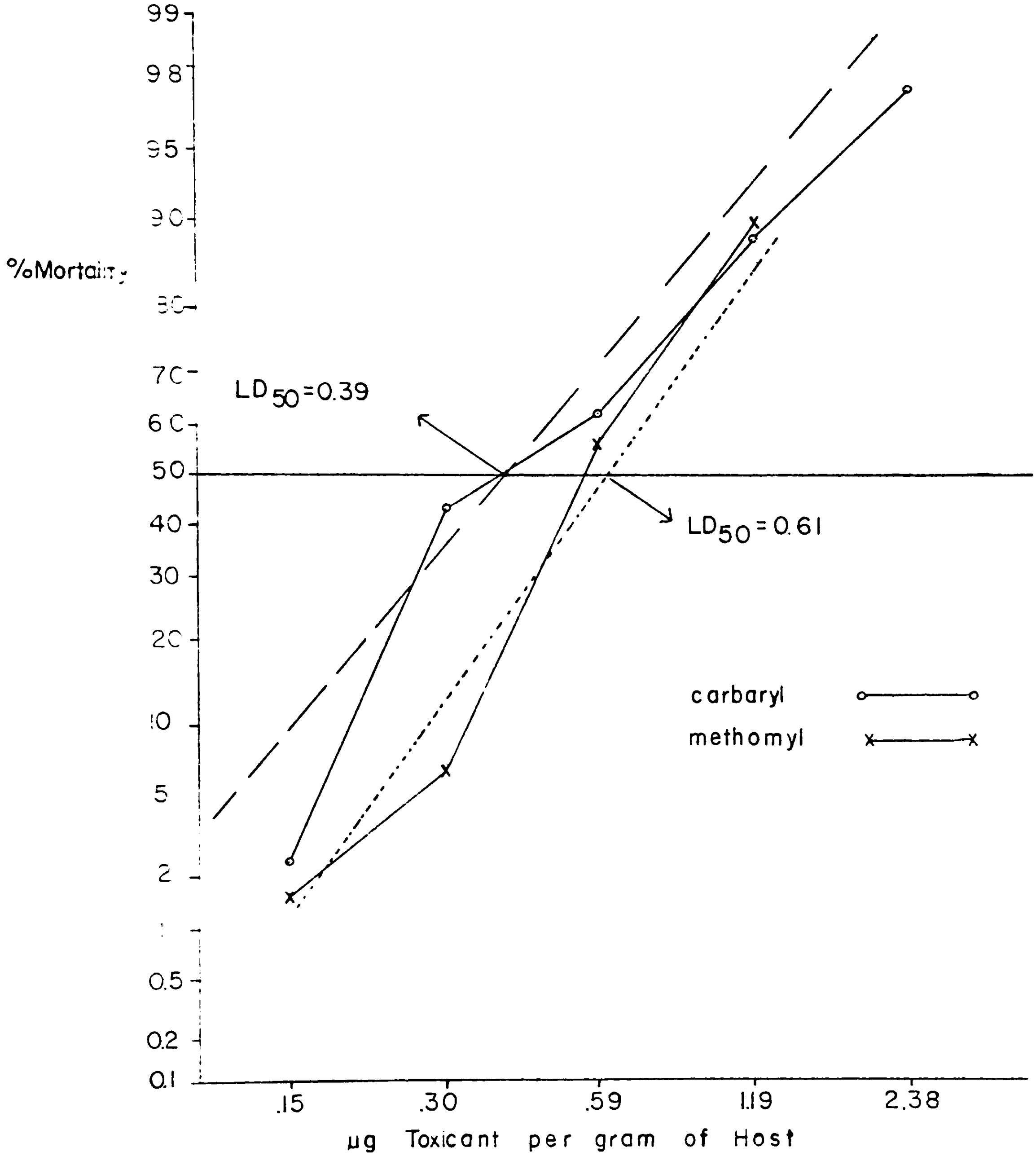

Fig. 2. Mortality of field collected Mexican bean beetles exposed to topical applications of insecticide.

Table 14. -- Observations of *P. scabra* larvae exposed to spores of *P. notatum* obtained from diseased larvae, TRACEC, 1974.

Observation date	Dish 1 3 unsprayed larvae sprayed foliage	Dish 2 3 sprayed larvae unsprayed foliage	Dish 3 3 unsprayed larvae unsprayed foliage
Sept 4	all normal	all normal	all normal
Sept 6	all normal	all normal	all normal
Sept 7	all normal	1 diseased larva	all normal
Sept 9	1 diseased larva	2 diseased larvae	all normal
Sept 10	1 dead larva covered with fungus	2 dead larvae both covered with fungus	all normal

DISCUSSION

COLLECTIONS

Mexican Bean Beetle

No important parasites were found to attack the Mexican bean beetle in the Tidewater area. No parasitized eggs or adults were found. Although six species of Diptera and one of Hymenoptera have been reported as parasites of E. varivestis in the United States (Howard and Landis, 1936) only one parasite, Lespesia aletiae (Tachinidae), was reared in this study. It has not been previously reported from E. varivestis. The possibility exists that larvae parasitized by other tachinids were found, however none survived to the adult stage.

The abnormally small size of the emerged specimens of L. aletiae, the fact that it has not been reported from the Mexican bean beetle, and the high mortality in the pupal stage suggest that the beetle is not completely suited to parasitism by this fly. Also, although it was present (reared from caterpillars) at TRACEC during both collecting years, specimens of the fly were not recovered from E. varivestis at this site. This suggests that L. aletiae parasitizes the beetle only when suitable hosts are difficult to find. Notes made at the Isle of Wight County site (September 9, 1972) support this hypothesis, as larval Lepidoptera were scarce.

Undoubtedly the most important predators of the Mexican bean beetle observed during collecting are the pentatomids P. maculiventris and S. anchorago. The spined soldier bug is the more important of the two due to its greater abundance. Adults and nymphs (except first instar) of both species are active predators. Even the small nymphs were observed attacking large hosts. Both predators often consume only a portion of the prey. Dissections of partially consumed prey revealed no preference for any particular organ. The fact that the prey is incompletely consumed probably increases the attack rate, as more individuals are required to satiate the predator's hunger. This in turn increases the value of the insect as a biological control agent.

Other predators of the beetle are of considerably lesser value and have been infrequently observed preying on the pest. These include nabids, geocorids, Orius insidiosus, and the wheel bug. Predation by Sinea diadema (F.), Acrosternum hilare, carabids, and chrysopids is recorded in the literature (Howard and Landis 1936) but has not been observed in the Tidewater area. Predation on the eggs, probably by adult E. varivestis and other coccinellids, has been observed, although this is of little value in the control of the beetle.

Brown Stinkbug

Limited collecting of this insect has shown that the most important biological control agent affecting its numbers is Euthera tentatrix, a tachinid parasite reared from adults. Collections have not been extensive enough to determine the abundance and distribution of this parasite. Although a few nymphs of the brown stinkbug were seen in the field, parasitized nymphs were not found.

A single predator of stinkbugs has been observed: a cantharid larva which feeds on eggs. The rarity of this predator, and scarcity of observed damaged eggs suggest that it is of little value in controlling stinkbugs.

Green Stinkbug

As with the brown stinkbug, no predators of *A. hilare* have been observed except a cantharid larva which preyed upon eggs. No parasites have been observed to attack the eggs or young nymphs. A single parasite of adults and late instar nymphs, *Trichopoda pennipes*, has been found. The high parasitization rate of the green stinkbug by this tachinid at TRACEC indicates that it can be an important control agent when it is numerous. Although adult parasites were observed in four counties in 1973 and 1974, they were seen in only one of five sites in Lancaster, Middlesex and Westmoreland Counties in these same years. The fly was not present in three of these latter sites despite moderate populations of adult stinkbugs. The uneven distribution of the fly shown from these data lowers its overall value as a control agent of the green stinkbug. Superparasitism of the stinkbug was commonly seen. Few parasitized nymphs were found, even when nymphs were numerous and adults were scarce. Apparently the fly prefers to attack adults. A more detailed analysis of parasitism by this fly follows in a later section.

Green Cloverworm

Data from green cloverworm collections show that a significant per cent (ca. 15 - 30) of larvae are killed by a complex of three dipterous and six hymenopterous parasites. Dipterous parasites (Tachinidae) were recovered in higher numbers in all collections, and thus are considered to be the more important parasites of *P. scabra*. As a group, the Hymenoptera are considered to be of lesser value.

One hymenopteran, *Mesochorus discitergus*, is reported by Barry (1970) to be a hyperparasite of the green cloverworm. He has reared this ichneumonid from *Rogas nolophanae* Ashmead and *Protomicroplitis facetosa*. Other hosts of this wasp listed by Muesbeck *et al*. (1951) include species of *Apanteles*, *Meteorus* and *Microgaster*. The host of the single specimen of *M. discitergus* in our study was not inspected for signs of hyperparasitism and thus it is possible that it actually parasitized a specimen of *Protomicroplitis* or another hymenopteran. The cocoon of another hyperparasitic wasp, *Ceratosmicra meteori*, was found on foliage in a soybean field in which the only phytophagus insect was *P. scabra*. This insect has also been reported by Barry (1970) as a hyperparasite of the green cloverworm, and a parasite of *Rogas nolophanae*.

Of the remaining Hymenoptera reared in this study, only *P. facetosa* has been reported in the literature as attacking the green cloverworm. *Brachymeria ovata*, *Venturia nigriscapus*, *Coccygomimus aequalis* and *Campoletis flavicincta* apparently have not been reported from this host.

Chaetophlepsis *sp*., *Lespesia* *aletiae*, and *Winthemia* *sinuata* have all been reported in the literature as parasites of *P*. *scabra*. Barry (1970), Lentz and Pedigo (1974) and Whiteside *et* *al*. (1967) all have indicated *W*. *sinuata* to be an important parasite, as has been found in this study. *L*. *aletiae* has been reported by Sherman, while *Chaetophlepsis* *sp*. has been reported by Barry (1970) and Whiteside *et* *al*. (1967).

Observations made during collection indicate that predation is also an important mortality factor of green cloverworm larvae. It is difficult to assess the relative values of the predators, as no quantitative measurements were made, but the most frequently observed predation was by *Polistes* wasps and the pentatomids *P*. *maculiventris* and *S*. *anchorago*. These are large predators which usually attack the larger larvae, and this may be the reason that they were so frequently observed. Predation by smaller insects is less easily observed, due to the small size of the predator and the prey.

Fungal infection is an important larval mortality factor during favorable environmental conditions. In this study it was the only biological control agent that was observed to cause population declines, which were sometimes quite dramatic. Epidemics of disease occur only during periods of warm, moist weather. Collections at TRACEC in 1973 were terminated after an epidemic of fungal disease eliminated most of the larvae. Observations made on August 27 showed more than half of the larvae in the field were killed by fungal disease. Symptoms of the disease have remained constant from year to year, although two different genera of fungi have been identified as pathogens. This may be due to identical symptoms produced by two fungi, or difficulty in identification.

Corn Earworm

The only parasite of H. zea found in this study, Winthemia rufopicta (Bigot), is mentioned as a parasite of the earworm by Bottrell et al. (1968). The incidence of parasitization was insignificant. Predation by entomophagus insects likewise was insignificant. No instance of predation was observed in this study, although J. C. Smith (TRACEC) has observed a specimen of Arilus cristatus feeding on a late instar larva in the field. Fungal disease has been observed to reduce populations of this insect, however in the witnessed cases the disease did not affect the larvae quickly enough to avoid serious damage to the crop. Because of the low tolerance for the type of damage incurred by this insect, none of the biological control agents which affect it were judged to be of value in reducing the pest population and the resultant damage.

Salt Marsh Caterpillar

Very few larvae of E. acrea were observed at TRACEC, however parasitization and predation of those few was significant. Of the seven specimens seen at this location in 1972, three were parasitized and two were killed by Polistes wasps. Reference to parasitization of this host by either of the parasites, Lespesia aletiae and Apanteles diacrisiae, could not be found. Based on such limited observations, the value of natural agents in controlling the low populations of this insect can only be speculated.

Yellow Striped Armyworm

Of the two parasites reared from P. ornithogalli in this study, only one, Campoletis flavicincta, has previously been reported from this host (Muesbeck et al., 1951). It parasitizes very small larvae, and has also been recovered from small green cloverworms. L. aletiae was reared from late instar larvae. Fungal disease is a more important control agent of the insect than parasitism. Populations of this minor defoliator were low in the Tidewater area during this study.

PLOT WORK RESULTS

Spray Test Samples

Due to the low numbers of beneficial insects in the samples, it is difficult to evaluate the effects of different chemical sprays. Also, random variation accounts for a significant per cent of the differences between treatments. A number of treatment samples show higher populations of beneficial insects than the check. Were the plot size and sample size increased, this sampling error would decrease, but this was not possible within our limitations.

In comparing the sweep net data from both years, some trends are visable. Monocrotophos is one material which definitely reduced populations of beneficial insects (and spiders). Azinphosmethyl, tested only in 1973, also reduced populations of beneficial insects and spiders. Methomyl and carbaryl, two commonly used soybean insecticides, both somewhat reduced populations of predators.

Pre- and post-treatment shake cloth counts were made on the early treatments of the 1974 spray test. Generally, counts of beneficial insects and spiders were higher in the shake cloth samples than in the sweep net samples. Considering that the shake cloth sample area is only three row-feet and the sweep net sample area was much larger (ten 180° sweeps across two center rows), the shake cloth technique is considered a better sampling method for the types of predators counted. The possibility that the differences were due to an extensive population decline of the predators during the two weeks between samplings is remote. More likely is the possibility that the predators predominantly occupy the middle and lower portions of the plants, which are not well sampled by sweeping.

Shake cloth samples also differ from the sweep net samples in that they show an increase of predators (except in monocrotophos plots) after treatment, while the sweep net samples indicate population declines after treatment with the same materials. This change can easily be attributed to differences in the time of day that the samples were taken. Dumas et al. (1962, 1964) have demonstrated that the time of day, as well as other factors, can significantly affect sampling of predators in field crops. This is the most logical explanation for the discrepancies observed at TRACEC, as the pre-treatment counts were made at mid-afternoon, and the post-treatment counts were made in early morning.

STUDIES ON *Trichopoda pennipes*

Data collected at TRACEC show that *T. pennipes* is a solitary internal parasite of adults and late instar nymphs of the green stinkbug. There does not appear to be any mechanism to avoid oviposition on a parasitized stinkbug, as a great many superparasitized hosts were found. Apparently, only one parasite completes development in each host. Elimination of excess larvae in superparasitized hosts must take place during the early instars, as only one maggot could be found in dissected superparasitized hosts (small maggots were easily missed). Beard (1940) attributed this elimination to cannibalism of young maggots.

Although the fly prefers the posterior ventral surface for oviposition on adult squash bugs (Beard 1940), flies at TRACEC exhibit a slight preference for the anterior ventral surface of the green stinkbug (Fig. 1). Shahjahan (1968) noted a preference for this same area on the southern green stinkbug in Hawaii. He also noted that successful penetration of the host by hatching maggots is affected by the position of the eggs on the body of the host. Larvae from eggs which are laid on the proboscis, antennae, or wing membrane fail to penetrate the host. Beard (1940) stated that the wings of squash bugs and the thickened cuticle of the thorax in overwintering squash bugs are areas through which the hatching maggots cannot penetrate.

Messenger and van den Bosch (1971) indicated that there are three strains of *T. pennipes* in the U. S. The eastern strain attacks the squash bug, the southeastern strain attacks pentatomids, and the western strain attacks a plant bug. In general, insects of each strain do poorly on or do not attack other hosts. As pentatomid parasites, the flies in Tidewater should be of the southeastern strain.

Data from the host preference test incidate that both the green stinkbug and the horned squash bug are readily attacked. The parasite was very reluctant to switch to a host other than the one for which it was searching when captured. Flies which were caught in soybeans generally would not oviposit on the horned squash bug (not found in soybeans), while those which were captured on watermelon vines would not oviposit on stinkbugs. There are two possible explanations for this: 1. Once an adult female begins searching for and parasitizing a particular species, it becomes "imprinted" and will not readily attack an alternate host, or 2. Both the eastern and the southeastern strains of _T. pennipes_ may occur in this area, and individuals of each do not readily attack the host(s) of the other strain.

Although Mitchell and Mau (1971) have shown that adult females of _T. pennipes_ respond to pheremones of (male) _N. viridula_, data from our test with the green stinkbug and the horned squash bug failed to show such a response. This may be due to low air flow in the apparatus, failure of the host to produce pheremone, or insufficient odor to elicit the response. Orientation of the fly by stinkbug "odors" (if it does occur) would be useful, because the stinkbugs move to different plants as the season progresses.

Adults of _T. pennipes_ were seen in the field only for short periods of several days. The spacing of these periods (Table 9) suggests a life cycle of approximately 22 days, as suggested by Beard (1940). In 1974, the first (overwintering) generation adults appeared on June 6 and 12. Second generation adults were then seen on June 28 and July 1. Third generation adults appeared from July 23 - August 1, and fourth generation flies were found from August 19 - 26. One set of observations, from the watermelon field, does not fit this schedule. Few flies were seen at that site, and the theory of two strains existing in the Suffolk area could explain the discrepancy. The flies at this site, as parasites of Anasa armigera, may be of the eastern strain.

Conditions were favorable for a fifth generation of flies (emerging September 10 - 17) in Suffolk, but this was not seen. Thus four generations of the fly occurred at TRACEC in 1974, with the possibility that a fifth did occur.

T. pennipes has been observed in abundance in Suffolk, and has been commonly seen in several surrounding counties. Adults or parasitized bugs have never been observed in the Northern Neck area, although a single specimen was reared from a stinkbug in Middlesex County (1973). Perhaps the geographical distribution of the southeastern strain is such that it only occurs in the southeastern part of Virginia, leaving the more northern areas to the eastern strain, which is rare in that area (very few melons and squash are grown there). If only the southeastern strain occurs in Virginia, perhaps the scarcity of hosts earlier in the year accounts for the fly's absence in the Northern Neck area.

STUDIES ON Podisus maculiventris AND Stiretrus anchorago

Laboratory testing with the predaceous stinkbugs has shown that immatures of the Mexican bean beetle are readily accepted prey. Individuals which fed exclusively on E. varivestis larvae did not accept other prey as readily as those which received a mixed diet. The observation that the stinkbugs preferred larvae to pupae parallels observations by Iwao and Wellington (1970) that they stalked active caterpillars more consistently than inactive ones. Larvae of the Mexican bean beetle are perfectly suited to predation by the spined soldier bug and S. anchorago because of the previously discussed point, and because of their total lack of defensive mechanisms against predation. When attacked, their attempts to escape are very feeble and ineffective. Larvae of the green cloverworm, on the other hand, violently flip away from the predator at the first contact of its beak or antennae. This defensive mechanism is fairly effective in preventing predation by the stinkbugs. Corn earworm larvae are very well protected against predation by the stinkbugs, due to their extremely aggressive disposition. Upon being attacked, H. zea larvae counterattack the predator, and often succeed in discouraging further aggression.

The fact that the predators often partially consume their prey directly affects the attack rate. Mukerji and LeRoux (1969) reported that hunger directly affected the attack rate of the spined soldier bug. Their conclusion that the stinkbug will kill more small lepidopterous prey than large ones is not confirmed in our study, as they do not always completely consume the prey. If they did completely consume their prey, the rate of attack would be lower.

The results of the small scale field testing of S. anchorago at TRACEC were encouraging. The plot in which nymphs were released at a rate of 1 per 3 feet showed a 20% decrease in the Mexican bean beetle population after 13 days. The population in the control plots was virtually unchanged. In the second plot, with a release density of 1 per 6 feet, the population of Mexican bean beetles declined 15% in seven days. The population of green cloverworms had also declined in both plots, due to fungal disease. Further observations of these plots were not made, because the nymphs became adults and dispersed into the surrounding field.

Warren and Wallis (1971) reported that the average development period for the spined soldier bug from egg to adult, was 23-35 days. A pre-mating period of 21 days was then followed by a pre-oviposition period averaging 10 days. Adults lived an average of 100 days. Thus, the minimum time span between generations is approximately 60 days. With the characteristic time lag between predator and prey populations, and the fact that the life cycle of the Mexican bean beetle can be as little as 45 days, the stinkbug population cannot keep up with increases in the beetle population. In addition, the population of E. varivestis is often fairly high before the predators first appear in the field.

The topical chemical application test showed that the LD_{50} for E. varivestis adults was 0.39 μg/gram. The test on P. maculiventris, although very limited, showed approximately the same LD_{50} level. The small test on S. anchorago showed an LD_{50} of 0.22 μg/gram.

SUMMARY AND CONCLUSIONS

A number of biological control agents of major importance were found in this study, and they are listed by host in Table 15.

Table 15. -- Major biological control agents of soybean insect pests in the Tidewater area of Virginia.

Pest Species	Natural Enemy	Classification
Epilachna varivestis	*Podisus maculiventris*	Predator
	Stiretrus anchorago	Predator
Acrosternum hilare	*Trichopoda pennipes*	Parasite
Euschistus servus	*Euthera tentatrix*	Parasite
Plathypena scabra	"Muscardine" fungi	Pathogens
	Winthemia sinuata	Parasite
	Lespesia aletiae	Parasite
Heliothis zea	"Muscardine" fungi	Pathogens

Mexican Bean Beetle

Biological control agents which attack the Mexican bean beetle in Tidewater are not effective enough to keep populations of the beetle in check. No significant parasitism of any of the life stages occurs. No fungi, bacteria or viruses affect their numbers. Predation is the only type of biological control which affects the insect, and most of this occurs in the larval stage. The most effective predator of *E. varivestis* in Tidewater is *Podisus maculiventris*, a predacious stink-bug. Both adults and nymphs are active predators, and rarely feed upon plant material. Together with Stiretrus anchorago, another predaceous pentatomid, they can reduce beetle populations, but cannot hold them below the economic injury level at the predator densities commonly seen in the field. The fact that the predators appear only in low numbers, late in the season, and the fact that their numbers cannot keep up with prey population increases suggest that they are of little use in controlling E. varivestis. Results of the laboratory rearing in this study suggest that mass rearing and augmentation of predator populations would be a difficult control method.

Brown Stinkbug

Euschistus servus occurs in relatively low numbers in Tidewater, and is parasitized by a tachinid fly, Euthera tentatrix. The rate of parasitization (of adults) is as high as 24% at TRACEC. The data are insufficient to determine the effect on the host population.

Green Stinkbug

There is only one observed bio-control agent which significantly affects populations of A. hilare in Tidewater. This agent, Trichopoda pennipes, is a fly which parasitizes an average of 50% of the adults in soybeans at TRACEC. It is of importance only in localized areas, and is common in southeastern Virginia, and less common in the Northern Neck area. It is probably an important population control factor of the stinkbug at TRACEC and may be the reason for the failure of the insect to increase to economic numbers at this site. The insect is an internal parasite of adults and large nymphs, and its eggs are placed randomly on the body surface. Superparasitism is common, but never does more than one maggot fully develop in each host. The adult is short lived, and is commonly seen on weed flowers. There are at least four generations per year at TRACEC, with the last two found in soybeans. The first generations parasitize stinkbugs on garden plants, weeds, and shrubs. The insect also attacks Anasa armigera, a coreid found in cantaloupe, squash, and watermelon fields. There is no conclusive evidence of other hosts in the Tidewater area. The possibility exists that there are two strains of the fly in the Tidewater area, one which attacks the green stinkbug, and one which attacks A. armigera. Unfortunately, this valuable parasite is not common in much of the Tidewater area. Further study may shed light on the reasons for its uneven distribution. Further study may also establish which strain(s) of the fly is (are) present in the Tidewater area, and determine the effects of alternate hosts (such as Anasa armigera) on the parasite population.

Green Cloverworm

A great number of biological control agents attack P. scabra in the Tidewater area, and undoubtedly account for its status as only a minor pest. The most important biological control agent which attacks P. scabra is fungal disease. This occurs every year in the Tidewater area (although it may be rare in some years). When environmental conditions are optimal, the desease becomes widespread. (It affects all lepidopterous larvae.) Pupae are not affected. High populations of larvae can be severely reduced in a matter of days. One or more pathogens may be involved in the disease, but the symptoms are always that of a white muscardine fungus.

Parasitism and predation are also important factors in reducing larval populations. A complex of nine insects parasitize approximately 20% of the larvae, while predation by a number of insects also causes significant mortality. The tachinid flies *Lespesia aletiae* and *Winthemia sinuata* are the most important larval parasites, while nabids, geocorids, predaceous stinkbugs, and *Polistes* wasps are the most important predators of the larvae. Less important larval parasites include *Chaetophlepsis sp.* (Tachinidae), *Campoletis flavicincta* (Ichneumonidae), *Venturia nigriscapus* (Ichneumonidae), and *Protomicroplitis facetosa* (Braconidae). *Coccygomimus aequalis* (Ichneumonidae) and *Brachymeria ovata* (Chalcididae) are larval-pupal or pupal parasites. *Mesochorus discitergus* (Ichneumonidae) is either a hyperparasite, or a larval parasite. A hyperparasitic chalcid, *Ceratosmicra meteori*, is associated with *P. scabra* in Tidewater.

It seems most likely that the combination of predation, parasitism and disease keeps the green cloverworm from building up to economic numbers on soybeans in the Tidewater area.

Corn Earworm

The most important biological control agent of *H. zea* on soybeans in Tidewater is fungal disease. It affects the earworm only under warm, moist conditions. However, even under optimum conditions, the disease does not reduce the larval population quickly enough to prevent serious crop damage.

One parasite of H. zea, Winthemia rufopicta (Tachinidae), attacks the larvae in Tidewater. As with predation, parasitism does not significantly affect populations of the host. In general, biological controls do not work for this insect, as tolerance for its damage is very low.

Insecticidal Effects on Entomophagus Insects

Data on the effects of systemic insecticide granules on beneficial insects were inconclusive. While they were not shown to be detrimental to entomophagus insect populations, neither were they proven to be harmless. Data on insecticidal sprays is more meaningful. Several insecticides are detrimental to beneficial insect populations, while those commonly used on soybeans (carbaryl and methomyl) seem to be somewhat detrimental. Limited data on topical application of carbaryl in the laboratory suggests that the LD_{50} for S. anchorago is lower than that for the Mexican bean beetle, while that of P. maculiventris is approximately the same as that for the beetle.

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APPENDIX

Appendix Table 1. -- Parasites of *Heliothis zea*.

Taxonomic group	Species	References
Diptera		
Phoridae	*Aphiochaeta sp.*	2
Sarcophagidae	*Boettcheria latisterna* Park.	1
	Helicobia rapax (Walker)	1
	Microcerella scrofa (Ald.)	1
Tachinidae	*Archytas californiae* (Walk.)	2
	A. marmoratus (Towns.)	1
	Eucelatoria armigera (Coq.)	1,2,3,6
	Euphorocera claripennis (Macq.)	2
	E. tachinomoides Townsend	3
	Lespesia archippivora (Riley)	1,3,4
	Lespesia frenchii (Will.)	1
	Voria aurifrons (Towns.)	3
	Winthemia rufopicta (Bigot)	3
Hymenoptera		
Braconidae	*Apanteles marginivestris* (Cress.)	2
	Bracon mellitor Say	1
	Chelonus texanus Cress.	2
	Meteorus leviventris (Wesm.)	2
	Microplitis croceipes (Cress.)	1,3,7,8
	Rogas melleus (Cress.)	1
	Vipio rugator (Say)	1
Eulophidae	*Euplectrus comstockii* Howard	1

(continued)

References:
1 Bibby (1942)
2 Blanchard and Conger (1932)
3 Bottrell *et al.* (1968)
4 Bryan *et al.* (1968)
5 Gonzalez *et al.* (1970)
6 Jackson *et al.* (1969)
7 Lewis (1970)
8 Snow *et al.* (1966)

Appendix Table 1., continued. -- Parasites of *Heliothis zea*.

Taxonomic group	Species	References
Hymenoptera (continued)		
Ichneumonidae	*Campoletis argentrifrons* (Cress.)	1
	Cremastus sp.	3
	Cryptus tejonensis Cress.	2
	Hyposoter exiguae (Vier.)	2
	Hyposoter sp.	8
	Ichneumon difficilis Cress.	2
	Pristomerus pacificus appalachianus Vier.	1
	Pristomerus spinator (F.) [sic]	3
Scelionidae	*Telenomus heliothidis* Ashm.	1
Trichogrammatidae	*Trichogramma minutum* Riley	1
	T. pretiosum Riley	5

References:
1 Bibby (1942)
2 Blanchard and Conger (1932)
3 Bottrell *et al.* (1968)
4 Bryan *et al.* (1968)
5 Gonzalez *et al.* (1970)
6 Jackson *et al.* (1969)
7 Lewis (1970)
8 Snow *et al.* (1966)

Appendix Table 2. -- Entomophagus insects which attack *Plathypena scabra*.

Taxonomic group	Species	References
	PARASITES	
Diptera		
Bombyliidae	*Villa lateralis lateralis* (Say)	5
Sarcophagidae	*Boettcheria cimbicis* (Towns.)	5
	Helicobia rapax (Walker)	6
Tachinidae	*Chaetophlepsis* n.s.	1,6
	Compsilura concinnata (Meigen)	6
	Copecrypta ruficauda (Wulp)	1
	Euphorocera claripennis (Macq.)	5
	E. floridensis Townsend	5,6
	Eusisyropa blanda (O.-S.)	2
	E. boarmiae (Coq.)	5
	Lespesia aletiae (Riley)	5
	Winthemia sp.	4
	W. sinuata Rein	1,3,6
Hymenoptera		
Braconidae	*Apanteles marginivestris* (Cress.)	1,6
	Meteorus autographae Muesbeck	1,6
	Meteorus sp.	1
	Microgaster facetosa Weed	1,6
	Rogas nolophanae Ashm.	1,3,4
Eulophidae	*Euplectrus plathypenae* How.	2
Ichneumonidae	*Campopleginae* n. sp. n. gen. [sic]	5
	Charops annulipes Ashm.	6
	Isdromas lycaenae (How.)	6

(continued)

References: 1 Barry (1970)
2 Chittenden (1901)
3 Lentz and Pedigo (1974)
4 Pedigo *et al*. (1973)
5 Sherman (1920)
6 Whiteside *et al*. (1967)

Appendix Table 2., continued. -- Entomophagus insects which attack *Plathypena scabra*.

Taxonomic group	Species	References
Hymenoptera (continued)		
Trichogrammatidae	*Trichogramma minutum* Riley	5
	HYPERPARASITES	
Hymenoptera		
Chalcididae	*Ceratosmicra meteori* Burks	1
Ichneumonidae	*Mesochorus discitergus* (Say)	1
	PREDATORS	
Heteroptera	*Nabis sp.*	4
	Orius insidiosus (Say)	4
Hymenoptera	*Polistes spp.*	5
Neuroptera	*Chrysopa sp.*	4

References:
1 Barry (1970)
2 Chittenden (1901)
3 Lentz and Pedigo (1974)
4 Pedigo *et al.* (1973)
5 Sherman (1920)
6 Whiteside *et al.* (1967)

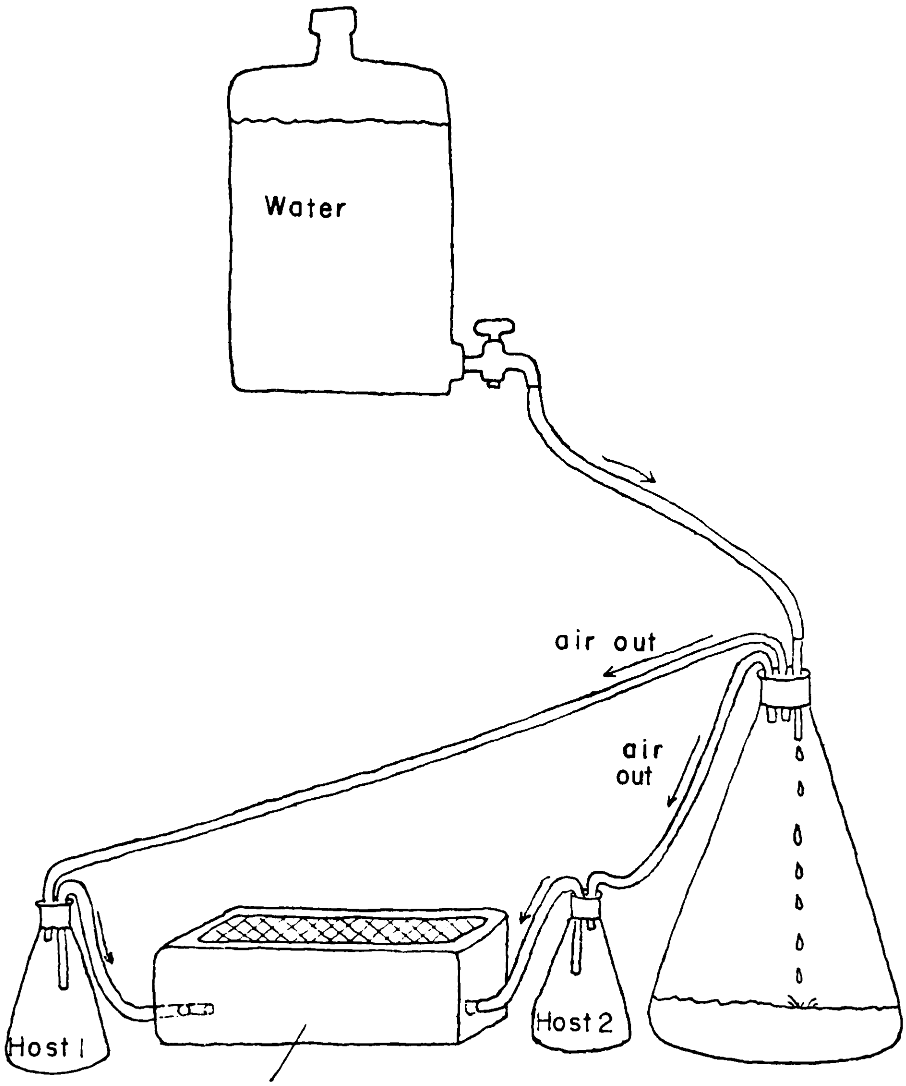

Fig. 3. Apparatus used to test olfactory response of _Trichopoda pennipes_ adults to various hosts. Parasite chamber is clear plastic, 3" X 5" X 12". Tubing is flexible plastic, 3/8" diameter.

VITA

Alan T. Eaton was born in Brockton, Massachusetts on August 25, 1950, son of Richard K. and Sarah A. Eaton. He graduated from Lexington High School in 1968 and attended the University of Massachusetts. In 1972 he earned a B. S. in Entomology from the University, where he worked as a research assistant in Entomology. He began graduate study at Virginia Polytechnic Institute and State University in June 1972.

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Signed Alan T. Eaton

BIOLOGICAL CONTROL AGENTS OF SOYBEAN INSECT PESTS

IN THE TIDEWATER AREA OF VIRGINIA

by

Alan Tucker Eaton

(ABSTRACT)

The species of biological control agents which affect soybean pests in the Tidewater area were investigated, and their relative values were determined.

Two pentatomids, Podisus maculiventris Say and Stiretrus anchorago F., were the only significant bio-control agents which attacked the Mexican bean beetle, Epilachna varivestis Mulsant. These predators were not able to hold the pest population in check.

A parasitic fly, Trichopoda pennipes F. was the only important biological control agent which attacked the green stinkbug, Acrosternum hilare (Say). Host and habitat preferences of the fly suggested the presence of two strains in Virginia. Distribution of the fly was very uneven.

Fungal disease was found to be an important control agent of many (larval) Lepidoptera. It was the most important control agent of Plathypena scabra (F.). P. scabra was also controlled by predation and parasitism. Nine parasites attacked the larvae and pupae.

No effective biological controls were found for the corn earworm, Heliothis zea (Boddie). The only significant control agent, fungal disease, acted too slowly to prevent economic damage by this insect.