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INSECTICIDE AND GROWTH REGULATOR EFFECTS ON THE LEAFMINER, *Liriomyza trifolii* (DIPTERA: AGROMYZIDAE), IN CELERY AND OBSERVATIONS ON PARASITISM

E. Grafius and J. Hayden

**ABSTRACT**

The effects of different insecticides were compared on survival and development of the leafminer, *L. trifolii*, in celery in Michigan and parasitism was assessed in this non-resident population. Avermectin, thiocyclam, and cyromazine effectively controlled *L. trifolii* larvae or prevented successful emergence as adults. Moderate to high levels of resistance to permethrin and chlorpyrifos were present. Avermectin caused high mortality of all larval stages and no adults successfully emerged. Thiocyclam caused high mortality to all larval stages, but did not affect adult emergence from the surviving larvae. Cyromazine acted most strongly against early stage larvae before visible mines were present, caused little direct mortality of larger larvae, but prevented successful adult emergence. No parasitoids emerged from 2029 larvae collected and reared, in contrast to studies in sites where *L. trifolii* is a year-round resident.


*Liriomyza trifolii* apparently does not overwinter in Michigan except in greenhouses. Field infestations are generally below economic levels, occur infrequently, and can usually be traced to importation of infested plant material, such as transplants, greenhouse plants, or celery for packing and shipping. Initial introductions to California, Canada, Colombia, and England are also thought to be the result of imported plant material (Parella et al. 1981, Lindquist 1983). Since infestations in Michigan celery fields are not common, no information is available on the susceptibility or resistance to insecticides of the presumably-imported *L. trifolii* or parasitoids associated with it.

The objective of this study was to compare effectiveness and action of experimental and registered materials against *L. trifolii* in Michigan celery. The interactions between pesticide applications, pesticide resistance in the pest, and biological control are important for management of *Liriomyza* (Oatman and Kennedy 1976). However, the importance of parasitism in non-resident populations of *L. trifolii* is unknown. Therefore, a secondary objective of the study was a preliminary assessment of parasitoids attacking the leafminers and evaluation of the effects of treatment on parasitism.

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Materials and Methods

Trials were conducted in a severely infested celery field near Hudsonville MI (Ottawa County). Initial leafminer populations had apparently been introduced from chrysanthemums discarded from a nearby greenhouse. Adult density was >500 per 100 sweeps and flies were present on nearly every new leaf. Estimated defoliation exceeded 80% and only new growth was free of visible mines. Plots were 3 rows by 25 ft., arranged linearly along the eastern border of the field with three replications per treatment, arranged in a randomized complete block design. Plots were numbered randomly within each block and all sampling and evaluations were done without knowledge of which treatment had been applied. Treatments were applied to the center row of each plot on 10 Sept. and 17 Sept. 1985 with a single nozzle CO₂ hand sprayer at 467 l/ha (50 gpa) and 2.11 kg/cm² (30 psi).

The following materials were selected to give a broad range of insecticide types and modes of action: (1) a standard organophosphate (chlorpyrifos), (2) a pyrethroid (permethrin), (3) an insect growth regulator (cyromazine), (4) a microbial product (avermectin), and (5) a new type of insecticide (thiocyclam). Rates were: avermectin, 0.17 kg ai/ha (kg active ingredient/ha); thiocyclam, 0.56 kg ai/ha; cyromazine, 0.84 kg ai/ha; chlorpyrifos, 1.87 kg ai/ha; and permethrin 0.19 kg ai/ha.

Ten leaflets from the new growth were collected at random from each plot after the first treatment, as soon as the spray had dried. The leaflets were too new to have visible mines, but numerous feeding and oviposition punctures were present on each leaflet. Leaflets from each plot were placed in plastic bags, returned to the laboratory and kept at room temperature (20–25°C). Larvae that emerged in the plastic bags were counted 9 and 13 days after collection and were retained in screen-covered vials. Adult emergence was assessed 22 days after collection. Observations for parasitoids were made when emerged larvae were transferred to vials and again when adult emergence was assessed.

Ten older leaflets with visible mines from each plot were also randomly collected immediately after treatment and returned to the laboratory for evaluation. Because of the growth habit of celery (leaves and stalks produced on alternating sides of the plant), leaflets of approximately the same age could be selected from each plant. The third or fourth oldest leaflets from randomly-selected plants were chosen for sampling. Mature larvae began emerging from these leaflets within 24h of collection. Leaflets were retained in plastic bags and larvae and pupae were counted 6 days after collection and retained in vials. Numbers of adults emerged from new and old leaflets were recorded 20 days after collection. Plastic bags and vials were also checked for the presence of emerged parasitoids. Percent successful adult emergence was defined as: 100 × (# adults + # larvae emerging from the respective leaflet).

On 25 Sept., 8 days after the second application, 3 plants were randomly selected from each plot. The terminal leaflet from each of the newest 3 stalks was collected from each plant and the number of visible mines recorded. The oldest of these 3 stalks was generally the same age as stalks sampled as "new growth without mines" at the beginning of the study. Leaflets were retained as before and the numbers of larvae emerging were recorded. Adult emergence was recorded and observations for parasitoid emergence were made 22 days after collection.

Results and Discussion

Survival and development. Dead adults were observed on foliage in all treatments immediately after spraying on 10 Sept. However, chlorpyrifos and permethrin were not effective in controlling the larvae or reducing new infestations. Chlorpyrifos is moderately effective in controlling L. trifolii in greenhouses in Michigan and Ohio (Smitley, Michigan State Univ., Pers. Comm.; Lindquist 1985), but had little or no effect on L. trifolii in studies in California (Parella et al. 1982b). In this study, avermectin, thiocyclam, and cyromazine reduced the number of larvae emerging from the new growth almost to zero (Figure 1a). Chlorpyrifos treatment after visible mines were present reduced
the numbers of larvae, but levels were still much higher than in either avermectin or thiocyclam treatments (Figure 1b). Avermectin and thiocyclam were highly effective even on the larger larvae present in older leaves with visible mines (Figure 1b). Cyromazine treatment only moderately reduced the numbers of larvae emerging to pupate from the older leaves, but surviving larvae did not successfully emerge as adults. Permethrin had little or no effect on larval or adult numbers from leaflets with no visible mines or leaflets with visible mines. This was similar to results reported by Parella et al. (1982b) for oxamyl and methomyl. Cyromazine may not be effective in reducing larval activity if larvae are already partially grown but will kill early instars and will prevent adult emergence. In contrast, in studies by Parella et al. (1982a) and Parella (1983) on chrysanthemum, cyromazine was as effective on third instars as on newly-eclosed larvae. These results contradict data from the present study. Differences may be due to variations in maturity of larvae, higher trans-cuticular movement of the chemical in chrysanthemum, differences in application rates, or other factors. Differences in tolerance to cyromazine may also exist between populations. Cyromazine resistance has recently been reported in house flies, Musca domestica L. (Bloomcamp et al. 1987) and the Michigan population was tested after the registration of cyromazine for L. trifolii control in Florida.

Numbers of new mines 15 days after initial treatment were significantly reduced by avermectin, thiocyclam and cyromazine, even under the extreme pressure of the small plot design (Table 1). However, the numbers of larvae that emerged from leaflets collected at the end of the experiment were significantly higher in the thiocyclam treatment than in either avermectin or cyromazine treatments. Numbers of adults emerged from the thiocyclam-treated leaflets were not significantly lower than from permethrin- treated or untreated leaflets. The intervals between treatments and between the last treatment and final sampling were perhaps too long for thiocyclam to be effective.

Cyromazine appeared to interfere with the pupation process and showed a clear effect on percent successful adult emergence (Table 2). High numbers of larvae emerged from cyromazine-treated leaves with visible mines (Fig. 1b), but most failed to pupate and none emerged as adults (Table 2). Avermectin treatment may have also affected pupation and adult emergence. The few larvae that did emerge from avermectin-treated leaflets did not mature to adults. Permethrin, chlorpyrifos, and thiocyclam had little or no effect on percent successful adult emergence from surviving larvae (Table 2). No assessment of adult fecundity was made.

Parasitism. Although 2029 larvae were collected from all treatments (including 783 from untreated plots) and 784 were reared to adults, there was no indication of parasitism. This complete lack of parasitoids was in marked contrast to results reported from other locations. In California, Trumble and Nakakihara (1983) reported at least 7 species of parasitoids from Liriomyza sativae Blanchard and L. trifolii and Oatman and Kennedy (1976) reported 9 species of parasitoids with up to 100% parasitism of L. sativae. Johnson (1987) reported more than 15 species of parasitoids and as much as 96% parasitism of L. trifolii and L. sativae in Hawaii.

In contrast to the populations studied previously, L. trifolii is not known to overwinter in Michigan and the study population was presumably introduced within a few weeks or months of the study. The lack of parasitism may be the result of: (1) few or no native parasitoids (perhaps attacking native agromyzids) in nearby crops or weeds, (2) few or no parasitoids introduced with the original pest population, (3) parasitoids eliminated by heavy insecticide applications in the greenhouse before escape or release, (4) parasitoids eliminated by the intensive treatment of the celery field before initiation of the experiments, or (5) insufficient time allowed or unsuitable conditions for parasitoid development and emergence after collection. The latter is unlikely, since samples were held in plastic bags and then in vials for a total of 20 to 22 days and at least some of the parasitoids would have been nearly mature at the time of collection and would have emerged, regardless of conditions. Also, the ca. 50% successful emergence of L. trifolii indicates that conditions were probably adequate. Smitley (Michigan State Univ., Pers. Comm.) has observed no significant parasitism in commercial greenhouses in Michigan. Intensive insecticide treatments in the greenhouse and in the field, perhaps combined with
Fig. 1. Larval emergence and subsequent adult success from leaflets collected immediately after initial treatment. A. Leaflets without visible mines at the time of collection. B. Leaflets with visible mines at the time of collection. Larval or adult numbers with different letters are significantly different (ANOVA, SNK test, p < .05).
Table 1. Number of visible mines, larval emergence, and adults from leaflets collected at the end of the study (15 days after initial treatment).

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>Visible mines per leaflet*</th>
<th>Mean no. larvae emerged per leaflet*</th>
<th>Mean no. adults per leaflet*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avermectin 0.15 SC 0.17 kg ai/ha</td>
<td>1.59 a</td>
<td>0.11 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Thiocyclam 50 SP 0.56 kg ai/ha</td>
<td>1.81 a</td>
<td>2.30 b</td>
<td>0.74 ab</td>
</tr>
<tr>
<td>Cyromazine 75 WP 0.84 kg ai/ha</td>
<td>2.63 ab</td>
<td>0.04 a</td>
<td>0.60 a</td>
</tr>
<tr>
<td>Chlorpyrifos 4 E 1.87 kg ai/ha</td>
<td>3.96 bc</td>
<td>3.96 c</td>
<td>1.52 b</td>
</tr>
<tr>
<td>Permethrin 2 EC 0.19 kg ai/ha</td>
<td>3.19 abc</td>
<td>2.96 b</td>
<td>0.93 ab</td>
</tr>
<tr>
<td><strong>Untreated</strong></td>
<td>4.33 c</td>
<td>4.93 d</td>
<td>1.30 ab</td>
</tr>
</tbody>
</table>

*Means followed by different letters are significantly different (SNK test, p < .05).

Table 2. Percent successful adult emergence from larvae reared from leaflets collected immediately after the first treatment or at the end of the study (8 days after the 2nd treatment).

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>Leaflets collected immediately after 1st treatment</th>
<th>Leaflets collected 8 days after 2nd treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% success** without visible mines (% success)**</td>
<td>with visible mines (% success)**</td>
</tr>
<tr>
<td>Avermectin 0.15 SC 0.17 kg ai/ha</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Thiocyclam 50 SP 0.56 kg ai/ha</td>
<td>x</td>
<td>34.3 b</td>
</tr>
<tr>
<td>Cyromazine 75 WP 0.84 kg ai/ha</td>
<td>x</td>
<td>0.0 a</td>
</tr>
<tr>
<td>Chlorpyrifos 4 E 1.87 kg ai/ha</td>
<td>30.0</td>
<td>25.7 b</td>
</tr>
<tr>
<td>Permethrin 2 EC 0.19 kg ai/ha</td>
<td>40.7</td>
<td>42.7 bc</td>
</tr>
<tr>
<td><strong>Untreated</strong></td>
<td>51.0 n.s.</td>
<td>50.0 c</td>
</tr>
</tbody>
</table>

**% success = 100 × (No. adults/No. larvae emerged from each leaflet). Means followed by different letters are significantly different (SNK test, p < .05).

*Excluded from analysis. Less than 5 larvae emerged/treatment (see Fig. 1 and Table 1).

a low rate of parasitoid introduction and low endemic levels, were therefore the most probable causes of the lack of parasitism.

ACKNOWLEDGMENTS

Thanks to Joseph Ingerson-Mahar for his assistance in conducting the research and to Fred Stehr and Dave Smitley for review and comments on the manuscript. Thanks also to the Michigan celery industry and Celery Research, Inc. for their financial support. Michigan Agricultural Experiment Station Journal Article No. 12334.
LITERATURE CITED


ANNOTATED LIST OF CRANE FLIES (DIPTERA: TIPULIDAE) FROM MENTOR MARSH, LAKE COUNTY, OHIO

Michael J. Bolton

ABSTRACT

Sixty-one species of Tipulidae, one species of Ptychopteridae, two species of Trichoceridae, and one species of Anisopodidae are recorded for Mentor Marsh and adjacent woodlands.

Following is an account of adults of the crane flies (Tipulidae), phantom crane flies (Ptychopteridae), winter crane flies (Trichoceridae), and wood gnats (Anisopodidae) collected from Mentor Marsh, Lake County, Ohio, and adjacent woodlands. Few collections of crane flies have been made in Ohio. No state list exists as for New York with 318 species (Alexander 1942). To date the only publication dealing specifically with Ohio's crane fly fauna is the Delaware County survey by Foote (1956), in which 146 tipulid species were listed.

Mentor Marsh is a natural freshwater marsh located in Lake County, Ohio, on the Lake Plain physiographic region. It covers about 324 ha and is 7.2 km long by 0.4 to 0.8 km wide. It was formed from a section of the Grand River that was isolated when the main channel formed a new easterly mouth into Lake Erie (Aronson 1974). Until 1959 the marsh was dominated by swamp forest. At this time because of a fluctuation in the water level, salt pollution from a dump site on Black Brook, or a combination of both, the dominant marsh vegetation shifted to cattails and more recently to common reed (Phragmites communis) (Isard 1966, Bernstein 1981). Common reed makes up large monodominant stands down the length of the marsh with cattails being the second most common plant type. Both common cattail (Typha latifolia) and narrow-leaved cattail (Typha angustifolia) are present in roughly equal numbers. The marsh is bordered on the north and south by upland woods. Haisly Creek and Black Brook are the marsh's main tributaries. Water flows out both the eastern end from Shipman Pond through a ditch toward the Grand River and out the western end into Mentor Lagoons Marina.

MATERIALS AND METHODS

Adult crane flies were collected from Mentor Marsh in 1978, 1981, 1982, and 1983. In 1978 two emergence traps 1 m in diameter were placed over areas of the marsh containing swamp loosestrife (Decodon verticillatus), arrow arum (Peltandra virginica), and common reed, while 24 traps were placed over cattails. Insects were collected from the traps about every four days from 11 June to 8 August and then preserved dry.

In 1981 I participated in a dipteran survey of Mentor Marsh that was conducted by Dr. Sonja Teraguchi of the Cleveland Museum of Natural History. Insects were collected from

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nine sites selected to include various vegetation types and to extend the entire length of
the marsh. Each site contained two floating emergence traps of 1 m diameter and five
stakes each of which had a floating, soapy-water pan trap tied at the water line and a
sticky trap at its top. Bolton (1983) contains more detailed information about the
collection sites. Trap collections were made for 24 hours every two weeks from 10 June to
18 August. Net collecting was also done at each site. All insects collected, except those
on the sticky traps, were preserved in the field with 95 percent ethanol. The sticky traps
were covered with cellophane and refrigerated at the laboratory.

Additional hand collections were made in the fall of 1981, the spring and fall of 1982,
and 28 April, 1983. The principle means of collecting was sweeping with an insect net
and hand picking the vegetation. The areas most frequently collected were upland woods
and marsh margins at various locations around the marsh.

All crane flies collected were enumerated and identified to species using the keys of
The voucher collection is deposited at the Cleveland Museum of Natural History.

ANNOTATED LIST OF SPECIES

A total of 61 species of Tipulidae, one of Ptychopteridae, two of Trichoceridae, and one
of Anisopodidae were found in Mentor Marsh and adjacent woodlands. They are listed
with their observed flight period, numbers collected, and habitat collected from.

PTYCHOPTERIDAE

*Bittacomorpha clavipes* (Fabricius). 14 May and 6–12 July, 16 males and five females,
marsh.

TRICHOcerIDAE

*Trichocera (Metatrichocera) garrettii* Alexander. 14 October, one male, upland woods.

*Trichocera (Trichocera) bimacula* Walker. 14 October to 1 November, 120 males and 37
females, marsh edge and upland woods.

ANISOPODIDAE

*Sylvicola fenestratis* (Scopoli). 1 November, one female, marsh edge.

TIPULIDAE

*Nephrotoma alterna* (Walker). 31 August, one male, upland woods.

*Nephrotoma ferruginea* (Fabricius). 7 June and 19 August, two males and two females,
a mating pair collected on each date from upland woods-field ecotones.

*Tipula (Schummelia) hermannia* Alexander. 31 August, one male and two females,
upland woods.

*Tipula (Platytipula) paterifera* Alexander. 26 September to 14 October, 13 males and one
female, open upland areas.

*Tipula (Platytipula) ultima* Alexander. 18 August to 1 November, 13 males and nine
females, upland woods and upland woods-field ecotones.
Tipula (Yamatotipula) furca Walker. 14 May to 29 September, 26 males and 11 females, marsh and upland woods.

Tipula (Yamatotipula) kennicotti Alexander. 16 August, two males, upland woods.

Tipula (Yamatotipula) sayi Alexander. 31 August to 8 September, six males and three females, marsh edge and upland woods.

Tipula (Yamatotipula) tricolor Fabricius. 31 August to 29 September, two males and one female, upland woods.

Tipula (Angarotipula) illustris Doane. 2 June to 17 August, 32 males and six females, marsh.

Tipula (Beringotipula) borealis Walker. 31 August to 8 September, eight males and seven females, upland woods.

Limonia (Limonia) globithorax (Osten Sacken). 17 June to 7 September, 10 males and two females, marsh and upland woods.

Limonia (Metalimnobia) immatura (Osten Sacken). 7 June and 7 September, three males and one female, marsh edge.

Limonia (Discobola) annulata (Linnaeus). 11 June and 27 September, one male and one female, marsh and upland woods.

Limonia (Rhipidia) fidelis (Osten Sacken). 8 June, one male, marsh.

Limonia (Rhipidia) duplicata (Doane). 14 May and 7 September, one male and one female, marsh edge and upland woods.

Limonia (Dicranomyia) divisa Alexander. 11 June, one male, marsh.

Limonia (Dicranomyia) haeretica (Osten Sacken). 7 June to 8 August and 27 September, 66 males and 13 females, marsh.

Limonia (Dicranomyia) immodestoides Alexander. 14-27 May and 3 August to 14 October, seven males and three females, marsh and upland woods.

Limonia (Dicranomyia) longipennis (Schummel). 22 June, one male, marsh.

Limonia (Geranomyia) communis (Osten Sacken). 3 August to 29 September, five males and six females, marsh and upland woods.

Limonia (Geranomyia) rostrata (Say). 31 August, two females, marsh edge and upland woods.

Limonia fusca Meigen. 31 August, one male, marsh edge.

Limonia rara (Osten Sacken). 8-22 June and 3 August, two males and four females, marsh.

Helius flavipes (Macquart). 27 May to 8 September, 95 males and 123 females, marsh and upland woods.

Helius mainensis (Alexander). 7-22 June and 3 August, seven males, marsh and upland woods.

Ula elegans Osten Sacken. 2 May and 27 September, one male and two females, marsh edge and upland woods.

Epiphagma fasciapennis (Say). 27 May to 22 June, 24 males and 13 females, marsh and upland woods.
Epiphragma solatrix (Osten Sacken). 27 May and 8 September, two males, upland woods.

Pseudolimnophila luteipennis (Osten Sacken). 14 May to 29 September, 690 males and 1332 females, marsh and upland woods.

Pseudolimnophila noveboracensis (Alexander). 22 June to 6 July, two males and one female, marsh.

Limnophila (Prionolabis) ruftbasis Osten Sacken. 7 June, two males, marsh edge and upland woods.

Limnophila (Prionolabis) walley? Alexander. 7–22 June, two males and one female, marsh. Specimens key to this species but Dr. Byers thinks they may be an undescribed species.

Limnophila (Dicranophragma) fuscovaria Osten Sacken. 27 May to 7 June, five males and one female, marsh and upland woods.

Limnophila (Euphyllidorea) auripennis Alexander. 7 June to 31 August, 26 males and 26 females, marsh and upland woods.

Shannonomyia lenta (Osten Sacken). 27 May, three males and one female, marsh edge.

Pilaria imbecilla (Osten Sacken). 27 May to 3 August, 21 males and 14 females, marsh and upland woods.

Pilaria meridiana (Staeger). 10 June to 3 August, 19 males and six females, marsh.

Pilaria quadrata (Osten Sacken). 14 May, one male, marsh.

Pilaria tenuipes (Say). 7 June to 27 September, 242 males and 228 females, marsh and upland woods.

Cladura flavoferruginea Osten Sacken. 14–26 October, 43 males and 10 females, upland woods.

Gnophomyia (Gnophomyia) tristissima Osten Sacken. 4–16 August, seven males, on a dead tree trunk in upland woods.

Gonomyia (Gonomyia) cognatella Osten Sacken. 18 August, one male, marsh.

Gonomyia (Gonomyia) subcinerea Osten Sacken. 27 May to 7 June and 17 July to 14 October, nine males and 51 females, marsh and upland woods.

Cheilotrichia (Empeda) stigmatic (Osten Sacken). 14 May, one female, upland woods.

Erioptera (Trimicra) pilipes (Fabricius). 11 June to 8 August, 21 males and 22 females, marsh.

Erioptera (Symplecta) cana (Walker). 14 May to 8 August and 7 September, 10 males and 34 females, marsh.

Erioptera (Erioptera) chlorophylloides Alexander. 7 June to 10 July, 84 males, marsh and upland woods.

Erioptera (Erioptera) furcifer Alexander. 3–27 July, two males, marsh.

Erioptera (Erioptera) septemtrionis Osten Sacken. 6 July to 17 August and 14 October, six males and four females, marsh and upland woods.

Erioptera (Erioptera) vespertina Osten Sacken. 6 July to 17 August, six males and eight females, marsh.
Erioptera (Mesocyphona) caliptera Say. 27 May to 26 September, 55 males and 192 females, marsh and upland woods.

Erioptera (Mesocyphona) parva Osten Sacken. 7 June and 20–27 July, one male and two females, marsh.

Erioptera (Psiloconopa) venusta Osten Sacken. 7 June, one male, upland woods.

Ormosia (Ormosia) serridens Alexander. 28 April to 2 May, 80 males and 22 females, marsh edge and upland woods.

Ormosia (Ormosia) manicata (Doane). 27 May to 7 June and 31 August to 8 September, 10 males and six females, upland woods.

Ormosia (Ormosia) pygmaea (Alexander). 14–27 May, one male and one female, upland woods.

Ormosia (Ormosia) romanovichiana Alexander. 28 April, one female, marsh edge.

Ormosia (Ormosia) rubella (Osten Sacken). 26–29 September, 30 males and 23 females, upland woods.

Molophilus (Molophilus) Jorcipulus (Osten Sacken). 27 May to 6 July, three males and eight females, marsh.

Toxorhina magna Osten Sacken. 3 August, one female, marsh.

ACKNOWLEDGMENTS

I thank Dr. Sonjo Teraguchi for providing me with the 1978 material, Drs. John Olive and George Byers for reviewing early copies of this manuscript, Dr. George Byers for verifying my voucher collection, and Cathy Warkovich for typing the manuscript. The Northeast Ohio Areawide Coordinating Agency funded the 1981 dipteran survey.

LITERATURE CITED


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FIELD MONITORING OF X-DISEASE LEAFHOPPER VECTORS (HOMOPTERA: CICADELLIDAE) AND INFECTED CHOKECHERRY IN MICHIGAN PEACH AND CHERRY ORCHARDS

Kirk J. Larsen¹ and Mark E. Whalon²

ABSTRACT

Populations of leafhopper vectors of X-disease, a major disease problem of the Michigan peach industry, were monitored by yellow sticky board traps and sweepnet samples during 1985 and 1986. Abundance of known leafhopper vectors varied throughout the stone fruit belt of Michigan, with Paraphlepsius irroratus common in the southwest Lower Peninsula, but representing 73.1% of all known vectors found. Other commonly found vectors included Scaphytopius acutus (22%), Colladonus citellarius (1.5%), and Norvellina seminuda (3.4%). Yellow sticky boards were the best monitoring method used, accounting for 90.3% of all vectors captured. The appearance of X-disease symptoms on chokecherry throughout the survey area indicated transmission between wild hosts was occurring in areas where X-disease is not yet a major problem to growers.

X-disease of peach and cherry is caused by a mycoplasmalike organism (MLO) and is vectored by leafhoppers. The X-disease research effort of the current stone fruit decline project requires up-to-date field monitoring of the abundance of X-disease vector leafhoppers and chokecherry. These data are needed to aid in assessing year to year variation in X-disease and leafhopper incidence, evaluating established control procedures and developing new X-disease management strategies.

Past research (Taboada et al. 1975, Rosenberger 1977, Rosenberger and Jones 1978) has demonstrated that at least nine species of leafhoppers that occur in Michigan are vectors of X-disease. Paraphlepsius irroratus (Say) is the most common known vector of X-disease in Michigan peach and cherry orchards (Taboada et al. 1975, Rosenberger 1977). It is also the most efficient vector in greenhouse tests (Rosenberger and Jones 1978). Both P. irroratus and Scaphytopius acutus (Say) are bivoltine in Michigan, with the two periods of adult activity being late June to July and late September to October (Taboada et al. 1975).

Michigan Department of Agriculture (MDA) annual peach surveys (Robinson 1985) indicated the incidence of X-disease has increased in peach orchards of southwest Michigan during the past several years. Chokecherry as an alternate host of X-disease (Gilmer et al. 1954) is considered the major source of X-disease inoculum outside the orchards. For this reason, MDA X-disease regulation No. 612 requires the removal of all chokecherry within 500 ft of peach and cherry orchards.

X-disease is a major peach disease problem in southwestern lower Michigan, but has

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Table 1. List of X-disease sites for the 1985 and 1986 field seasons with fruit type, weather station, and site location data.

<table>
<thead>
<tr>
<th>Year</th>
<th>Site</th>
<th>County</th>
<th>Fruit</th>
<th>Weather Station</th>
<th>Distance a (km)</th>
<th>N, Lat. W, Long.</th>
</tr>
</thead>
<tbody>
<tr>
<td>86</td>
<td>Bainbridge Center</td>
<td>Berrien</td>
<td>Peach</td>
<td>Watervliet</td>
<td>8.0</td>
<td>42° 7' 86° 17'</td>
</tr>
<tr>
<td>85</td>
<td>Clarksville</td>
<td>Ionia</td>
<td>Peach</td>
<td>Clarks ville</td>
<td>0.0</td>
<td>42° 52' 85° 15'</td>
</tr>
<tr>
<td>85</td>
<td>East Lansing</td>
<td>Ingham</td>
<td>Cherry</td>
<td>MSU Hort Farm</td>
<td>1.6</td>
<td>42° 41' 84° 30'</td>
</tr>
<tr>
<td>85,86</td>
<td>Fennville</td>
<td>Allegan</td>
<td>Peach</td>
<td>Fennville</td>
<td>0.0</td>
<td>42° 36' 86° 9'</td>
</tr>
<tr>
<td>85</td>
<td>Hartford</td>
<td>Van Buren</td>
<td>Peach</td>
<td>Watervliet</td>
<td>5.6</td>
<td>42° 14' 86° 10'</td>
</tr>
<tr>
<td>85,86</td>
<td>Lawrence</td>
<td>Van Buren</td>
<td>Peach</td>
<td>Paw Paw</td>
<td>6.4</td>
<td>42° 12' 86° 4'</td>
</tr>
<tr>
<td>86</td>
<td>Manistee</td>
<td>Manistee</td>
<td>Cherry</td>
<td>Bear Lake</td>
<td>4.8</td>
<td>44° 19' 86° 14'</td>
</tr>
<tr>
<td>86</td>
<td>Northport</td>
<td>Leelanau</td>
<td>Peach</td>
<td>Lk. Leelanau</td>
<td>8.0</td>
<td>45° 6' 85° 38'</td>
</tr>
<tr>
<td>86</td>
<td>Walkerville</td>
<td>Oceana</td>
<td>Cherry</td>
<td>Mears</td>
<td>13.5</td>
<td>43° 43' 86° 10'</td>
</tr>
</tbody>
</table>

aDistance (km) between site and weather station.

not been a severe problem north of Kent County. Many factors may be limiting the distribution of X-disease. Past monitoring of X-disease in Michigan (Taboada et al. 1975, Rosenberger 1977, Mowry 1982) has not been done north of the Peach Ridge area of Kent County on a regular basis. About 58% of Michigan's peach acreage is located in Berrien and Van Buren counties (Fedewa and Psodna 1982), and these are the counties hardest hit by X-disease (Robinson 1985).

The leafhopper monitoring reported here was a survey of the entire southern Michigan stone fruit belt. The objectives of this survey were to determine how the abundance and distribution of X-disease vector leafhoppers and symptoms on chokecherry differ temporally and spatially throughout the west coast of Michigan.

MATERIALS AND METHODS

Field Season and Research Sites: During the 1985 and 1986 field seasons, traps were placed in the field during the first week of May. Monitoring occurred weekly in 1985 and biweekly in 1986 and ended ca. 15 November after several hard frosts and the first snow.

Five sites located in Michigan's Lower Peninsula were monitored in 1985 and six sites in 1986 (Table 1). Weather data such as temperature and the resulting degree day accumulations for each site were obtained from the Michigan State University Cooperative Crop Monitoring Service (CCMS) using agricultural weather observation stations located at or near each field site.

Survey of Chokecherry Exhibiting Symptoms: The abundance of wild sources of X-disease inoculum in Michigan was surveyed by biweekly monitoring of chokecherry. In 1986, an 8-km route leaving each field site along two lane roadways was selected and all chokecherry clumps or individual bushes observed exhibiting X-disease symptoms were counted. The average number of infected chokecherry/km was then calculated for each site.

X-disease Vector Leafhopper Survey: The abundance and distribution of known X-disease vector leafhoppers were monitored. In 1985, monitoring was performed weekly at the Lawrence, Hartford, Fennville, Clarksville, and East Lansing sites. In 1986, monitoring was performed biweekly at the Lawrence, Bainbridge Center, Fennville, Walkerville, Manistee, and Northport sites.

Monitoring was performed with yellow sticky board traps and by sweep net sampling. Six yellow sticky board traps were hung at each site ca. 1.5 m above the orchard
groundcover. The traps were 12.5 × 25 cm made of 0.25 in plywood and painted with sun yellow enamel and coated with Tree Tanglefoot®. These traps were replaced on each visit to the site and returned to the lab for examination and removal of captured leafhoppers. Sweep net samples were taken from different areas in and around each orchard site. Four sweep samples were taken, each consisting of 25 sweeps with a 37.5 cm diameter net. Each sweep was ca. a 1.5 m pass through the groundcover foliage. The sweep samples were deposited in plastic bags, placed in a cooler for transport back to the laboratory, and then frozen at -20°C in the lab to kill all insects. Sorting, leafhopper identification to species, and counts of abundance and sex took place in the laboratory.

RESULTS

Field Season: During 1985, temperature effects as measured by degree day accumulations (Baskerville and Emin 1969) were similar at all sites (Fig. 1). The 1986 total accumulations are similar to the 1985 total accumulations for both the Lawrence and Fennville sites. Generally higher temperatures were experienced in both mid-July and early October of 1986. The difference in total degree day accumulation between the Northport (1820 DD) and Lawrence (2585 DD) sites was dramatic, where an average accumulated difference of 765 DD was realized. Average accumulated degree days showed a 478 DD difference between the average of northwestern (1980 DD) and southwestern (2458 DD) weather stations.

Survey of Chokecherry Exhibiting Symptoms: During 1986, chokecherry exhibiting symptoms of X-disease was first observed in southwestern Lower Michigan in late-June and in northwestern Lower Michigan in mid-July. By early September, up to six infected chokecherry/km were visually evident. This delay in symptom expression between southwest and northwest is similar to the mean degree day accumulation for those areas.

X-disease Vector Leafhopper Survey Leafhopper populations were about five times greater in 1985 than in 1986. Although the generations peaked at different dates in 1985 and 1986, the peaks did occur at approximately the same number of accumulated degree days (Fig. 2). Differences in X-disease vector leafhopper density occurred both between field sites (T = 2.06; df = 24; P = 0.05) and between 1985 and 1986 field seasons (F = 75.89; df = 1,4; P < 0.05).

Representatives of all leafhopper species known to vector X-disease in Michigan were found during both the 1985 and 1986 field seasons. Only four of these, P. irroratus, S. acutus, Colladonus clitellarius (Say), and Norvellina seminuda (Say) were present in numbers greater than 1% of all the known vector leafhoppers captured (Table 2). The relative abundance of these leafhoppers in the field during 1985 and 1986 was P. irroratus 73.1%, S. acutus 22.0%, C. clitellarius 1.5%, and N. seminuda 3.4%.

Some sites supported larger populations of these vectors than others (Table 3). P. irroratus was very common in the East Lansing, Lawrence, Hartford, and Fennville sites. S. acutus was found easily at the Hartford site and in good numbers in Lawrence and Fennville. C. clitellarius was found most commonly at the Manistee site, while N. seminuda was found easily in East Lansing and often in Fennville, but was not found at or north of Walkerville.

Yellow sticky board traps captured 90.3% of all known X-disease vector leafhoppers captured during 1985 and 1986. There was no significant difference in this monitoring method capture rate between the two generations (F = 2.784; df = 1,9; P ≥ 0.05). The sex ratio of P. irroratus leafhoppers did not significantly differ between the yellow board trap and sweep net monitoring methods, with male leafhoppers accounting for 65% of the captures on yellow sticky board traps, and 42% of the captures in sweep nets. There was no significant difference in this captured leafhopper sex ratio between the two generations (F = 1.093; df = 1,9; P ≥ 0.05).

DISCUSSION

The similarity of the degree day accumulations during 1985 was due to the concentration of all 1985 field sites in the southwestern and central Lower Peninsula. The 1986 sites...
had greater latitude differences from south to north and a corresponding decrease in degree day accumulation northward.

The two week lag in degree day accumulation probably explains the delay in chokecherry development and X-disease symptom expression. The presence of chokecherry along roadways indicates that many bushes are not being eradicated per MDA regulations and therefore may once again be serving as a major alternate host of X-disease pathogen.

Of all the known species of X-disease vector leafhoppers found present in 1985 and 1986, only four seem to be common enough to warrant our attention unless one of the rare species is found to have a very high MLO infection rate or its feeding behavior
Fig. 2. Mean number of X-disease vector leafhoppers captured by yellow sticky board traps and in sweep nets, based on average degree day accumulations in 1985 and 1986 at all sites.

Table 2. Total number of X-disease vector leafhoppers captured by yellow sticky board traps and sweep nets, and percent relative abundance of each found in Michigan for both 1985 and 1986 field seasons.

<table>
<thead>
<tr>
<th>Species</th>
<th>1985 Total</th>
<th>% of total</th>
<th>1986 Total</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>P. irroratus</td>
<td>1790</td>
<td>72.47</td>
<td>278</td>
<td>60.57</td>
</tr>
<tr>
<td>S. acutus</td>
<td>529</td>
<td>21.42</td>
<td>144</td>
<td>31.37</td>
</tr>
<tr>
<td>C. clitellarius</td>
<td>20</td>
<td>0.81</td>
<td>17</td>
<td>3.70</td>
</tr>
<tr>
<td>N. seminuda</td>
<td>92</td>
<td>3.72</td>
<td>5</td>
<td>1.09</td>
</tr>
<tr>
<td>Scaphoideus spp.</td>
<td>23</td>
<td>0.93</td>
<td>4</td>
<td>0.87</td>
</tr>
<tr>
<td>Fieberiella florii (Stal.)</td>
<td>2</td>
<td>0.08</td>
<td>3</td>
<td>0.65</td>
</tr>
<tr>
<td>Orientus ishidae (Mat.)</td>
<td>1</td>
<td>0.04</td>
<td>4</td>
<td>0.87</td>
</tr>
<tr>
<td>Gyponana lamina DeLong</td>
<td>13</td>
<td>0.53</td>
<td>4</td>
<td>0.87</td>
</tr>
<tr>
<td>Totals</td>
<td>2470</td>
<td></td>
<td>459</td>
<td></td>
</tr>
</tbody>
</table>

Predisposes it to transmit more frequently. *P. irroratus* is still the most common vector leafhopper in Michigan, representing 73% of the total number caught, with *S. acutus* second most common at 22%. This confirms the earlier work by Taboada et al. (1975) and Rosenberger (1977). The graphic evidence (Fig. 2) that X-disease vectors are bivoltine is largely influenced by the two generations of *P. irroratus*, which constitutes the largest portion of the vector population. Further work on the number of generations of other vector species found in Michigan would help to clarify this observation.

Distributions of leafhopper populations were influenced by sample location in the state. *P. irroratus* was commonly found in the southwest and central sites. Since the second
Table 3. Number of X-disease vector leafhoppers captured at each field site during 1985 and/or 1986.

<table>
<thead>
<tr>
<th>Site</th>
<th>P. irroratus</th>
<th>S. acutus</th>
<th>C. clitellarius</th>
<th>N. seminuda</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bainbridge Center</td>
<td>40</td>
<td>21</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Clarksville</td>
<td>101</td>
<td>45</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>East Lansing</td>
<td>641</td>
<td>19</td>
<td>4</td>
<td>45</td>
</tr>
<tr>
<td>Fennville</td>
<td>217.5</td>
<td>94.5</td>
<td>3.5</td>
<td>13.5</td>
</tr>
<tr>
<td>Hartford</td>
<td>276</td>
<td>145</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Lawrence</td>
<td>244</td>
<td>96</td>
<td>1.5</td>
<td>8.5</td>
</tr>
<tr>
<td>Manistee</td>
<td>39</td>
<td>17</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>Northport</td>
<td>2</td>
<td>23</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Walkerville</td>
<td>46</td>
<td>22</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Totals</td>
<td>1606.5</td>
<td>482.5</td>
<td>32.0</td>
<td>75.0</td>
</tr>
<tr>
<td>Means</td>
<td>178.5</td>
<td>53.6</td>
<td>3.6</td>
<td>8.3</td>
</tr>
<tr>
<td>% of total</td>
<td>73.1</td>
<td>22.0</td>
<td>1.5</td>
<td>3.4</td>
</tr>
</tbody>
</table>

*average of 1985 and 1986 data.

C. clitellarius was found in significant numbers only at the Manistee site and thus may be an important vector in that area. Since the most common vector leafhopper found in Leelanau County was S. acutus, but at a low density when compared with other sites, the chance of X-disease transmission by leafhoppers there seems low.

Selection of sampling methods for use in future X-disease monitoring efforts should consider the effectiveness of the yellow sticky board traps, with over 90% of all vector leafhoppers captured by this method. Although sweep net sampling is the best method of detecting leafhoppers moving into and out of orchards in a short period of time (Mowry and Whalon 1984), sweep net sampling alone is of minor importance and an inefficient, labor-intensive, and incomplete sampling method for long-term X-disease vector monitoring.

Presence in the northwest area of chokecherry exhibiting X-disease symptoms indicate that a wild source of X-disease inoculum is present, and that transmission among chokecherry does occur. However, the limited distribution of populations of vector leafhoppers in this region may be preventing the vector transmission of X-disease to peach and cherry in the northwest part of Lower Michigan.

ACKNOWLEDGMENTS

We thank Jay Matthes and Martha Zemper for their assistance in the field, and Alan Jones, David Smitley and James Miller for reviewing early drafts of this manuscript. The yellow sticky board trap handling equipment used in this study was donated by Dr. Al Jones of the Department of Botany and Plant Pathology. This is Michigan State University Agricultural Experiment Station Journal Article No. 12379. This research was supported in part by USDA grant no. 85-CRSR-2-2551 to Michigan State University.
LITERATURE CITED

SEASONAL OCCURRENCE OF PINE ROOT COLLAR WEEVIL, *HYLOBIUS RADICIS* (COLEOPTERA: CURCULIONIDAE), IN RED PINE STANDS UNDERGOING DECLINE

Kenneth F. Raffa1 and David J. Hall2

ABSTRACT

A trapping scheme was devised for sampling the pine root collar weevil, *Hylobius radicis*, in mature red pine plantations in Wisconsin. Adult weevils were trapped throughout the 1986 field season, and the method appears sensitive enough to discern temporal and spatial trends. The number of weevils caught was higher in stands symptomatic of the general condition currently labelled Red Pine Decline and Mortality. In some stands there was a strong tendency for trap catches to be particularly high near certain trees. Seasonal trends and sex ratios were compared with published reports of *H. radicis* activity in Michigan.

Plantations of red pine, *Pinus resinosa*, in southern and central Wisconsin are currently experiencing a very common and damaging, but ill-defined condition simply labeled “Red Pine Decline and Mortality.” The condition is typified by a group of dead trees at the center, around which are several rows of trees that appear to have stunted growth during the last few growing seasons. A circle of these stunted trees dies every year thus causing the pocket to enlarge. The trees are generally 20–45 years old. A variety of microorganisms and insects can be cultured or reared from the killed trees, thus precluding any immediate identification of one organism as a sole cause of death. In addition, these plantations may occupy unfavorable sites, and so physiological stress cannot be eliminated as a source of the decline.

The killed trees are invariably infested with pine engravers, *Ips pini* (Say) and/or *Ips grandicollis* (Eichhoff), with the accompanying blue stain caused by *Ceratocystis* associates. The stunted trees are frequently infested with the red turpentine beetle, *Dendroctonus valens* (LeConte), and *Leptographium* associates. However, we frequently find larvae and/or completed brood galleries of the pine root collar weevil, *Hylobius radicis* Buchanan, in these trees as well. Because *Ips* and *D. valens* have much shorter development times (Schenk 1961) than *H. radicis* (Millers 1965), the life stages present can be used to infer the sequence of attack. These preliminary observations caused us to suspect that root collar weevils may infest trees initially, and stress their hosts to the degree that bark beetles can then colonize them. Attack by *Ips* beetles is fatal to the tree within 1 or 2 years.

During this study we conducted trappings of root collar weevil adults throughout the 1986 season. Our objective was to monitor the activities of weevils in red pine plantations in various levels of decline.

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Table 1. Location and site description of red pine plantations sampled for *H. radicis* adults.

<table>
<thead>
<tr>
<th>Stand</th>
<th>Location</th>
<th>Year Planted</th>
<th>DBH (cm)</th>
<th>Site Index</th>
<th>Basal Area</th>
<th>Type and degree of tree mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arena 1</td>
<td>Iowa T8N, R4E, Sec. 23</td>
<td>1945</td>
<td>20.7</td>
<td>64</td>
<td>130</td>
<td>Adjacent to large pocket.</td>
</tr>
<tr>
<td>Arena 2</td>
<td>Iowa T8N, R4E, Sec. 23</td>
<td>1952</td>
<td>16.8</td>
<td>54</td>
<td>120</td>
<td>None.</td>
</tr>
<tr>
<td>Spring Green</td>
<td>Sauk T8N, R4E, Sec. 18</td>
<td>1945</td>
<td>21.7</td>
<td>63</td>
<td>150</td>
<td>Adjacent to large pocket.</td>
</tr>
<tr>
<td>Bakken's Pond</td>
<td>Sauk T8N, R3E, Sec. 8</td>
<td>1961</td>
<td>13.3</td>
<td>75</td>
<td>195</td>
<td>One small pocket.</td>
</tr>
<tr>
<td>Webster</td>
<td>Burnett T40N, R15W, Sec. 24</td>
<td>1969</td>
<td>16.3</td>
<td>47</td>
<td>30</td>
<td>Individual trees dying in one year—no pockets; no decline.</td>
</tr>
</tbody>
</table>
MATERIALS AND METHODS

Five red pine plantations were selected for study. Three of these were undergoing decline in the typical pocket pattern and had experienced significant mortality over the last three years. One (Webster) was undergoing scattered mortality of individual trees. One (Arena 2) showed no evidence of decline. The general site information is given in Table 1.

We modified a trap originally described by Maki (1969). Aluminum door screen supported with 14-gauge steel wire formed a sloping skirt around the lower stem of the tree. The upper end of the skirt was formed into an inverted funnel which fed through the inverted lid of a 12 oz. jar. The upper edge of the skirt was nailed to the tree with a shingle nail; the lower end was held in place by stapling the two wires to the tree where they crossed. A small pine twig was placed in the jar to arrest the beetles that entered. The jar was supported by tying it to the tree with cotton cord. As adult weevils ascended the tree during nocturnal feeding (Millers 1965, Wilson 1968a, 1968b, Wilson and Millers 1983), they walked into the jars and became trapped.

Within each stand, a 100-tree plot sampling universe was selected. Twenty trees were randomly selected within each plot for trapping.

Beetles were sampled from mid-May to early October, 1986. All of the stands in Iowa and Sauk counties (Table 1) were sampled on the same dates. The Webster plantation was examined separately. Weevil species and sex were determined using the methods of Warner (1966) and Wilson et al. (1966), respectively.

The number of weevils trapped was analyzed by two-way ANOVA (Steel and Torrie 1960) for sources of variation due to sampling date and plot location. The Webster plot was not included in this two-way ANOVA because of the different sampling dates. Within plots, a one-way ANOVA (Steel and Torrie 1960) was conducted for sampling date, and a one-way ANOVA was conducted for tree number. Means were compared by Duncan’s Multiple Range Test (Steel and Torrie 1960). The numbers of males and females trapped in all plots were compared by paired-t analysis (Steel and Torrie 1960).

RESULTS

The total trap catches are shown in Table 2. The Webster, Spring Green, Arena 1, and Bakken’s Pond stands were most highly infested.

There were very pronounced differences in weevil densities among the various stands ($F = 6.38; P < 0.001$). There was a weaker effect due to time of sampling ($F = 1.86; P < 0.06$). In general, weevil numbers were greater earlier in the season (Figure 1). The Bakken’s Pond ($F = 2.55; P < 0.002$), Webster ($F = 2.06; P < 0.04$), Arena 1 ($F = 1.76; P < 0.045$), and Spring Green ($F = 1.57; P < 0.087$) stands showed a strong relationship between weevil numbers and seasonal occurrence. The only stand that showed no relationship between sampling date and beetle numbers was the Arena 2 stand, which also contained the fewest weevils.

Weevil populations were five times higher in the stands that had been undergoing decline and mortality than in the non-declining Arena 2 stand (Figure 1). We did not include the data from the Webster plot in this calculation because of the difference in the pattern of mortality described above. If these data had been included, however, the difference would be even more pronounced (Table 2). The weevil catches occurred in the same rank order as the severity of stand decline (Table 1).

The within-stand spatial distribution of weevils depends on their population density. Weevil populations were highly clustered about certain trees in stands where their densities were moderate (Spring Green $F = 3.27; P < 0.001$; Arena 1 $F = 1.67 P < 0.041$) but a more uniform distribution occurs at the lower (Arena 2 $F = 0.72$; ns) and higher (Bakken’s Pond $F = 1.09$; ns, Webster $F = 0.76$; ns) densities. In the Spring Green stand, 27% of the weevils were captured at one tree. At both Spring Green and Arena 1, half of the weevils were trapped at only 3 of the 20 trap trees. Weevil distributions were random in the other stands.
Fig. 1. Number of *H. radicis* adults trapped in stands containing (Square) and not containing (Circle) clusters of dead and dying trees characteristic of Red Pine Decline and Mortality.

Table 2. Number of *H. radicis* adults trapped in red pine plantations in Wisconsin. Means followed by the same letter are significantly different at $P < 0.05$.

<table>
<thead>
<tr>
<th>Stand</th>
<th>Arena 1</th>
<th>Arena 2</th>
<th>Spring Green</th>
<th>Bakken’s Pond</th>
<th>Webster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>35</td>
<td>8</td>
<td>58</td>
<td>28</td>
<td>87</td>
</tr>
<tr>
<td>Mean</td>
<td>2.33AB</td>
<td>0.53C</td>
<td>3.87A</td>
<td>1.87BC</td>
<td>—</td>
</tr>
</tbody>
</table>

The sex ratio of trapped beetles was 1.5 male: 1.0 female. However a paired-t test indicates that we cannot reject the assumption of a 1:1 ratio with any degree of confidence ($t = 1.18, df = 3, P = 0.32$).

**DISCUSSION**

This is the first attempt to quantify *H. radicis* populations in Wisconsin. This method is sensitive enough to discern seasonal and spatial trends in adult weevil numbers. The peak period of root collar weevil activity in south-central Wisconsin is earlier than that reported in the northern lower peninsula of Michigan (Wilson 1975). Wilson (1975) observed peak adult activity in mid-June, whereas we observed peak activity in late May (Table 3). Peak trap catch in northwestern Wisconsin, however, occurred on 3 July (Figure 2). Thus there appears to be a strong latitudinal gradient in weevil emergence, although there are surely differences due to yearly variation as well.

The period of adult activity was also longer in our region, as Wilson (1975) did not observe any weevils after 15 September. The median date of weevil capture was 30 June
Fig. 2. Seasonal occurrence of *H. radicis* adults in south-central (Circle) and northwestern (Square) Wisconsin red pine plantations.

in south-central Wisconsin, compared to 18 June in northern Michigan (Wilson 1975). The median date of weevil capture was 2 July in northwestern Wisconsin.

The seasonal distribution data (Figure 2) show two major peaks in *H. radicis* adult numbers in south-central Wisconsin. Weevils were significantly less abundant from late July to mid-August than in the preceding or following periods (Table 3). These peaks probably correspond to the emergence of overwintering adults in the spring, and the development of new adults in late summer to early fall (Millers 1965). There also appear to be two peaks in northwestern Wisconsin (Figure 2), but we do not have sufficient data for statistical analysis.

Our observed sex ratio of 1:1 agrees with earlier reports by Millers (1965) and Wilson (1975), although there is some indication that a larger sample size would have revealed a higher percentage of males caught during nocturnal feeding.

The disproportionately high occurrence of *H. radicis* in plantations characteristic of Red Pine Decline and Mortality suggests that they are involved in this pathology. This view is supported by our field observations. We have examined 79 trees in Red Pine Decline Pockets in and near the Bakken’s Pond stand. Twelve of the 13 living trees infested with *D. valens* had previously been attacked by *H. radicis*. Only 28 of the 66 trees not attacked by *D. valens* had signs of previous *H. radicis* infestation ($X^2 = 10.8$; $p < 0.001$).

Root collar weevils have primarily been considered a pest of young pine plantations, but these results suggest they may be a serious threat to more mature trees as well. We cannot discern at this time whether *H. radicis* is an important agent in the onset of the Red Pine Decline symptoms, or whether these weevils simply orient to trees that are sufficiently stressed to allow colonization by a number of insects and microorganisms. We are currently investigating their potential role as vectors of *Leptographium* and predisposing agents to *Ips* and *D. valens*. 

---

**Table 3**

<table>
<thead>
<tr>
<th>Date</th>
<th>Weevil Numbers</th>
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<tbody>
<tr>
<td>May 20</td>
<td>5</td>
</tr>
<tr>
<td>July 1</td>
<td>15</td>
</tr>
<tr>
<td>Aug 1</td>
<td>10</td>
</tr>
<tr>
<td>Sept 1</td>
<td>5</td>
</tr>
<tr>
<td>Oct 1</td>
<td>5</td>
</tr>
</tbody>
</table>

---
Table 3. Means separation (Duncan's Multiple Range Test) of *H. radicis* adults caught in south-central Wisconsin red pine plantations during 1986. Means followed by the same letter are not significantly different at p < 0.05.

<table>
<thead>
<tr>
<th>Time</th>
<th>Mean</th>
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<tbody>
<tr>
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<td>5.00</td>
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<tr>
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<td>July 31</td>
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<tr>
<td>August 21</td>
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</tr>
<tr>
<td>August 25</td>
<td>2.75</td>
</tr>
<tr>
<td>August 28</td>
<td>1.25</td>
</tr>
<tr>
<td>September 29</td>
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<tr>
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<td>0.25</td>
</tr>
<tr>
<td>October 6</td>
<td>1.50</td>
</tr>
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</table>

ACKNOWLEDGMENTS

Emmanuel Oradei assisted in trap construction. Shane Weber, John Trobaugh, and Sharon Nieland assisted in collecting and examining the weevils. We thank them for their help. The critical review of Louis F. Wilson is greatly appreciated. This work was in part supported by USDA grants CRCR-1-2077 and FSTY-9-0210, and the Wisconsin Department of Natural Resources.

LITERATURE CITED


NEW HOST RECORDS AND DEVELOPMENTAL NOTES ON THE PEAR SLUG *CALIROA CERASI* (HYMENOPTERA: TENTHREDINIDAE), FEEDING ON *COTONEASTER* AND *CHAENOMELES* SPECIES.

Kenneth F. Raffa and Gregory L. Lintereur

ABSTRACT

The pear slug, *Caliroa cerasi* was collected and reared to adulthood on flowering quince and three species of *Cotoneaster*. This is the first record of *C. cerasi* attacking any member of the genus *Chaenomeles* and the first confirmation of feeding on *Cotoneaster* in North America. Adult emergence, oviposition, and larval development were evaluated under both laboratory and field conditions. Females lay an average of 48 eggs, with about two-thirds of the oviposition occurring during their first 24 hours. A method for monitoring adult emergence in the field was developed.

The pear slug, *Caliroa cerasi* (L.) is an introduced sawfly pest of Eurasian origin that is most commonly found on Rosaceae (Cook 1914, Britton 1921). Defoliation of ornamental *Prunus* and *Craetaegus* is occasionally severe enough to require insecticidal suppression (Carl 1972, 1976). Damage to *Cotoneaster* by larval *Caliroa* spp. may also be significant (Johnson and Lyon 1976), but because no adults have been reared from these specimens and larval keys are inadequate for species confirmation (Smith 1971; pers. commun), the role of *C. cerasi* remains uncertain. The pear slug is not known to attack *Chaenomeles* (Smith 1971).

Severe defoliation of several *Cotoneaster* and *Chaenomeles* species was observed in Madison, WI during July and August, 1986. Our experiments were conducted to determine the identity of the *Caliroa* species, and determine its developmental success on various *Cotoneaster* hosts.

MATERIALS AND METHODS

Larvae were collected from 24 August–4 September, 1986 in Madison, WI on hedge (*Cotoneaster lucidus*), many-flowered (*C. multiflorus*), and cranberry (*C. apiculatus*) cotoneaster, and a quince hybrid (*Chaenomeles speciosa × Chaenomeles japonica*). Host plants were confirmed by E. Hasselkaus, Horticulture Department, University of Wisconsin.

Ten larvae from each host were reared in an environmental chamber held at 22°C, 16:8 L:D. The larvae were kept in 22 × 6 cm plastic boxes. Fresh shoots of the appropriate host species were secured in vials of distilled water with cotton plugs. Late instar larvae were provided with 50:50 mixes of soil and sphagnum moss for cocooning. The chambers were observed daily for adult emergence. Adult specimens were submitted to S. Krauth, Dept. of Entomology, Univ. of Wisconsin for identification.

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Adults were transferred to new chambers containing fresh foliage so that oviposition could be observed. Only hedge cotoneaster was available by this time due to autumn senescence. These chambers were examined daily. Oviposition, adult survival, and larval eclosion were recorded.

Three sites at which infestations occurred in 1986 were examined from 1 May to 7 July, 1987. Two plantings consisted of hedge cotoneaster, while the remaining site was a mixture of cranberry cotoneaster, many-flowered cotoneaster and hybrid quince. Wooden boxes (43 cm × 31 cm × 2.5 cm high) were placed on the soil beneath the shrubs. A 2.5 cm o.d. × 5.7 cm glass vial was screwed into a hole at the top of the box. Damp, crumpled paper toweling was provided in the vial. These boxes were examined every one to four days throughout the sampling period. There were 6, 5, and 3 boxes at sites 1, 2, and 3, respectively. Each time the vials were sampled, the hedges were extensively examined for C. cerasi adults, eggs, and larvae. Percent defoliation was estimated at these sites, and neighboring sites were examined periodically.

Spatial and temporal distribution of sawflies collected in the traps were analyzed by ANOVA (Steel and Torrie 1960). Curve fitting was performed using the linear regression subprogram of RS1/RPL by BBN.

RESULTS AND DISCUSSION

All adult sawflies were confirmed as C. cerasi. The tentative host plant identifications were also confirmed. This is the first record of C. cerasi attacking any member of the genus Chaenomeles and the first confirmed feeding on Cotoneaster in North America. The latter observation is significant because European C. cerasi consist of several ecotypes with regard to host plant utilization (Carl 1972) and the source of the American introduction is unknown.

The levels of damage in the field (% leaf skeletonization) were: Hedge cotoneaster-90%, cranberry cotoneaster- 50%, hybrid quince- 35%, many-flowered cotoneaster-10%. Since all of these shrubs were within 15 m of each other, this suggests a relative preference for hedge cotoneaster.

Larvae began to spin cocoons on 9 September, and all cocooning was completed by 19 September. Larvae were able to complete development on all four hosts. Dissection of cocoons indicated that adults are fully formed within about 10 days. Adults emerged from 29 September to 15 October. Survival from late instar larvae to adults averaged 26.7 ± 22.5% (P < 0.05) with no apparent differences between hosts.

Adults began ovipositing almost immediately. They averaged 48.5 ± 17.8 (P < 0.05, N = 6) eggs per female, with most of the eggs being deposited during the first day (Figure 1). This corresponds very closely to the fecundities of 50.3 and 47.0 reported on larvae fed Prunus by Tadic (1956) and Carl (1972), respectively. However, no eggs were deposited after 4 days, compared to the mean ovipositional period of 7.4 days observed under laboratory conditions by Carl (1972). Two females were observed for the first two hours after being provided with host tissue (14:00), and they laid 7 and 8 eggs respectively during this period. Females were able to produce viable eggs regardless of the host plant on which they developed. Adult longevity averaged 3.0 ± 0.94 (P < 0.05, N = 6) days.

The females are photopositive and undergo reflex immobilization if disturbed. The latter response consists of the insect folding up its legs and rolling downward. Eggs turn from dark brown to light tan in three to four days. Larval eclosion occurs six to seven days after oviposition and averages 50.1 ± 34.9% (P < 0.05) under these conditions. Early larval feeding is indicated by small ‘shot holes’ in the foliage. Cocoons occurred after 14 days, demonstrating complete development on hedge cotoneaster.

The first C. cerasi to emerge in the field in 1987 were observed on 10 May. Emergence continued until 17 June, after which no adults were present (Figure 2a). The box traps were effective in capturing C. cerasi adults. After completing development, the sawflies emerge from the soil and orient to the light source, thus becoming trapped in the vials.
The folds of moistened paper provide them with sufficient footing and shelter to help prevent their return to the ground. Adults were captured in the traps from 20 May to 8 June (Figure 2b).

Peak adult emergence occurred from 21 May to 4 June, with 90% of the visually located and 82% of the trapped sawflies being found during this period. The clustered temporal distribution was highly significant ($F = 2.32$, $P < 0.003$). Spatial distribution was highly clustered as well. Only Site 2 provided enough trapped sawflies for statistical analysis, and at this location 93% were found in only two of the five boxes ($F = 2.53$, $P < 0.045$).

The trapping method provided a good estimate of total *C. cerasi* adults present. The number of visually located adults (VL) was related to the number of trapped adults (TR) on each day by

$$VL = (12.40 \times TR) + 4.41 \quad r^2 = 0.60, \quad F = 28.77, \quad P < 0.001.$$ 

Egg blisters first appeared on 26 May and newly formed blisters were observed as late as 1 July. The first larvae emerged on 4 June, and brood from the first generation were present until late July. Minor pin-hole feeding scars were present on 4 June, but extensive shrub damage was not apparent until mid-June.

Defoliation was most severe on hedge cotoneaster. By 27 June, both hedge cotoneaster sites had undergone at least 85% damage, consisting of about 75% brown skeletonized leaves and approximately 10% leaf drop. Damage at the mixed site was only about 1%. By early July, damage to the hedge cotoneasters was 90–95%, and damage to cranberry
Fig. 2. Emergence of C. cerasi in 1987 from Cotoneaster sites experiencing defoliation in 1986. a) Sawflies located by direct observation; b) Sawflies collected in box traps.

cotoneaster, hybrid quince, and many-flowered cotoneaster was 20%, 10%, and < 1%, respectively. This corresponds with our 1986 field observations. By mid-July second generation egg blisters were observed. At the same time a group of hedge and many-flowered cotoneasters located near (0.4 km) the two infested hedge cotoneaster sites was undergoing the early stages (<1% damage) of infestation. These plants were probably being attacked by emigrants from the heavily infested sites, as there was no other apparent source of pear slugs. This supports the view of Carl (1972) that outbreaks over
large areas usually originate from very small, localized populations. Some flushing of new foliage follows severe defoliation.

Our results suggest that where the pear slug requires control tactics on ornamental Prunus, neighboring Cotoneaster and Chaenomeles should be considered as potential reservoirs for population buildup. Conversely, these hedge species are susceptible to pear slug attack. Of these, hedge cotoneaster appears most important. Trapping emergent adults as described may be a useful passive method of monitoring for the pear slug, as our trap catches preceded egg blisters and noticeable defoliation by about six days and one month, respectively, and related to actual pear slug numbers.

ACKNOWLEDGMENT

This work was partially supported by the Wisconsin Department of Natural Resources and McIntire-Stennis WIS03014. We thank E. Hasselkaus and S. Krauth for identifications, and D. R. Smith for personal communication. The critical review of S. Codella, University of Wisconsin, is greatly appreciated.

LITERATURE CITED

RECORDS OF AMPULICIDAE IN MICHIGAN
(HYMENOPTERA: SPHECOIDEA)

Mark F. O'Brien

ABSTRACT

Two species of Ampulicidae, Dolichurus greenei and Ampulex canaliculata, are reported from Michigan for the first time.

To date, there have been no published records of Ampulicidae from Michigan. The following records are new for the state and extend the known ranges considerably. Specimens are deposited in the University of Michigan Museum of Zoology (UMMZ), Michigan State University Collection (MSU), and the collection of D. P. Cowan (DPC).


The above specimens were all collected from Malaise traps. The Klinger Lake specimens were collected at the edge of an oak-pine forest bordering a sandy lane. There are no prey records from Michigan, but this widely distributed eastern species nests under leaf litter in woods and preys upon nymphs of Parcoblattina spp. (Krombein 1955).


The Marquette County record for A. canaliculata is the northernmost record for this species. The Huron Mountains support populations of Parcoblatta pennsylvanica (De Geer), which are especially common under loose bark and rocks on the south-facing exposed rock outcrops, the type of situation where the A. canaliculata specimen was captured.

Ampulex canaliculata is rather widely distributed in the eastern United States (Krombein 1979) and nests in cavities in twigs, under loose bark, and borings in wood (Krombein 1979). Williams (1919) gave a detailed account of its nesting behavior, and Krombein (1967) has studied this species in trap nests. Parcoblatta virginica (Bruner), Parcoblatta sp., and Ischnoptera sp. have been previously recorded as prey (Krombein 1979).

Due to the rather cryptic behavior of ampulicids, it is not surprising that they have been rarely collected in the state. They appear to be locally common, however, as evidenced by the numbers of D. greenei captured in a Malaise trap in St. Joseph County. Undoubtedly, further Malaise trapping in suitable habitats will turn up other specimens in the future.

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ACKNOWLEDGMENTS

I thank D. P. Cowan, Western Michigan University, and D. C. L. Gosling, Huron Mountain Wildlife Foundation, for the specimens they provided, and R. L. Fischer, Michigan State University, for letting me examine the Hymenoptera collection.

LITERATURE CITED


THE PEST STATUS OF YELLOWJACKETS IN OHIO
(HYMENOPTERA: VESPIDAE)

Kenneth J. Stein and Dana L. Wrensch

ABSTRACT

Since 1975 in Ohio, there has been an escalation in the number of complaints and inquiries regarding yellowjackets (Vespula and Dolichovespula spp.) to the Ohio pest control operators, the Ohio Cooperative Extension Service (OCES) County Agents and the OCES Entomologists at the Ohio State University. A survey was distributed in May 1985 to both groups in order to determine the pest status of yellowjackets in Ohio.

The results of this survey strongly suggest that yellowjackets in Ohio are largely an "economic pest", with most economic disturbances associated with homeowners, outdoor businesses, and outdoor recreational facilities.

The perception that yellowjacket populations have been increasing in the Eastern United States and the Midwest is shared by several authors (Menke and Snelling 1975, Morse et al. 1977, Davis 1978, Akre et al. 1980, MacDonald et al. 1980, 1984, Parrish and Roberts 1982).

Menke and Snelling (1975) described an "increasing abundance" of Vespula germanica (F.) in New York, Pennsylvania, New Jersey, Delaware, and Maryland. They believed that the increase began in the late 1960's and that perhaps V. germanica was becoming more common than the native V. maculifrons (Buysson).

Morse et al. (1977) ascribed pest status to V. germanica after they found that 88% of 1,022 randomly collected vespids in Ithaca, New York, during the summer of 1974-1975 were V. germanica.

Davis (1978) noted increasing numbers of yellowjackets in urban environments throughout various parts of the world and pointed to man's restructuring of natural environments as favorably enhancing the establishment of yellowjacket colonies.

MacDonald et al. (1980) described the spread of V. germanica into the northern Midwest, specifically Indiana, Illinois, Michigan, and Minnesota. Although Morse et al. (1977) believed they traced the spread of V. germanica through Ohio in 1976, MacDonald et al. (1980) obtained a specimen from Rock Creek, Ohio in 1971.

MacDonald et al. (1980) believed that V. germanica was emerging as the primary urban pest yellowjacket throughout Indiana and cited increasing numbers of telephone calls regarding yellowjackets at the Department of Entomology, Purdue University, The Indiana State Board of Health, and the State Entomologist's Office as indicative of increasing yellowjacket population densities. Although the majority of these phone calls were from concerned homeowners, there was a proportionate number of inquiries from pest control operators noting a rise in numbers of phone requests to treat structurally-located yellowjacket colonies. Akre et al. (1980) provided further support to the observation that the German yellowjacket was becoming the primary urban/industrial pest yellowjacket. These authors observed an increase in inquiries from the general public and

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thought that the public's knowledge was insufficient for either the proper control of yellowjackets or the determination of their pest status. Although most experts (e.g. Akre and MacDonald) agreed that *V. germanica* was increasing in urban environments, no one had actually quantified this perception prior to 1980. Parrish and Roberts (1982) demonstrated that *V. germanica* colonies were more closely associated with human population density in urban environments than the other yellowjacket species and saw this yellowjacket's potential to become an important urban pest.

Davis (1978) and Akre et al. (1980) have documented some of the damages and problems that arise when yellowjackets conflict with people. Akre et al. (1980) cite instances where logging and sawmill operations have been curtailed because yellowjacket densities were extremely high, and workers could not perform their jobs effectively. In addition, the production of food products within fruit processing plants declined when yellowjackets were abundant within them. The yellowjackets were attracted to the smell of fruit and sweet juices emanating from the processing plant, and became so numerous that they repelled the employees. Consequently, the employees refused to work for fear of being stung. Hawthorne (1969) reported that yellowjackets in California cost agricultural operations an estimated $200,000 in 1968. Most of these losses were due to attacks of yellowjackets on fruit pickers and feedlot workers. Davis (1978) also estimated that thousands of dollars are lost annually in beekeeping throughout the world because of yellowjackets. Even in North America, yellowjackets are a nuisance to beekeepers, often creating severe financial losses (Akre et al. 1980). In all these instances, yellowjackets are directly responsible for lost man-hours, lost wages, and medical expenses due to treatment of stings, and thus are a factor when assessing the overall economic importance of yellowjackets.

Although most people believe that yellowjackets are a nuisance, very few recognize their ecological significance as predators (MacDonald et al. 1980, Akre et al. 1980). Several authors (Spradbery 1973, MacDonald et al. 1974, Greene et al. 1976, Schmidt-mann 1977, Akre et al. 1980) have described some of the beneficial aspects of yellowjackets, including their role as predators of pest insects. However, depending on the locality, it may be difficult to determine whether yellowjackets are more of a nuisance than a benefit. Akre et al. (1980) and MacDonald (1980) believe more research is needed in order to fully understand the beneficial nature of yellowjackets.

In 1975 in Ohio, survey entomologists noted an increase in yellowjacket populations (Lewis 1975). During 1983–1986, official records of the OCES (based on the number of phone calls) have suggested that the yellowjacket has been the most abundant "pest" in Franklin County (W. F. Lyon pers. comm.).

In 1985, a survey was distributed (in cooperation with the OCES) to 88 OCES County Agents (CA's) and 185 Ohio Pest Control Operators (PCO's). The primary intent of the survey was to assess qualitatively whether the yellowjackets in Ohio create sufficient losses to be considered an economic pest. In addition, the survey provided information to determine the working knowledge possessed by the professionals who deal with yellowjacket problems on a regular basis. The results might point to needed areas of research aimed at yellowjacket ecology and control.

**METHODS**

A survey was developed (Table 1) to provide results for evaluating the perceptions held by the PCO's and the CA's regarding yellowjackets. This survey asked a variety of questions about yellowjacket ecology, biology, control, abatement and economic damages. These questions were based on yellowjacket-related problems described in the literature and discussions with the extension entomologists at The Ohio State University. Draft copies of the survey were critiqued by Dr. Donald Johnston and Dr. William Lyon of the Entomology Department at The Ohio State University. Eighty-eight surveys were sent to the CA's and 185 were sent to the PCO's.
RESULTS AND DISCUSSION

The number of surveys returned by the PCO's was 71 out of a total of 185 distributed (38.4% returned). The CA's had a much higher response, returning 78 surveys out of 88 sent (88.6% returned). Refer to Table 1 for the responses given to each question.

The response to question 1 indicates the perceptions of the relative abundance of yellowjackets in Ohio prior to May, 1985. Fifty-five percent of the PCO's and CA's observed yellowjackets to be frequently or occasionally troublesome. This observation is strongly reinforced by the response to question 2; the majority of the PCO's and CA's (54.1%) have answered 50–100 yellowjacket inquiries/year during 1983 and 1984. PCO's overall received more inquiries. This large number of inquiries concurs with what has been observed by the OCES entomologists for the past three years in Columbus, Ohio. Furthermore, 63.3% of the total agents surveyed (question 3) thought yellowjackets were increasing as a pest. Our results affirm the views of several entomologists who believed yellowjacket populations to be increasing or expanding their range.

The PCO's and the CA's both received 71.2% (question 4) of all their yellowjacket complaints during August and September. These two months correspond to near maximum worker populations of most vespids (MacDonald, 1980) and therefore strengthen the likelihood that the PCO's and CA's are describing yellowjackets and not other insect pests. The majority of these complaints (54.5%; question 5) come from homeowners, businesses, and outdoor recreational facilities. The origin of these complaints accurately depicts the nature of the yellowjacket problem in Ohio; essentially, yellowjackets are an urban problem. Although there is more than one species of yellowjacket found in Ohio's urban environments, V. germanica's foraging behavior and nest-site location makes it largely responsible for the nuisance problem.

Although the survey results indicate that some businesses (question 5) and farmers (question 6) often complain about yellowjackets, the yellowjackets in Ohio are apparently not as severe a pest as that described by Davis (1978) and Akre et al. (1980). Both of these authors have indicated that yellowjackets in California, Oregon and Washington frequently become economic pests for many businesses and industries.

Question 7 was designed to investigate the cumulative economic cost of yellowjacket disruption in a specific area. Although 54.6% of the agents responded to question 7 with no opinion/no information, about 20% considered them causing in excess of $5,000/year damage. Thus, when the respondents had information, yellowjackets are economically important. These costs may not be “severe” in the sense of Davis (1978) and Akre et al. (1980) but are nevertheless greater than one would assign to nuisance pest status. The PCO's and the CA's perceptions of yellowjackets are incomplete because certain aspects of the economic importance of yellowjackets are unknown. Their reports do not include the medical costs due to treatment of yellowjacket stings, which will be confined largely to medical facilities and insurance companies, or building costs associated with yellowjacket structural damage. Evidence that yellowjackets in Ohio are an economically important pest are reinforced by question 8. Thirty-one point four percent of the PCO's and CA's believed abatement funding is warranted for yellowjackets as for mosquitoes.

Some of the economic complaints included an agent who spoke of yellowjackets stripping the skins off of a grape crop and ruining them. By the time he treated it with pesticide, it was too late. Additional complaints come from roadside fruit vendors who find that yellowjackets can be so dense on fruit at times that people are repelled at the sight and will not remain to buy. One PCO treated trash cans (for yellowjackets) at a county fair where 112 people were stung in one week. One positive comment came from a pig farmer who was going to destroy a yellowjacket nest until he noticed that the yellowjackets were removing flies from his pigs. Apparently the beneficial aspects of yellowjackets are often overlooked.

The PCO's and CA's are the personnel who deal with urban yellowjacket problems on a regular basis. Therefore it is surprising that only 28.2% of the respondents claimed to have knowledge of the species of yellowjackets in their homes (question 9). This total consists of 50.7% of the PCO responses compared to only 8% of the CA's reporting. This
discrepancy is not unexpected because PCO’s are involved in yellowjacket extermination, and are thus more likely to know species.

Also surprisingly, only 40.3% of the respondents thought yellowjackets have any positive ecological benefit (question 10). This total consists of 47.7% of the PCO’s versus only 34.2% of the CA’s responding in the affirmative. Although it does not require a knowledge of vespid ecology to effectively remove unwanted yellowjacket colonies, it is remarkable that a majority of experienced agents do not know that yellowjackets have some ecological benefit.

Most of the respondents preferred carbaryl as the best pesticide to kill yellowjackets (63.8%, question 11). The distinction between PCO’s and CA’s is interesting here: 91.7% of the CA’s chose carbaryl as compared to only 44.0% of the PCO’s, of whom 30.1% preferred dichlorvos.

Question 12 attempted to investigate future control strategies. The response to question 12A and 12C included an appreciable number of responses that suggested poison baits, attractant lures, and repellents were useful for yellowjacket control. The literature regarding yellowjacket control for the last ten years or so is replete with references to potential control by the use of poison baits, attractant lures and repellents (Akre et al. 1980, MacDonald et al. 1976, MacDonald 1980). Even though poison baits, attractant lures and repellents are not a widespread method of control, 46.7% of the PCO’s and CA’s were aware of their potential.

Although male sterile techniques would theoretically be possible as a control strategy, yellowjackets have a unique biology, and it is doubtful that such a control strategy would ever be practical. However, 37.7% of the PCO’s and CA’s (question 12) believed male sterile techniques would be effective as a control strategy.

The results of this survey indicate that the persons most likely to handle complaints about yellowjackets consider them a serious economic pest. The number and recent increasing frequency of phone calls (in Ohio), and the variety of businesses making inquiries, supports the hypothesis that yellowjackets are a serious urban pest.

The PCO’s and CA’s do not have the specific information necessary for assessing the medical costs related to the treatment of yellowjacket stings and allergic reactions. In addition, economic losses to the business community caused by yellowjackets may also remain unknown. Thus, the PCO’s and CA’s perceptions and responses to this survey underestimate the actual economic impact caused by yellowjackets.

At the February, 1986 National Urban Entomology Conference in College Park, Maryland, many entomologists, PCO’s and CA’s believed the yellowjacket to be a primary urban pest (R. D. Akre pers. comm.). Questions were raised regarding the lack of current research applied to yellowjackets. Perhaps additional investigations such as this survey will help stimulate research (or funding) in other states where yellowjackets are also economically important. Ultimately, this research may lead to an increased knowledge of yellowjacket ecology and control.

ACKNOWLEDGMENTS

Sincere appreciation is extended to Dr. Bill Lyon of The Ohio State University Department of Entomology for his advice and assistance in conducting this survey. The Ohio Cooperative Extension Service staff, Marti Gilkerson, Nancy Robinson and Jeanette Janszen, were very helpful in distributing the survey and referring phone calls from people with yellowjacket problems. This study was part of the research undertaken for the senior author’s Master of Science thesis at The Ohio State University.

LITERATURE CITED


APPENDIX

TABLE 1. Twelve questions of a survey that were sent to the County Agents (CA's) and the registered Ohio Pest Control Operators (PCO's) in 1985. Following the answers to each of the questions are the total number and percent total number of responses given by the PCO's and CA's.

T = Combined responses from both Pest Control Operators and County Agents; % = Percent of responses; N = Total number of responses; NA = No response

For the following questions please circle the one letter or letters that best represents your opinion.

1) Yellowjackets have been a problem in my area:

<table>
<thead>
<tr>
<th>%</th>
<th>(N)</th>
<th>%</th>
<th>(N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Very much and often troublesome</td>
<td>55.0</td>
<td>(82)</td>
<td>C. Very little, rarely receive inquiries and complaints</td>
</tr>
<tr>
<td>B. Only occasionally, or infrequently troublesome</td>
<td>40.3</td>
<td>(60)</td>
<td>D. Not at all</td>
</tr>
</tbody>
</table>

2) How many inquiries or complaints have you received about yellowjackets in the last two years?

<table>
<thead>
<tr>
<th>%</th>
<th>(N)</th>
<th>%</th>
<th>(N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Greater than 100/year</td>
<td>25.7</td>
<td>(38)</td>
<td>C. 10 or more, but less than 50/year</td>
</tr>
<tr>
<td>B. 50 or more, but less than 100/year</td>
<td>28.4</td>
<td>(42)</td>
<td>D. Less than 10 per year</td>
</tr>
</tbody>
</table>
3) Yellowjackets are increasing as a pest in your area:
   A. Yes 63.3 (95)  
   B. No 15.3 (23)  
   C. No opinion/no information 21.3 (32)

4) What month of the year do you receive the most calls involving inquiries or complaints about yellowjackets?
   A. June 4.5 (10)  
   B. July 18.0 (40)  
   C. August 37.4 (83)  
   D. September 33.8 (75)  
   E. October 5.8 (13)  
   F. Other— NA NA

5) Circle any of the following letters that reflect areas of complaint or inquiries about yellowjackets:
   A. Homeowners 26.9 (144)  
   B. Amusement or recreational facilities 15.5 (83)  
   C. Business facility 12.1 (65)  
   D. Vegetable or fruit grower 3.5 (19)  
   E. Vegetable or fruit seeder 3.5 (19)  
   F. Restaurant or food vendor 11.0 (59)  
   G. Education (school teachers or students wanting biological or pest status information) 5.8 (31)  
   H. Pest control companies 3.9 (21)  
   I. Persons expressing fear of the insect or its sting 18.9 (96)  
   J. Hospitals, doctors, veterinarians (63.2 (17)  
   K. Other— NA NA

6) Yellowjackets have probably been responsible for the destruction or damage to which of the following commercial products:
   A. Beehives 7.6 (11)  
   B. Grapes 15.2 (22)  
   C. Melons 9.0 (13)  
   D. Apples 24.1 (35)  
   E. Peaches 11.0 (16)  
   F. Plums 4.8 (7)  
   G. Fruit juice companies, wineries, cider manufacturers 13.1 (19)  
   H. Bakeries 9.0 (13)  
   I. Other— 6.2 (9)

7) If you can assess the cumulative economic cost of yellowjacket damage or disruption in your area, would you estimate that cost at:
   A. Greater than $10,000/year 9.9 (14)  
   B. Less than $5,000/year, but more than $10,000/year 14.2 (20)  
   C. $1,000 or more, but less than $5,000/year 11.3 (16)  
   D. Less than $1,000/year 9.9 (14)  
   E. No opinion/no information 54.6 (77)

8) Should there be funding appropriated similarly to mosquitoes for abatement control programs?
   A. Yes 31.4 (43)  
   B. No 68.6 (94)

9) Do you have any knowledge of the species of yellowjacket in your home?
   A. Yes 31.4 (43)  
   B. No 68.6 (94)
10) Do you personally think yellowjackets have any positive ecological benefit?
   A. Yes  
   B. No  
   C. No opinion

11) What is the best pesticide to kill yellowjackets?
   A. Carbaryl (Sevin)  
   B. Resmethrin (Synthrin)  
   C. Dichlorvos (DDVP)  
   D. Other—

12) What is a future control strategy that might work to reduce yellowjacket infestations?
   A. Poison baits  
   B. Male sterile techniques  
   C. Attractants and repellents  
   D. Genetic engineering  
   E. Trapping
FIRST RECORD OF THE TRUE KATYDID, *PTEROPHYLLA CAMELLIFOLIA* (ORTHOPTERA: TETTIGONIIDAE: PSEUDOPHYLLINAE) IN NORTH DAKOTA

Edward U. Balsbaugh, Jr.

ABSTRACT

The true katydid, *Pterophylla camellifolia*, is recorded as a new state record for North Dakota.

A single male specimen of the northern true katydid, *Pterophylla camellifolia* (Fabricius), was captured 13 September 1987, in north Fargo, Cass County, North Dakota, by Dr. Thomas P. Freeman. The calling of this or of other true katydids in the area had been disturbing the neighborhood residents. A follow-up for additional specimens was made by me on the night of 15 September, but neither calling nor additional katydids were detected.

*Pterophylla camellifolia* has been recorded from Massachusetts and Ontario south to Florida and west to Iowa and eastern Texas (Hebard 1941, Beier 1960). Its occurrence in North Dakota is probably accidental, perhaps introduced with imported nursery stock.

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1Approved by the Director of the North Dakota Agricultural Experiment Station as Journal Series No. 1591.

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OCCURRENCE OF THE BAT TICK, *ORNITHODOROS KELLEYI* (ACARI: ARGASIDAE), IN MICHIGAN

B. M. O'Connor and J. S. H. Klompen

**ABSTRACT**

The bat tick, *Ornithodoros kelleyi*, is recorded from Michigan for the first time. A single female was collected in a building on the University of Michigan campus in Ann Arbor.

*Ornithodoros kelleyi* Cooley and Kohls, is an ectoparasite of vespertilionid bats over much of North America, ranging from British Columbia and Arizona to New York and Cuba. In the Great Lakes region, this tick has been reported from Minnesota, Wisconsin, Illinois, Pennsylvania, New York (Cooley 1942), Ohio (Bequaert 1946), and Indiana (Wilson 1958, Whitaker 1982). This species has not been previously reported from Michigan and was not collected during a recent survey of bat ectoparasites in the state (Dood & Kurta 1982). Reported hosts for this tick in North America include *Eptesicus fuscus* (Palisot de Beauvois), *Myotis lucifugus* (Le Conte), *M. californicus* (Audubon & Bachman), *Pipistrellus subflavus* (Cuvier), *P. hesperus* (Allen), and *Antrozous pallidus* (Le Conte). The morphology and life history of this species have been reviewed by Sonenshine (1962) and Sonenshine and Anastas (1960).

On 3 February 1988, a single female specimen of *O. kelleyi* was collected by the authors from an inside wall on the second floor of the University of Michigan Museum of Zoology, in Ann Arbor, Washtenaw Co., Michigan. The specimen was preserved and deposited in the collection of the Insect Division in the museum, labelled with the voucher number HK 88-0202-1. The area of the building where the tick was collected has periodically harbored colonies of big brown bats (*E. fuscus*) and occasionally silver-haired bats (*Lasionycteris noctivagans* [Le Conte]) although the presence of hibernating bats in the area could not be verified at the time the tick was collected. *Eptesicus fuscus* appears to be the preferred host of this tick in the Great Lakes region. Whitaker (1982) reported 14.5% infestation of 491 *E. fuscus* examined in Indiana, with an average of 0.26 ticks per bat. In contrast, the only other host utilized in Indiana, *Myotis lucifugus*, exhibited an infestation rate of only 2.4% of 84 bats examined, with 0.08 ticks per bat.

Although *O. kelleyi* has been found in human habitations on several occasions (Cooley 1942, Sonenshine & Anastas 1960), it is unlikely that these ticks will bite humans and their occurrence should not cause alarm. Sonenshine & Anastas (1962) found that nymphs and adults would feed only upon bats although larvae fed readily upon laboratory rats.

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