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Fifth instar of *Epiptera opaca* (Homoptera: Fulgoroidea: Achilidae). Drawing by Stephen W. Wilson, Department of Biology, Central Missouri State University, Warrensburg.

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DESCRIPTION OF THE FIFTH INSTAR OF *EPIPTERA OPACA*  
(HOMOPTERA: FULGOROIDEA: ACHILIDAE)

Stephen W. Wilson

*Epiptera opaca* (Say) ranges from Quebec south to Georgia and west to Ontario and Mississippi; it has also been recorded from British Columbia (Beirne 1950, Wilson and McPherson 1980). This achilid has been associated with pines (Hepburn 1967); otherwise no information on the biology of this species is available. Based on observations of *E. fusca* (Walker), Hepburn (1967) noted that the immature stages of all species of *Epiptera* probably live beneath the loose bark of dead trees, presumably feeding on fungal hyphae. The immatures of *E. opaca* have never been described. Fennah (1950) illustrated a fifth instar nymph of *E. fusca* but provided no description; Osborn (1922) illustrated and briefly described the fifth instar nymph of *E. slossoni* (Van Duzee); and Linnavuori (1951) illustrated and described the fifth instar nymphs of two species of *Cixidia*. To my knowledge, there are no other published descriptions or illustrations of immature Achilidae.

The following description is based on two nymphal *E. opaca* collected with four adult males in a sawdust pile in southern Illinois. The collecting data for the specimens are: Oblong, Illinois, 4 August 1958, G. T. Riegel collector, in sawdust pile.

DESCRIPTION OF FIFTH INSTAR

Measurements of the pinned nymphs were made with an ocular micrometer. Body length was measured from the tip of the vertex to the tip of the abdomen; width was measured across the widest part of the body; thoracic length was measured along the midline from the anterior margin of the pronotum to the posterior margin of the metanotum.

Fifth instar (Fig. 1). Length 7.01–7.05 mm; thoracic length 2.35–2.45 mm; width 3.50–3.51 mm.

Form elongate, dorsoventrally flattened, widest across mesonotal wingpads. Body dark brown with yellowish markings.

Head dark brown, yellow medially on vertex. Vertex subquadrate, narrowing apically, anterior corners rounded, weakly carinate anterior and lateral margins. Frons subrectangular, narrowing slightly apically, slightly longer than wide, broadest just beneath eyes, lateral margins subparallel to slightly convex, each lateral margin carinate (outer carina) with an irregular inner carina present in anterior half on each side ca. 2/3 the distance from midline to lateral carina; notched medially at frontoclypeal juncture; with two irregular rows of pits between inner and outer carinae. Clypeus narrowing distally, consisting of a subconical, basal postclypeus and an elongate, subconical distal anteclypeus. Beak apparently 3-segmented, extending to 3rd abdominal sternite; segment 1 covered by anteclypeus, segment 2 ca. 1½–2 times length of 3. Eyes dark reddish-brown, somewhat reduced. Antennae with scape reduced, ring-like; pedicel lacking sensoria, ca. 3 times length of scape; distal flagellum whip-like with base bulbous.

Thoracic nota with a longitudinal, median carina, dark-brown with yellowish markings; divided by a longitudinal mid-dorsal line into three pairs of plates. Pronotum with anterior margin broadly rounded, posterior margin slightly sinuate; each plate subtriangular, with an oblique longitudinal carina in median 1/2 extending from anterior margin almost to posterior margin and bordered medially and posteriorly by a row of six pits; with a slightly sinuate...
oblique longitudinal carina in lateral 1/3 extending from near anterior margin to posterior margin and bordered by a row of indistinct pits laterally. Mesonotum with median length ca. 2 times that of pronotum; each plate with a weak longitudinal oblique carina near midline, with a slightly convex longitudinal carina in median 1/3, and a weak longitudinal oblique carina in lateral 1/3; with a row of four pits just lateral to convex carina and several indistinct pits median and lateral to lateralmost carina; wingpad extending almost to tip of metanotal wingpad. Metanotum with median length ca. 2/3 that of mesonotum; each plate with a slightly convex longitudinal carina in median 1/3; wingpad extending to 3rd abdominal tergite. Pro- and mesocoxae elongate, dorsoventrally flattened; metacoxae smaller, hidden behind enlarged cup-like trochanters; remaining segments of legs bearing short setae. Metatibia with one black-tipped spine in distal 1/2 of shaft and a row of seven black-tipped spines at apex. Pro- and mesotarsi 2-segmented, segment 1 wedge-shaped, segment 2 subconical and curved with a pair of slender brown claws and pale pulvillus apically. Metatarsi 3-segmented, segments 1 and 2 each bearing an apical row of seven black-tipped spines ventrally, segment 3 similar to segment 2 of other legs.

Abdomen 9-segmented. Tergites 4–9 each with a row of indistinct pits laterally on either side; tergites 6–8 each with a large yellowish dorsal ovoid waxpad on either side, wax pads occupying from ca. 1/2 area of tergite to almost all of tergite; tergites 5–9 each with a pit on either side in median 1/3. Segment 9 with tergite curving around ventral sides, surrounding anus.

ACKNOWLEDGMENT

I would like to thank Dr. G. T. Riegel, Department of Zoology, Eastern Illinois University, Charleston, for the loan of specimens.
LITERATURE CITED

NEARCTIC ENDOTHENIA SPECIES: A NEW SYNONYMY, 
A MISIDENTIFICATION, AND A REVISED STATUS 
(LEPIDOPTERA: TORTRICIDAE)

William E. Miller

ABSTRACT

Two Nearctic taxa are treated: *Endothenia hebesana* (Walker) and *E. nubilana* (Clemens). *Endothenia daeckeana* (Kearfott) is deemed a junior synonym of *E. hebesana* because structural differences previously alleged to distinguish them intergraded when examined allometrically. A published record of the Palaearctic *E. gentianaana* (Hübner) in Michigan is shown to be based on misidentified specimens referable to *E. hebesana*. Differences are confirmed between *E. nubilana* and the Palaearctic *E. quadriramulana* (Haworth), including structure of male uncus, and the former is elevated to species status.

Three identity problems are dealt with here. One problem concerns *Endothenia daeckeana* (Kearfott) whose current status as a species distinct from *E. hebesana* (Walker) is doubtful. The second concerns Beebe’s (1954) report of the Palaearctic *E. gentianaana* (Hübner) in Michigan, which is based on a misidentification. The third concerns *E. quadriramulana nubilana* (Clemens), which differs structurally from the Palaearctic *E. quadriramulana* (Haworth) and thereby warrants separate status. The above four Nearctic names are resolved into two.

Nomenclatural summaries that follow are limited to primary literature. The letter n denotes number of specimens or observations underlying a particular statement. Color numbers refer to those of Smith (1975); the colors were estimated under fluorescent light without magnification. Museum abbreviations are AM-American Museum of Natural History, AP-Academy of Natural Sciences of Philadelphia, BM-British Museum (Natural History), Br-collection of A. E. Brower, CN-Canadian National Collection, He-collection of J. R. Heitzman, IS-Illinois Natural History Survey, NM-National Museum of Natural History, UMi-University of Michigan Museum of Zoology, UMN-University of Minnesota, Twin Cities, and UWI-University of Wisconsin, Madison.

*Endothenia hebesana* (Walker) 
(Figs. 1–4)

*Sciaphila hebesana* Walker (1863: 342) (holotype: male, “N. Amer.”, genit. prep. 11616, forewing 7.0 mm long; in BM, wing and genitalia photos in AM; Fig. 2).
*Carpcocapsa inexpertana* Walker (1863: 394) (holotype: female, “N. Amer.”, genit. prep. 11646, forewing 7.5 mm long; in BM, wing and genitalia photos in AM).
*Olethreutes daeckeana* Kearfott (1907: 12) (lectotype designated by Heinrich 1926: female, Tom’s River, N. J.; in AM; wings and abdomen missing). NEW SYNONYMY
*Endothenia gentianana* Beebe (1954: 26); (not Hübner). Misidentification and misspelling

---

1North Central Forest Experiment Station, USDA Forest Service, St. Paul, MN. 55108. Present address: Department of Entomology, University of Minnesota, St. Paul, MN 55108.

**Male.** Forewing 5.0–8.2 mm long, pattern as in Figure 1, with colors ranging from dusky brown to clay (Nos. 19 to 26) (48n). Genitalia as in Figure 2, with sacculus containing 24–72 small spines and uncus 0.11–0.18 mm wide (47n), both ranges depending partly on body size.

**Female.** Forewing 5.0–8.2 mm long, pattern and colors as in male (34n). Genitalia as in Figures 3, 4, signum 0.18–0.48 mm long, depending partly on body size (30n).

**Biology.** Biological information about the species in North America is given by Fink (1915), Gibson (1929), Ries (1929), Brower and Brower (1971), and Hilton (1982). The life cycle is univoltine or multivoltine depending on latitude, the late instar larva or pupa overwintering. The larva feeds mostly on developing host seeds, less frequently on other parts. The hosts of reared adults examined in this study, including types, were *Antirrhinum, Gerarda, Iris, Teucrium, Veronica, Sarracenia, Scrophularia,* and *Scutellaria.* Additional hosts reported in the literature are *Gentiana, Orthocarpus, Penstemon, Physostegia, Solidago, Stachys, Tigridia, Verbasum,* and *Verbena.* Seven of these genera represent the family Scrophulariaceae, four the family Labiatae, and the remaining six one family each (Fernald 1950, and others), totalling no less than eight host plant families. The insect is known commonly as the verbena bud moth.
**Discussion.** The name *E. daeckeana* was proposed for moths developing on the pitcher plant genus, *Sarracenia*. According to Heinrich (1926), *E. daeckeana* differs from *E. hebesana* by being "somewhat larger, with forewing broader and rounded at apex, and with slightly larger genitalia." Differentiating the two forms has always been difficult, and collections contain few nonreared specimens determined as *E. daeckeana*. Forbes (1923) suggested that *E. daeckeana* was a "variant" of *E. hebesana*, noting that the latter had also been reared from *Sarracenia*.

In the present study I attempted to confirm the alleged forewing width and genital size differences between *E. daeckeana* and *E. hebesana* by examining forewing length, forewing width, male uncus width, number of spines on one male valval sacculus, and female signum length. Measurements were made as follows: forewing length from tegulum to apex including fringe, forewing width from tornus to costa perpendicular to the length axis excluding fringe, uncus width in ventral view at the widest extremity, and signum length along the greatest dimension. Forewing length, an index of body size (Miller 1977), was used to standardize the other measurements. Moths reared from *Sarracenia* were taken to be *E. daeckeana*, and those from other hosts, *E. hebesana*.

The average size of reared adults is summarized by host below:

<table>
<thead>
<tr>
<th>Mean forewing length (mm)</th>
<th>On <em>Sarracenia</em> (n)</th>
<th>On other hosts (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>7.6 (4)</td>
<td>6.9 (8)</td>
</tr>
<tr>
<td>Females</td>
<td>7.7 (3)</td>
<td>6.8 (9)</td>
</tr>
</tbody>
</table>

The moths from *Sarracenia* averaged significantly larger than those from other hosts (P_F < 0.02). They also averaged darker, although similar extremes of lightness and darkness occurred in both host categories.

The other measurements formed homogeneous configurations similar to those of forewing width vs. forewing length (Fig. 5). All such measurements of moths from *Sarracenia* fell within the ranges observed for the moths from other hosts. Like forewing width, means of other measurements increased or decreased in a predictable way depending on wing length (Table 1). Also, regressions were similar among different host partitions of the total sample (Fig. 5). Thus the quoted differences between *E. daeckeana* and *E. hebesana* relate to size of moth regardless of host or other factors.

The average color and size differences between moths from *Sarracenia* and those from other hosts could reflect geographic or ancient melanism (Kettlewell 1973) and nutritional differences among host plants. In any case, such differences are states of population characters rather than species characters.

Concerning *E. gentianiana* (Hübner), genitalia of four males prepared by Beebe were located at UMi, but not the pinned adults. These genitalia differ markedly from true *E. gentianaeana* (Kuznetsov 1978). All are within the *E. hebesana* ranges of uncus width and valval spine count given above and are indistinguishable in other respects as well. They also differ structurally from other Nearctic *Endothenia* species, nearly all of which were examined in this study.

Interestingly, *E. hebesana* has recently been reported to occur in the Palaearctic Region (Opheim 1972, Kuznetsov 1978).

**Material Examined.** Besides types, I also examined specimens from Illinois, Michigan, Minnesota, Quebec, Wisconsin, New York, New Jersey, Missouri, Maine, Massachusetts, and Idaho. This material was obtained from IS, UMi, UMn, UWi, AM, NM, CN, He, and Br.

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*Endothenia nubilana* (Clemens), REVISED STATUS

(Figs. 6–10)

*Siderea nubilana* Clemens (1865: 140) (lectotype designated by Darlington 1947; male, locality of origin unknown; wings illustrated by Miller 1973; in AP).
Table 1. Statistics and mathematical relations between characters (y) and forewing length (l) in *Endothenia hebesana*.

<table>
<thead>
<tr>
<th>Character</th>
<th>n</th>
<th>Mean</th>
<th>Standard error of estimate about regression</th>
<th>r²</th>
<th>Parameters a</th>
<th>Parameters b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pooled male and female forewing width (mm)</td>
<td>7b</td>
<td>3.4</td>
<td>0.14</td>
<td>0.90</td>
<td>0.13</td>
<td>1.61**</td>
</tr>
<tr>
<td></td>
<td>71c</td>
<td>2.9</td>
<td>0.32</td>
<td>0.54</td>
<td>0.49</td>
<td>0.94**</td>
</tr>
<tr>
<td></td>
<td>16d</td>
<td>3.1</td>
<td>0.36</td>
<td>0.21</td>
<td>0.96</td>
<td>0.61</td>
</tr>
<tr>
<td></td>
<td>62e</td>
<td>2.9</td>
<td>0.30</td>
<td>0.66</td>
<td>0.44</td>
<td>1.00**</td>
</tr>
<tr>
<td></td>
<td>23f</td>
<td>3.1</td>
<td>0.32</td>
<td>0.52</td>
<td>0.44</td>
<td>1.00**</td>
</tr>
<tr>
<td></td>
<td>55g</td>
<td>2.8</td>
<td>0.31</td>
<td>0.59</td>
<td>0.47</td>
<td>0.99**</td>
</tr>
<tr>
<td></td>
<td>78h</td>
<td>2.9</td>
<td>0.31</td>
<td>0.60</td>
<td>0.44</td>
<td>0.99**</td>
</tr>
<tr>
<td>Female signum length (mm)</td>
<td>29</td>
<td>0.32</td>
<td>0.052</td>
<td>0.32</td>
<td>0.07</td>
<td>0.81*</td>
</tr>
<tr>
<td>Male single valval spine count</td>
<td>47</td>
<td>41</td>
<td>6.9</td>
<td>0.36</td>
<td>6.5</td>
<td>0.97**</td>
</tr>
<tr>
<td>Male uncus width (mm)</td>
<td>45</td>
<td>0.14</td>
<td>0.013</td>
<td>0.21</td>
<td>0.07</td>
<td>0.38**</td>
</tr>
</tbody>
</table>

*Refers to nonlinear fitting of the allometric equation, y = a(l^b).

*b* Reared from *Sarracenia*.

*c* Excluding specimens reared from *Sarracenia*.

*d* Reared from hosts other than *Sarracenia*.

*e* Excluding specimens reared from hosts other than *Sarracenia*.

*f* Reared from any host.

*g* Nonreared.

*h* All specimens.

*P* < 0.05.

**P* < 0.01.

*Sericoris vetulana* Walsingham (1879: 32) (lectotype designated here: male, "Scott's Valley, Lake Co., Ca... 17-19 VI. 1871, Lectotype male *Sericoris vetulana* Wlsm., genit. prep. 11619, forewing 8.5 mm long; in BM).

*Endothenia antiquana nubilana*; Heinrich (1926: 105).

**Male.** Forewing 7.8–9.9 mm long, pattern as in Figure 6, with colors ranging from fuscus to buff (Nos. 21–24, 124) (14n). Genitalia as in Figures 7, 10, with uncus 0.21–0.30 mm wide and containing 7–17 short apical spines (10n).

**Female.** Forewing 7.5–10.0 mm long, pattern and colors as in male (9n). Genitalia as in Figures 8, 9 (5n).

**Biology.** The larva feeds in stem bases of *Stachys* (Putman 1942). Capture dates range from 16 June to 23 August (23n).

**Discussion.** *Endothenia nubilana* is similar in forewing color pattern to the Palaearctic *E. quadrimaculana* (Haworth) (= *antiquana* Hübner). No differences have been found between the two taxa in female genitalia, and both are known to feed on *Stachys*, *Endothenia quadrimaculana* also using *Mentha* and *Symphytum* (Bradley et al. 1979).

Walsingham (1879) noted that *Endothenia nubilana* (= *vetulana* Walsingham) is smaller bodied, and Heinrich (1926) noted that males have more short apical spines on the uncus.
Fig. 5. Relation of forewing width (y) to forewing length (l) in different host partitions of the total *Endothenia hebesana* sample. Each point represents one adult. Solid lines represent adults depicted in the scatter diagrams. The dashed line accompanying each solid line represents all remaining adults not depicted in the scatter diagram.

However, Heinrich added "I doubt very much if the (latter) character is constant," and he proposed the above trinomial.

In the present study, I examined the foregoing differences as well as compared uncus widths. Forewing length and uncus width were measured as described for *E. hebesana*. Forewing length served as an index of body size.

In the samples assembled, *E. nubilana* averaged more short apical spines on the uncus, smaller uncus width, thicker lateral projections of the uncus, and smaller forewing length than *E. quadrimaculana*, but there was some overlap between the two species in all these attributes (Figs. 10, 11, Table 2). Further study of unci showed that the expression of spine number was basically different between the taxa: despite its higher total spine count, *E.*
**Figs. 6–9. Endothenia nubilana.** 6, Wings of female from Aweme, Manitoba; 7, Genitalia of male from Ramsey Co., MN (DH 406811); 8, Sterigma and associated structures of female from Cass Co., MN (DH 826803); 9, Corpus bursae and signum of specimen in Figure 8.

*nubilana* averaged 0.02 small apical spines per unit of uncus width compared with 0.06 in *E. quadrimaculana*. This difference in particular argues against regarding the two taxa as conspecific.

**Material Examined.** Besides types, I also examined *E. nubilana* specimens from Minnesota, Wisconsin, North Dakota, and Manitoba. This material was obtained from UMn, UWi, and NM. The *E. quadrimaculana* specimens originated in Germany, England, and the European USSR, and were obtained from NM and AM.

Table 2. Comparison of three characters between males of *Endothenia nubilana* (10n) and *E. quadrimaculana* (13n).

<table>
<thead>
<tr>
<th>Character</th>
<th>Species</th>
<th>Mean</th>
<th>Standard Error</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. short apical</td>
<td><em>nubilana</em></td>
<td>12</td>
<td>1.0</td>
<td>7–17</td>
</tr>
<tr>
<td>spines on uncus</td>
<td><em>quadrimac.</em></td>
<td>5</td>
<td>0.3</td>
<td>4–8</td>
</tr>
<tr>
<td>Uncus width (mm)</td>
<td><em>nubilana</em></td>
<td>0.26</td>
<td>0.01</td>
<td>0.21–0.30</td>
</tr>
<tr>
<td></td>
<td><em>quadrimac.</em></td>
<td>0.32</td>
<td>0.01</td>
<td>0.28–0.38</td>
</tr>
<tr>
<td>Forewing length</td>
<td><em>nubilana</em></td>
<td>8.8</td>
<td>0.23</td>
<td>7.8–9.9</td>
</tr>
<tr>
<td>(mm)</td>
<td><em>quadrimac.</em></td>
<td>9.9</td>
<td>0.26</td>
<td>8.1–11.0</td>
</tr>
</tbody>
</table>

* All means differ significantly between species (*P* < 0.01).

ACKNOWLEDGMENTS

For specimen loans and other assistance, I thank T. E. Moore, F. H. Rindge, A. E. Brower, R. L. Brown, J. R. Heitzman, G. L. Godfrey, R. D. Shenefelt, P. J. Clausen, and David Hagler. Figure 1 is from the N. S. Obraztsov type photo collection and is reproduced through the courtesy of AM.

LITERATURE CITED

FIELD EVALUATION OF TRAP COMPONENTS FOR THE
INTRODUCED PINE SAWFLY, DIPRION SIMILIS
(HYMENOPTERA: DIPRIONIDAE)

H. A. Thomas

ABSTRACT

Three sizes of the Conrel Delta trap, a yellow cardboard tube trap, and the Pherocon II standard trap generally used in detection surveys were evaluated. Tests were run for 41 days in the summer of 1980 and 35 days in the spring of 1981. The lure in all traps was the standard 38-cm cotton dental roll charged with 10 female equivalents of crude virgin female pheromone extract. In 1980, all test traps outperformed the standard Pherocon II model. In 1981, the Pherocon II traps captured more males than any of the others. The catch in the Delta traps appeared to be roughly proportional to their size.

An additional test in 1981 evaluated three types of cigarette filters compared with the dental roll as the pheromone dispenser. After 79 days, the cigarette filter-baited traps were still capturing sawflies whereas the traps baited with the dental rolls stopped catching males after 51 days.

Following discovery of the introduced pine sawfly, Diprion similis (Hartig), in western North Carolina (Drooz et al. 1979), detection surveys were carried out along the Blue Ridge Parkway and subsequently in a 20,700-km² area encompassing contiguous portions of North Carolina, Tennessee, and Virginia. The surveys were conducted with a trap system consisting of the Pherocon® II trap (Zoecon Corp., Palo Alto, CA), baited with a dental roll (No. 2, 1-1/2'' [38 cm] Johnson & Johnson, New Brunswick, NJ) charged with 10 female equivalents (FE) of crude pheromone extracted from virgin female sawflies in the laboratory. The choice of the trap, the pheromone, and the dispenser was based on experience with these components by researchers at the University of Wisconsin (H. C. Coppel, pers. comm.) (Jewett et al. 1978, Casida et al. 1963, Kraemer et al. 1979).

To obtain further information that may improve detection surveys, sawfly responses to different types of traps and pheromone dispensers were evaluated in a study established in the infested area at Linville, North Carolina, during 1980 and 1981.

METHODS AND MATERIALS

Two types of traps were compared to the white Pherocon II as the standard. These were the orange Delta® trap in three sizes, 183, 230, and 305 mm long, and a yellow tube trap made by removing the ends of the familiar quart ice-cream container, spraying the outside

1 USDA Forest Service, Southeastern Forest Experiment Station, Research Triangle Park, NC 27709. The use of proprietary names does not constitute an official endorsement by the USDA or the Forest Service.


with chrome-yellow paint (Seymour's, Inc., Sycamore, IL) and coating the inside with Tac-Trap® (Animal Repellants, Inc., Griffin, GA). Thus we would obtain information on the effect of three colors as well as the effect of size on catch capability. Each trap was baited with a No. 2 dental roll charged with 10 FE of crude pheromone extract. Traps were placed 15 m or more apart, approximately 2 m above ground on branches of eastern white pine, *Pinus strobus* L. The sequence of distributing the traps was random with respect to type of trap, and the positions of the traps were rearranged at least twice during the study.

In 1980, two traps of each type were deployed along the southwest side of a field at Linville. We trapped for 41 days, from 7 July to 18 August. The 1981 trap site was approximately 5 km north of the 1980 location. Three traps of each kind were deployed, one of which contained no bait. We trapped for 35 days, from 6 May to 10 June.

In September 1981, three types of cigarette filters (Liggett & Myers Tobacco., Inc., Durham, NC) were tested against the dental roll as the pheromone dispenser in a separate test at another site. The filters, made of cellulose fiber, were designated A (= 24.2 mm dia.), B (= 24.1 mm dia.), and C (= 20.6 mm dia.). Type A was paper wrapped; B and C were fiber wrapped. Both the rolls and the filters were treated with 10 FE of sawfly pheromone and placed in Pherocon II traps. The traps were visited every 8-10 days and returned to the laboratory after 79 days. Each treatment and the control were replicated twice; their positions were rearranged twice during the study.

**RESULTS AND DISCUSSION**

The average number of sawflies captured by type of trap, adjusted for duration of the trapping period in the two years are given in Table I. In 1980, visual defoliation estimates in the trapping area indicated that the sawfly population had declined considerably from its high level and was characterized as moderate. Under these conditions, all test traps captured more sawflies than the standard Pherocon II model. In 1981, the population had further declined and was estimated to be light. Then, the Pherocon II trap caught the most males. The yellow tube trap captured virtually nothing. In both years, the numbers of sawflies captured in the Delta traps appeared to be positively correlated with trap size. In the 1981 control traps, no sawflies were captured.

A direct comparison of catch data from year to year is inappropriate because of the confounding factors of year, location, and population level. The 1980 data failed to show a detectable difference in response of male sawflies to any of the three trap colors, white, yellow, or orange. The difference in construction among the traps of different colors may be less important than weather or microenvironment affecting flight in the immediate vicinity of the traps. The hovering, zigzagging flight of male sawflies approaching the pheromone source may increase the likelihood of contact with trap surface, and thus may explain why the larger traps caught more sawflies.

**Table 1. Number of male *Diprion similis*/trap/day captured in three types of traps in 1980-81, Linville, NC.**

<table>
<thead>
<tr>
<th>Trap type</th>
<th>Summer 1980</th>
<th>Spring 1981</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pherocon II</td>
<td>1.07</td>
<td>2.6</td>
</tr>
<tr>
<td>Delta 183 mm</td>
<td>1.54</td>
<td>0.25</td>
</tr>
<tr>
<td>230 mm</td>
<td>5.79</td>
<td>0.91</td>
</tr>
<tr>
<td>305 mm</td>
<td>6.32</td>
<td>1.24</td>
</tr>
<tr>
<td>Yellow tube</td>
<td>1.63</td>
<td>0.01</td>
</tr>
</tbody>
</table>

*Trapping periods: 41 and 35 days, respectively.*

*Average of total number of sawflies in two replications per type of trap.*
In the test evaluating the release of lure from dental rolls, all the cigarette filter-baited traps outperformed those baited with the standard dental roll (Table 2). All replicates of filters except one outperformed the dental roll by a factor of 2X or more. One replicate of filter B did relatively poorly in comparison with all other filter replicates, yet captured sawflies at a rate about equal to the mean of the dental roll replicates. The latter stopped attracting after 51 days. All filter replicates were still active at the termination of the test (79 days).

The results show that the Pherocon II or the Delta traps are suited to trapping *D. similis* and, when ease of use is considered, the Pherocon II can adequately provide qualitative information about the population. If trapping-out were the objective, a larger trap may be advantageous.

The cigarette filters appear to offer an improvement over the conventional dental rolls. Not only did they appear more efficient in pheromone release, but are much less expensive. No detectable difference could be seen however between the filter specifications and their efficiency as lure dispensers; all the filters appeared similar in the number of sawflies trapped.

### Table 2. Number of male *Diprion similis* in traps with pheromone released from filters or dental rolls, Linville, NC, 1981.

<table>
<thead>
<tr>
<th>Day</th>
<th>Dental roll</th>
<th>Filter A</th>
<th>Filter B</th>
<th>Filter C</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>3.5</td>
<td>8.5</td>
<td>11</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td>16</td>
<td>12</td>
<td>24</td>
<td>129.5</td>
<td>14.5</td>
<td>0</td>
</tr>
<tr>
<td>25</td>
<td>6.5</td>
<td>5.5</td>
<td>119.5</td>
<td>205</td>
<td>0</td>
</tr>
<tr>
<td>37</td>
<td>6.5</td>
<td>156</td>
<td>28</td>
<td>59.5</td>
<td>0</td>
</tr>
<tr>
<td>44</td>
<td>1.5</td>
<td>143.5</td>
<td>275</td>
<td>53.5</td>
<td>0</td>
</tr>
<tr>
<td>51</td>
<td>1</td>
<td>37</td>
<td>24</td>
<td>27.5</td>
<td>0.5</td>
</tr>
<tr>
<td>59</td>
<td>0</td>
<td>17.5</td>
<td>24</td>
<td>9.5</td>
<td>0</td>
</tr>
<tr>
<td>65</td>
<td>0</td>
<td>3.5</td>
<td>3</td>
<td>7.5</td>
<td>0.5</td>
</tr>
<tr>
<td>73</td>
<td>0</td>
<td>7</td>
<td>1.5</td>
<td>7.5</td>
<td>0</td>
</tr>
<tr>
<td>79</td>
<td>0</td>
<td>0</td>
<td>7.5</td>
<td>13.5</td>
<td>0</td>
</tr>
</tbody>
</table>

* Numbers are the average of total number of replicates.

### ACKNOWLEDGMENTS

The valuable assistance of Carolyn Stone and Ashley Buchanan in the field work is gratefully acknowledged as is the donation of Delta traps by the Conrel Corp. and the cigarette filters by Liggett & Myers Research Department.

### LITERATURE CITED


STATUS AND MANAGEMENT OF PYRETHROID RESISTANCE IN THE PREDATORY MITE, AMBLYSEIUS FALLACIS (ACARINA: PHYTOSEIIDAE)¹

B. A. Croft²

ABSTRACT

Low levels of (5–15 fold) resistance to synthetic pyrethroid (SP) insecticides occur in unexposed apple orchard populations of the predatory mite, Amblyseius fallacis Garman. Permethrin resistance in one strain has been elevated 60–500 fold by selections in greenhouses. Multiple resistances to DDT and azinphosmethyl are present and cross-resistance to SP-related compounds is generic at 10–250 fold. Permethrin resistance appears due to both hydrolytic esterase and knock down resistance mechanisms. Permethrin resistance appears to be polygenic and more recessive than dominant; it is unstable in the presence of high densities of susceptible immigrant types, but is reasonably stable in the presence of unselected, resistant immigrant types. Successful establishment of SP-resistant mites into SP-treated, commercial apple orchards was monitored using electrophoretic finger-printing techniques over a two year period. Aspects of management of resistance in A. fallacis to improve IPM are discussed.

Amblyseius fallacis Garman is a phytoseiid predator of phytophagous mites which occurs on many agricultural crops and has developed strains resistant to a wide variety of pesticides. On apple, endemic strains are resistant to DDT (Smith et al. 1963, Croft et al. 1982), several organophosphates (OP's) (Croft et al. 1976), carbaryl (Croft and Meyer 1973) and permethrin (Strickler and Croft 1981). These developed resistances provide for predator survival in orchards and allow for increased biological control of the spider mites Panonychus ulmi (Koch) and Tetranychus urticae (Koch) when insecticides are used to control a wide range of orchard insect pests other than mites.

To the synthetic pyrethroids (SP's) (which are only beginning to be used for control of apple pests), resistance in A. fallacis was developed by selection in laboratory experiments (Strickler and Croft 1981, 1982) before widespread use occurred in the field. This was done with intent of avoiding problems associated with development of highly resistant pest mites while predatory phytoseiid mites remained susceptible. Phytoseiid mites usually only develop resistances in the field after resistance in spider mites has occurred and only if the pesticide continues to be used for control of other pests (see Fig. 2, Croft 1982).

In this paper, research to genetically improve A. fallacis by developing and establishing resistant strains in orchards is summarized including (1) background status of resistance in endemic orchard populations of predators, (2) baseline data on the susceptibility and variability of SP resistance, (3) selection of SP resistance in field and laboratory populations, (4) multiple and cross resistances to permethrin, (5) selectivity of SP compounds, (6) the inheritance and stability of SP resistance, (7) the mechanisms of SP resistance, and (8) possible procedures for release and management of SP resistant phytoseiids in the field.

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² Department of Entomology, Oregon State University, Corvallis, OR 97331.
BACKGROUND STATUS OF RESISTANCE TO SP'S IN A. FALLACIS

Considering the variety of insecticides used in commercial apple production in the USA over the past 30 years (see types in Croft 1981), it was expected that a previously selected potential for resistance to SP's would be present in field populations of A. fallacis. It is known for example, that the knock down resistance (kdr) mechanism of DDT resistance is also common to pyrethroid-resistant house flies, certain mosquitos, and the cattle tick. For many years, A. fallacis was directly exposed to DDT in the field and resistance eventually developed to this compound (e.g. Oatman 1976, Croft et al. 1982). Other resistance mechanisms such as esterases and mixed-function oxidase (MFO) detoxification enzymes which contribute to OP and carbamate resistance in A. fallacis may influence SP resistance (Scott et al. 1983).

To study these resistance relationships, the variability of permethrin susceptibility in 12 field strains of A. fallacis was evaluated to identify strains for use in SP selection experiments (Strickler and Croft 1981). Results of this survey are given for two groups of strains including seven recently collected field populations and five earlier collected, susceptible (S) populations in Table 1. The intrinsic susceptibility level of A. fallacis to permethrin is in the range of .00017-.00043% AI as indicated in seven of 12 strains tested (Table 1). The field collected Fennville, Graham, and Monroe colonies showed only low levels of resistance. The Kleins strain which had never received any exposure to SPs in the field showed a 7.7 fold resistance which likely was due to the use of other insecticides applied in the past (possibly DDT). The Geneva strain which had been exposed to the SPs fenvalerate and permethrin in an experimental orchard for three previous years, showed a near 15-fold permethrin resistance increase. Undoubtedly it, along with the other field strains with more limited resistance, provided the basis for the higher resistance levels achieved by selection in greenhouse experiments (see later discussion).

Table 1. Permethrin LC50 and dosage mortality curve statistics for 12 Amblyseius fallacis populations (adapted from Strickler and Croft 1981).

<table>
<thead>
<tr>
<th>Permethrin</th>
<th>LC50</th>
<th>Confidence Limit</th>
<th>Slope</th>
<th>Intercept</th>
<th>$\chi^2$</th>
<th>df (x = .05)</th>
<th>Sig.</th>
<th>Resistance $^a$ Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Field Collected Colonies</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collins</td>
<td>.00017</td>
<td>.00009-.00025</td>
<td>1.31</td>
<td>9.94</td>
<td>5.00</td>
<td>3</td>
<td>N.S.</td>
<td>1</td>
</tr>
<tr>
<td>Paw Paw</td>
<td>.00030</td>
<td>.00015-.00051</td>
<td>.99</td>
<td>8.48</td>
<td>3.46</td>
<td>3</td>
<td>N.S.</td>
<td>1.8</td>
</tr>
<tr>
<td>Hudson</td>
<td>.00043</td>
<td>.00020-.00074</td>
<td>1.17</td>
<td>8.93</td>
<td>6.05</td>
<td>3</td>
<td>N.S.</td>
<td>2.5</td>
</tr>
<tr>
<td>Fennville</td>
<td>.00063</td>
<td>.00025-.00096</td>
<td>2.45</td>
<td>12.86</td>
<td>.59</td>
<td>3</td>
<td>N.S.</td>
<td>3.7</td>
</tr>
<tr>
<td>Graham</td>
<td>.00075</td>
<td>—</td>
<td>1.23</td>
<td>8.84</td>
<td>17.65</td>
<td>3</td>
<td>P &gt; .005</td>
<td>4.4</td>
</tr>
<tr>
<td>Kleins</td>
<td>.0013</td>
<td>.00096-.0018</td>
<td>1.42</td>
<td>9.09</td>
<td>1.26</td>
<td>3</td>
<td>N.S.</td>
<td>7.7</td>
</tr>
<tr>
<td>Geneva</td>
<td>.0025</td>
<td>.0020-.0032</td>
<td>3.27</td>
<td>13.51</td>
<td>4.31</td>
<td>3</td>
<td>N.S.</td>
<td>14.7</td>
</tr>
<tr>
<td><strong>Laboratory Colonies</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rose Lake</td>
<td>.00018</td>
<td>.00009-.00027</td>
<td>1.21</td>
<td>9.56</td>
<td>5.48</td>
<td>3</td>
<td>N.S.</td>
<td>1.1</td>
</tr>
<tr>
<td>Rasch &amp; Klackle</td>
<td>.00033</td>
<td>.00017-.00055</td>
<td>1.10</td>
<td>8.81</td>
<td>7.26</td>
<td>3</td>
<td>N.S.</td>
<td>1.9</td>
</tr>
<tr>
<td>Garden</td>
<td>.00038</td>
<td>.00023-.00054</td>
<td>1.84</td>
<td>11.30</td>
<td>.40</td>
<td>3</td>
<td>N.S.</td>
<td>2.2</td>
</tr>
<tr>
<td>Composite</td>
<td>.00043</td>
<td>.00026-.00066</td>
<td>.86</td>
<td>7.90</td>
<td>2.01</td>
<td>3</td>
<td>N.S.</td>
<td>2.5</td>
</tr>
<tr>
<td>Monroe</td>
<td>.00083</td>
<td>.00045-.0013</td>
<td>1.30</td>
<td>9.01</td>
<td>1.14</td>
<td>3</td>
<td>N.S.</td>
<td>4.9</td>
</tr>
</tbody>
</table>

$^a$ Fold resistance as compared with the most susceptible colony (Collins).
The results shown in Table 1 shed light on the intrinsic potential and expected selection time or number of treatments required for *A. fallacis* to develop SP resistance under field conditions. While resistance rates of development would obviously be influenced by previous selection histories, number of applications, degree of orchard isolation, etc., after three years the Geneva strain demonstrated a resistance level of 15-fold when exposed to regular field programs of 4–7 SP applications/season. This resistance level allowed for some survival of these mites at a field dosage (.005–.05%) A.I. range. Hull and Starner (1983) observed similar levels of resistance in Pennsylvania populations of *A. fallacis* exposure to multiple SPs applications/season for five consecutive years in the field.

**SELECTION FOR SP RESISTANCE IN *A. FALLACIS***

In 1979, a laboratory selection experiment in greenhouses was begun with three populations. The initial two were started with a mix of the strains listed in Table 1 and tests included a repeated permethrin selection (GH-1) and an alternating permethrin-azinphosmethyl (GH-2) selection test. A third population (Geneva, Table 1), established from a single colony having the highest initial resistance level to permethrin, was also selected repeatedly with permethrin (Strickler and Croft 1982).

In Figure 1, the results of the selection experiments are illustrated; the permethrin treated population (GH-1) showed a 64-fold increase in resistance after about 12 applications, but

![Diagram](image-url)  
**Fig. 1.** Selection of permethrin resistance in three strains of *Amblyseius fallacis* when selected with permethrin and alternating permethrin and azinphosmethyl in greenhouse experiments (after Strickler and Croft 1982).
thereafter leveled off for the next 10 selections. Mites in the alternating, SP-OP selection experiment (GH-2) achieved a similar SP resistance in 18–20 selections (10 permethrin selections). The Geneva strain did not greatly increase its already moderate level of permethrin resistance after 10 selections with permethrin (Fig. 1, Strickler and Croft 1982). Both the permethrin-alone and alternating permethrin-azinphosphomethyl (GH-1 and Geneva) selected strains maintained relatively high levels of azinphosphomethyl resistance throughout the experiments (Fig. 2, Strickler and Croft 1982).

In summary, the selection results presented in Figure 1 demonstrate increased resistance to permethrin to a level which would provide for survival of mites in the field at the low end of the recommended field rate (.005–.01% A.I.). Unfortunately resistance levels plateaued for each treatment and higher levels were not obtained. While these results indicate a limit to selection of SP resistance in the laboratory, they do not preclude that higher levels might not be achieved in the field when selection was continued over longer time periods and as other modifying mechanisms of resistance became involved.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{cross_resistance.png}
\caption{Cross resistance relationships in a permethrin-resistant and susceptible strain of Amblyseius fallacis to seven pyrethroid type insecticides (after Croft et al. 1982).}
\end{figure}
FEATURES OF CROSS AND MULTIPLE RESISTANCE TO PERMETHRIN

In the comparisons made by Strickler and Croft (1981) there were no negative correlations between permethrin and azinphosmethyl resistance in *A. fallaciis*. In fact, Strickler and Croft (1982) showed a slow increase in azinphosmethyl resistance in the presence of permethrin (only) selection, indicating a slight positive correlation and suggested that a common mechanism of resistance occurs between these two compounds (possibly esterases? see later discussion).

In Table 2, the levels of multiple resistance to the insecticides azinphosmethyl, DDT and carbaryl in relation to pyrethroid resistant strains of *A. fallaciis* are shown (Croft et al. 1982). The GH-I strain (permethrin only of Strickler and Croft 1982) had relatively high levels of resistance to azinphosmethyl and DDT in addition to permethrin, but virtually no cross-resistance to carbaryl. The Geneva strain was even more resistant to azinphosmethyl and DDT than GH-1 and moderately resistant to permethrin. Monroe, which had no resistance to azinphosmethyl, had low levels of DDT and permethrin resistance. Collins showed high levels of azinphosmethyl and relatively high DDT resistance, but virtually no permethrin resistance (Table 1). The Fennville strain had moderate to high levels of azinphosmethyl and DDT resistance, a low level of pyrethroid resistance and the highest LC50 value for carbaryl.

Cross-resistance from permethrin to seven pyrethroids in the GH-I strain (as compared to the Rose Lake strain) was very broad as indicated by LC50 values (Fig. 2) ranging from 8–230 fold (Croft et al. 1982). Even a moderate cross-resistance to a mix of natural pyrethroids was manifest (11.8 fold). Comparing structure activity relationships between the various pyrethroids, a pattern was apparent (Fig. 2). In both the resistant and susceptible strains, the -cyanophenoxybenzyl esters of dihalovinyl-chrysanthemic acid (i.e. decamethrin, cypermethrin) were more toxic than the compounds more closely related to the natural pyrethroids (i.e. allethrin). The greatest resistance difference between the susceptible and resistant strains was manifested in the four most toxic pyrethroids.

---

Table 2. Levels of permethrin, azinphosmethyl, DDT, and carbaryl resistance among nine strains of the predatory mite *Amblyseius fallaciis* (after Croft et al. 1982).

<table>
<thead>
<tr>
<th>Strain</th>
<th>Permethrin 3.4 EC</th>
<th>Azinphosmethyl 50 WP</th>
<th>DDT 50 WP</th>
<th>Carbaryl 50 WP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LCS50</td>
<td>Fold-R</td>
<td>LCS50</td>
<td>Fold-R</td>
</tr>
<tr>
<td>Rose Lake</td>
<td>0.00018&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1</td>
<td>0.007&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1</td>
</tr>
<tr>
<td>Monroe</td>
<td>0.00083</td>
<td>5</td>
<td>0.010</td>
<td>1</td>
</tr>
<tr>
<td>Composite</td>
<td>0.00043</td>
<td>3</td>
<td>0.013</td>
<td>2</td>
</tr>
<tr>
<td>Collins</td>
<td>0.00017</td>
<td>1</td>
<td>0.18</td>
<td>26</td>
</tr>
<tr>
<td>Graham</td>
<td>0.00075</td>
<td>4</td>
<td>0.24</td>
<td>34</td>
</tr>
<tr>
<td>Kleins</td>
<td>0.0013</td>
<td>8</td>
<td>0.09</td>
<td>13</td>
</tr>
<tr>
<td>Geneva</td>
<td>0.0025</td>
<td>15</td>
<td>0.21</td>
<td>30</td>
</tr>
<tr>
<td>GH-1</td>
<td>0.022</td>
<td>129</td>
<td>0.11</td>
<td>16</td>
</tr>
<tr>
<td>Fennville</td>
<td>0.00063</td>
<td>4</td>
<td>0.13</td>
<td>19</td>
</tr>
</tbody>
</table>

<sup>a</sup> See history of strains in Strickler and Croft (1981, 1982).
<sup>b</sup> Data taken from Strickler and Croft (1981, 1982).
<sup>c</sup> Percent A.I. of material in water.
<sup>d</sup> A conservative estimate based on mortality at 1.2% sol and assuming a maximum slope of 4.0 probits of change/10 fold increase in concentration. Tests with higher dosage solutions gave inconsistent results due to difficulties in maintaining uniform solutions.
In a related study, Croft and Wagner (1982) examined cross-resistance to permethrin between resistant (R) and S strains of *A. fallacis* to find pyrethroids with selective acaricidal activity on the principal prey of this predator, *T. urticae*. Figure 3 gives the ld-p line for four experimental pyrethroids in relation to both R and S strains of both species. Only small differences in LC$_{50}$ values were observed between R (OP) and S strains of *T. urticae* indicating little cross-resistance to OP's; very low slope values for each compound to this pest species were also observed (Fig. 3, Croft and Wagner 1982). To R (permethrin) and S strains of *A. fallacis*, ld-p curves showed steeper lines and cross-resistances in the range of 2–46 fold with SD-57706 giving the largest difference.

With regard to selectivity, fluvalenate and especially NIC 85913 showed little potential; however, SD-57706 and ZR 3903 at the lower concentration levels of 0.001–0.025% A.I. were more toxic to adult prey than predatory mites which demonstrated a potential for selectivity with these types of pyrethroid compounds. Additional research is needed to identify SP

![Graph showing LC$_{50}$ response curves for permethrin-resistant (R) and -susceptible (S) strains of *A. fallacis* and organophosphate-resistant and -susceptible strains of *T. urticae* to four pyrethroid insecticides.](image-url)

Fig. 3. LC$_{50}$ response curves for permethrin-resistant (R) and -susceptible (S) strains of *A. fallacis* and organophosphate-resistant and -susceptible strains of *T. urticae* to four pyrethroid insecticides.
compounds that are more completely selective to the predators over their prey while at the same time maintaining their useful insecticidal properties for controlling other key pests of agricultural crops (see further discussion of means to accomplish this selectivity for apple pests in Croft and Wagner [1982], Croft [1981, 1982]).

MECHANISMS OF RESISTANCE

Data of Table 2 indicate that several mechanisms of insecticide resistance are present in field strains of \textit{A. fallacis}. For example, several biochemical mechanisms of DDT (e.g. DDT-dehydrochlorinase, Mixed-Function Oxidase [MFO] and pyrethroid \textit{(kdr, MFO, esterase)} resistance are known. Only \textit{kdr} and MFO are common to both groups of compounds. In the data shown in Table 2, there are strains which are both DDT + pyrethroid resistant (GH-1) and others which are DDT resistant, but SP susceptible (Collins). Also, other mechanisms of resistance common to OP's could confer contributing mechanisms to pyrethroid resistance (e.g. esterase, MFO). Such diversity in mechanisms of resistance might be expected in populations from orchards which have been exposed for 30 years to a wide range of insecticides.

One apparent conclusion from the data in Table 2 is that the MFO’s, which are common mechanisms of carbaryl resistance, are not a major factor in these strains of \textit{A. fallacis} (Table 2). LC50 values to carbaryl were similar for all strains tested and near the values observed for a wide variety of S strains as reported by Croft and Meyer (1973) and Croft and Hoying (1975).

To evaluate possible mechanisms of resistance in \textit{A. fallacis}, Scott et al. (1983) studied toxicity and synergized responses of several strains of this predator (i.e. those listed in Table 2). Using the synergists piperonyl butoxide and DEF in LC50 studies with methoxychlor, they found that most strains showed only low levels of oxidative activity further indicating that MFO’s were not the major mechanism of resistance observed (with the possible exception of carbaryl resistance in the Fennville strain, Table 3). They concluded that resistance in certain strains to both DDT and permethrin was due primarily to the \textit{kdr} mechanism (e.g. GH-1, Fennville) while in others resistances to these compounds may be related to DDT dehydrochlorinase (e.g. Geneva, Collins). Hydrolytic esterases played a significant role in both OP and SP resistance in the GH-I strain and to a lesser degree in the Fennville and Geneva strains.

In related biochemical experiments, Mullin et al. (1982) examined basic differences in whole body enzyme levels in \textit{S} and \textit{R} strains of \textit{T. urticae} (OP) and \textit{A. fallacis} (SP) (Table 4). As measured by conversion of aldrin to dieldrin epoxidase, MFO activity was ca. 5 times lower in the susceptible strains of predator than prey mites. However, there were no differences in degradation of aldrin epoxidase between \textit{R} (GH-1) and \textit{S} (Rose Lake) strains of \textit{A. fallacis} which is consistent with the data from synergist studies with respect to MFO activities (Table 4). With cytosolic \textit{cis} epoxide hydrolase (that fraction usually associated with food substrate detoxification), prey levels of enzyme were significantly higher than predator levels. Between SP \textit{R} and \textit{S} strains of predators there also were significant differences in enzyme levels (Table 4). Glutathione transferase was much more common in predator vs. prey mites with significantly higher levels present in resistant vs. susceptible strains of the predator. With esterase levels, \textit{S} prey and predator strains had similar amounts, but the \textit{R} predator strain showed much higher levels than the \textit{S} strain again confirming that either SP or OP resistance or both resistances is due to higher levels of these enzymes.

Considering the differential response of \textit{T. urticae} vs. \textit{A. fallacis} in detoxification potentials (Table 4), data indicate possible factors contributing to resistance and to the overall generally greater susceptibility of the entomophagous species as compared to its prey. Data also give clues to possible means for exploiting selectivity differences between the two species (e.g. compare MFO vs. glutathione transferase, see further discussion in Mullin et al. [1982]).
Table 3. Toxicity and synergized compound studies of mechanisms of insecticide resistance in six strains of the predatory mite *Amblyseius fallicis*.

<table>
<thead>
<tr>
<th>Compounds</th>
<th>LC50 Toxicity Studies</th>
<th>LT50 Synergist Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>DDT</td>
<td>Methoxy chlor</td>
</tr>
<tr>
<td>Rose Lake</td>
<td>1.0(.032)</td>
<td>1.0(.068)</td>
</tr>
<tr>
<td>Collins</td>
<td>41ᵃ</td>
<td>6</td>
</tr>
<tr>
<td>Kleins</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Geneva</td>
<td>43</td>
<td>3</td>
</tr>
<tr>
<td>GH-I</td>
<td>45</td>
<td>18</td>
</tr>
<tr>
<td>Fennville</td>
<td>29</td>
<td>13</td>
</tr>
</tbody>
</table>

ᵃ Fold resistance level over the susceptible—Rose Lake strains (LC₅₀ in percent A.I.)
ᵇ Significance of difference between synergized/non-synergized compound at a 1:3 ratio of synergists to toxicant. NS = non significant from 1:1 ratio.
ᶜ LT₅₀ values instead of LT₅₀.
ᵈ Significantly greater than 1.0 at P ≤ 0.05 level
ᵉ Significantly greater than 1.0 at P ≤ 0.10 level
Table 4. Detoxification capability of the predatory mite *Amblyseius fallacis* and its prey *Tetranychus urticae*. Activity is expressed in pmol/min-mg protein for a combined microsomal plus cytosolic fraction; \( \bar{x} \pm SD \) from 3–5 separate enzyme preparations.

<table>
<thead>
<tr>
<th>Mite Species</th>
<th>Enzyme Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aldrin Epoxidase</td>
</tr>
<tr>
<td></td>
<td>trans</td>
</tr>
<tr>
<td><em>A. fallacis</em></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>0.27</td>
</tr>
<tr>
<td>( \pm 0.22 )</td>
<td>( \pm 49 )</td>
</tr>
<tr>
<td>R</td>
<td>0.23</td>
</tr>
<tr>
<td>( \pm 0.14 )</td>
<td>( \pm 55 )</td>
</tr>
<tr>
<td><em>T. urticae</em></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>1.44(^{b})</td>
</tr>
<tr>
<td>( \pm 0.25 )</td>
<td>( \pm 74 )</td>
</tr>
<tr>
<td>R</td>
<td>1.60</td>
</tr>
<tr>
<td>( \pm 0.36 )</td>
<td>( \pm 178 )</td>
</tr>
</tbody>
</table>

Interspecific difference between susceptible strains: \(^{a}\) for \( P < 0.01 \); \(^{b}\) for \( P < 0.005 \); \(^{c}\) for \( P < 0.001 \). Intraspecific difference: \(^{d}\) for \( P < 0.01 \); \(^{e}\) for \( P < 0.05 \); \(^{f}\) for \( P < 0.005 \). Significance is indicated for strain with the higher enzyme level.

**GENETIC ANALYSIS**

In Figure 4, the *ld-p* lines to permethrin for individual *R* and *S* parent strains, the *F* or parent cross (combined) and backcross (combined) matings of *R* and *S* strains of *A. fallacis* are presented; statistical properties of these lines are summarized in Table 5 (from Croft and Whalon 1982). Parental strain LC\(_{50}\) values were 0.017 and 0.026% A.I. and 0.000072 and 0.00039% permethrin in water, respectively for *R* and *S* strains at the beginning and end of the test. The *F* cross hybrid LC\(_{50}\) was 0.00051% A.I., which was intermediate in susceptibility, but more close to the susceptible parent line than to the resistant strain response curve (Fig. 4). The backcross *ld-p* line gave an LC\(_{50}\) value of 0.000062% A.I. which was very near the value of the susceptible strain indicating a recessive genetic basis for the resistance. The *ld-p* line for the backcross did not show a flattened slope in the mid-dosage range, indicative of a monogenic relationship (i.e. reflecting a 1:2:1 ratio in the resistance response).

These data are very similar to those reported for crosses made between permethrin resistant and susceptible strains of *Metaseiulus occidentalis* (Nesbitt) by Hoy et al. (1980). They observed a polygenic, recessive type response in parent and the subsequent backcrosses and hypothesized the SP resistance would likely be unstable in the field in the presence of large populations of immigrant susceptible types.

**RELEASE EXPERIMENTS INTO COMMERCIAL APPLE ORCHARDS—1980**

Three strains of *A. fallacis* including the two permethrin resistant strains GH-1 and Geneva, and a susceptible strain (Composite, Table 1) were released into a 0.8-ha commercial apple orchard near Fennville, Michigan, in 1980. Release treatments were replicated in six trees and there were four release treatments including a check which contained populations of the indigenous strain of predators. Predator and prey were followed during the growing season by randomly selecting 50 leaves/tree at 7–14 day intervals throughout the season. A total of 2,500 mites were released/tree in late June to early July. A total of three permethrin and one fenvalerate sprays at relatively high rates were applied to the trees and surrounding vegetation during the growing season (Whalon et al. 1982).

In Table 6, the densities of predatory mites found at each sample date are given for the four treatments. In early season (May–June), virtually no indigenous mites were present except on non-treated vegetation surrounding the orchard.
Table 5. LC$_{50}$ values to permethrin of genetic cross between resistant and susceptible strains of the predatory mite *Amblyseius fallacis*.

<table>
<thead>
<tr>
<th>Strain-Date Cross</th>
<th>LC$_{50}^a$</th>
<th>Slope</th>
<th>(C.I. (95%))$^a$</th>
<th>Fold R$^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistant 24/6/81 (GH-1)</td>
<td>.017</td>
<td>1.53</td>
<td>.012--.023</td>
<td>435.9</td>
</tr>
<tr>
<td>Resistant 16/9/81 (GH-1)</td>
<td>.026</td>
<td>1.65</td>
<td>.019--.036</td>
<td>666.7</td>
</tr>
<tr>
<td>Susceptible 24/6/81 (Collins)</td>
<td>.000072</td>
<td>1.80</td>
<td>.000047--.00010</td>
<td>1.8</td>
</tr>
<tr>
<td>Susceptible 16/9/81 (Collins)</td>
<td>.000039</td>
<td>1.75</td>
<td>.000025--.000053</td>
<td>1.0</td>
</tr>
<tr>
<td>Parent Cross 24/6/81</td>
<td>.00051</td>
<td>1.90</td>
<td>.00041--.00065</td>
<td>13.1</td>
</tr>
<tr>
<td>R ½ × S δ, combined</td>
<td>.000062</td>
<td>1.40</td>
<td>.000039--.000085</td>
<td>1.6</td>
</tr>
</tbody>
</table>

$^a$Express as percent A.I. concentration in water.

$^b$In comparison to susceptible (Collins strain) 16/9/81 test.

The first application (197.6 ml/ha) of permethrin of 23 July, after the predator releases, represented approximately 1/8 the maximum recommended field rate or 1/2 the average recommended full rate. This treatment reduced the susceptible predatory mite populations from an average of 2.60 to 0.16 mites/leaf by 4 August. Several predator mites were collected in the indigenous or check trees on 25 July. Microelectrophoresis analysis indicated that they were either GH-1, Geneva, or a hybrid of GH-1 and Geneva strains (see later discussion). Both resistant released strains were generally unaffected by the first low-rate application of permethrin (Table 6).

The next application of permethrin (1780 ml/ha) on 7 August represented a full recommended field rate and it virtually eliminated the susceptible strains from all six replicate trees (Table 6). Predators collected in these trees after 11 August were either GH-1, Geneva, or possible hybrids of these two strains. This full-rate permethrin application reduced both the GH-1 and Geneva strains. There was no significant (P ≤ 0.05) difference between the GH-1 and Geneva strains before or after the permethrin treatments. Since both strains survived the field application rate of permethrin, it is likely that they could survive similar rates in commercial orchards.

Fenvalerate was applied at the recommended full field rate of 1482 ml/ha on 3 September (Table 6). The GH-1 strain survived and increased from 0.59 to 0.68 mites/leaf after this application, but the Geneva strain declined and was all but eliminated by 22 September. It is not clear if the Geneva strain lacked the fenvalerate cross-resistance potential exhibited by the GH-1 strain (Table 1) (Croft et al. 1982) or whether other circumstances like a disadapted diapause response or possibly rapid reversion to susceptibility contributed to this poor survival.

The characteristic microelectrophoresis-carboxylesterase banding patterns for each of the predatory strains is presented in Figure 5. Measurements were made from the sample start position to the approximate center of each band. In all, seven strains tested produced seven distinct bands: B at 4.4 cm, C at 4.8, D at 5.3, E at 5.7, F at 6.1, G at 6.6, and H at 8.2–10.0 cm. The run front was at 19.0 cm and the gel end at 20.0. Bands at A (between 2.6–4.3 cm) have been associated with *T. urticae* prey enzymes. While there was some variation between individual mites of the same strain (particularly in intensity), all strains except the Composite Susceptible, produced bands at position D. The Indigenous strain was similar to
Fig. 4. Log-concentration mortality responses of parent resistant (GH-I) susceptible (Collins), parent cross and backcrossed populations of *Amblyseius fallacis* to permethrin (percent A.I.).

Table 6. The synthetic pyrethroid application dates and rates, predatory mite release dates, mite sample dates and average predatory mite numbers/leaf following releases of *A. fallacis* (SP resistant) into a commercial apple orchard.\(^a\)

<table>
<thead>
<tr>
<th>Date</th>
<th>Release</th>
<th>GH-1</th>
<th>Geneva</th>
<th>Susceptible</th>
<th>Indigenous</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-7</td>
<td>SAMPLE</td>
<td>0.85 ± 0.42</td>
<td>0.82 ± 0.24</td>
<td>0.42 ± 0.63</td>
<td>0.0</td>
</tr>
<tr>
<td>16-7</td>
<td>SAMPLE</td>
<td>1.43 ± 1.23</td>
<td>1.76 ± 1.33</td>
<td>2.60 ± 1.96</td>
<td>0.0</td>
</tr>
<tr>
<td>23-7</td>
<td>PERMETHRIN 200 ml/ha</td>
<td>1.85 ± 1.53</td>
<td>0.59 ± 1.84</td>
<td>0.22 ± 0.15</td>
<td>0.01 ± (-)</td>
</tr>
<tr>
<td>25-7</td>
<td>SAMPLE</td>
<td>1.33 ± 0.77</td>
<td>1.73 ± 1.55</td>
<td>0.16 ± 0.78</td>
<td>0.00</td>
</tr>
<tr>
<td>7-8</td>
<td>PERMETHRIN 780 ml/ha</td>
<td>0.86 ± 0.67</td>
<td>0.63 ± 1.34</td>
<td>0.00</td>
<td>0.41 ± 0.33</td>
</tr>
<tr>
<td>11-8</td>
<td>SAMPLE</td>
<td>0.49 ± 0.21</td>
<td>0.43 ± 1.41</td>
<td>0.21 ± 0.61</td>
<td>0.17 ± 0.63</td>
</tr>
<tr>
<td>3-9</td>
<td>FENVALERATE 1482 ml/ha</td>
<td>0.59 ± 0.75</td>
<td>0.16 ± 0.71</td>
<td>0.11 ± 0.70</td>
<td>0.11 ± 0.48</td>
</tr>
<tr>
<td>12-9</td>
<td>SAMPLE</td>
<td>0.63 ± 0.38</td>
<td>0.05 ± (-)</td>
<td>0.01 ± 0.25</td>
<td>0.0</td>
</tr>
</tbody>
</table>

\(^a\) Permethrin (1780 ml/ha) was applied on 29/5 and 21/6/1981 while Fenvalerate (2500 ml/ha) was applied on 15/6. Mites were sampled on 21/6 and 28/6 after these applications and no *Amblyseius fallacis* were found in the trees or orchard ground cover.

\(^b\) GH-1 was released on 28/6/1981, while Geneva and the susceptible strains were released on 3/7.
the susceptible, but produced a faint but definite band at D. The Composite Susceptible strain demonstrated almost no esterase activity at all, except for a variable intensity at C and H. The two resistant, released strains, Geneva and GH-1, as well as the overwintered strain (1981 Field Collected), produced very similar patterns with bands at C, D, E, F, and G. Several of the strains (Composite Susceptible, 1981 Field Collected and Geneva) also produced a clear band at H, however the bands of the resistant strains were much darker than in the Indigenous, Composite Susceptible or Susceptible, indicating a greater quantity of enzyme or perhaps two or more unseparated bands.

The microelectrophoretic technique provided a useful tool in identifying the resistance origins of individual predatory mites. We were able to confirm the survival of the mites originating from the Geneva or GH-1 strains (these strains could not be separated by enzyme banding studies) in all the replicated release trees following both applications of permethrin. From population studies it appeared that only the GH-1 strain persisted following a late season fenvalerate treatment. The Indigenous predatory mites were not detected within the synthetic pyrethroid block after 21 June, but were readily collected from surrounding azinphosmethyl treated blocks. The Susceptible strain survived the first application of permethrin at low rates, but was not detected after the second full-rate permethrin spray or first full-rate fenvalerate applications. The predators found in the Indigenous and Susceptible treatment trees (Table 2) after 25 July and 27 August, respectively, exhibited banding patterns characteristic of the GH-1 or Geneva strains. These individuals were probably dispersing from nearby GH-1 and Geneva release trees. Several of the predatory mites found especially late in the growing season exhibited uncharacteristic banding patterns and we hypothesize that these individuals were either long range dispersers or hybrids of the various strains.

FIELD STUDIES—1981

Predator populations in the experimental release plots were again followed both by electrophoretic esterase evaluation and dosage-mortality assessments in 1981 (Croft and Whalon 1983). Again SP’s were applied to the block, but only once in early season in the entire block. Predator assessments were made in early, mid, and late season.

In Table 7, the LC50 values for four strains: (1) released SP resistant (GH-1), (2) released Susceptible, (3) Indigenous, and (4) subsequently Field Collected mites, from the perme-

Table 7. Summary of LC50 values for indigenous, released and subsequently collected field populations of *Amblyseius fallacis* occurring in a commercial apple orchard treated with permethrin (Fennville, MI, 1981).

<table>
<thead>
<tr>
<th>Strain (Date of Collection)</th>
<th>LC50a</th>
<th>CI (95%)b</th>
<th>Slope</th>
<th>Resistance Levelb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Released and Indigenous Strains (1980)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistant-Released</td>
<td>.0090</td>
<td>.0070--.011</td>
<td>1.94</td>
<td>53</td>
</tr>
<tr>
<td>Susceptible-Released</td>
<td>.00017</td>
<td>.00009--.00025</td>
<td>1.31</td>
<td>1</td>
</tr>
<tr>
<td>Indigenous</td>
<td>.0003</td>
<td>.00011--.00057</td>
<td>1.73</td>
<td>2</td>
</tr>
<tr>
<td>Field Collected Strains (1981)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>08/5</td>
<td>.0034</td>
<td>.0024--.0043</td>
<td>1.96</td>
<td>20</td>
</tr>
<tr>
<td>15/6</td>
<td>.016</td>
<td>.013--.024</td>
<td>1.25</td>
<td>94</td>
</tr>
<tr>
<td>05/9</td>
<td>.00077</td>
<td>.001--.0005</td>
<td>1.08</td>
<td>4</td>
</tr>
</tbody>
</table>

a In percent A.I. permethrin in water.
b As compared to the susceptible released strain.
thrin-treated, commercial apple orchards are summarized. In early spring 1981, resistant mites were present in the release orchard following the overwintering period; the LC₅₀ response of 0.0034%, A.I. permethrin was somewhat lower than that of the original release population, but still 20 and 10 fold higher than the Susceptible released and Indigenous strains, respectively. By midseason following selection with a field application of permethrin at (70.2g A.I./ha.), the LC₅₀ value of the released mites was even higher than that of the original release strain (Table 7, LC₅₀ value = 0.016% A.I. permethrin).

Johnson and Croft (1981) have shown that orchards typically are exposed to high densities of migrating A. fallacis in late season. In the absence of subsequent sprays, predator populations in the experimental orchard were undoubtedly influenced by a large influx in SP-susceptible immigrant predators which hybridized with the resistant mites. Thereafter the recessive nature of the resistance when hybridization occurred was manifested in the field LC₅₀ of collected mites (LC₅₀ value = 0.00077% A.I., Table 7). Electrophoretic studies to fingerprint the esterase detoxification enzymes associated with each of these three groups of predators collected in the field provided further evidence of these conclusions.

Fig. 5. Microelectrophoretic banding patterns in susceptible, released-susceptible, released-resistant indigenous and recovered populations of the predatory mite, *Amblyseius fallacis*, made in a commercial apple orchard (1980–1981).
SP-resistant predators when surrounded by similar resistant, but unexposed predator populations, immigrated to plants without predators at daily rates of 0.005-0.03 individuals/leaf (these levels would be somewhat higher than those found in orchards, except late in the growing season [Johnson and Croft 1981]). Resistance in these colonies to both permethrin and azinphosmethyl (a resistance which is due to a relative dominant, single gene factor in *A. fallacis* [Croft et al. 1976]) in the absence of selection remained relatively high for at least 25 generations or ca. one year (Fig. 6). In laboratory tests where immigration did not occur (Fig. 6), a similar pattern of resistance was observed. This further confirmed that SP resistance in *A. fallacis* was reasonably stable over time in the absence of hybridization with *S* types. These data indicate that there was no lack of fitness or other properties of genetic instability in the SP resistant mites tested in these experiments under the conditions of laboratory rearing and selection. Possibly similar degrees of fitness and resistance would be observed in the field provided that large regional SP resistant predator populations were present (as in the case of OP resistant strains).

In conclusion, permethrin resistance in our selected strain of *A. fallacis* appears to be a recessive, polygenic trait which is highly susceptible to reversion toward susceptibility following hybridization with immigrant susceptible types. In this study, reversion occurred even after applying a single permethrin application early in the growing season before most spider mite-predator interactions had occurred. This type of limited use would be preferable

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**Fig. 6.** LC₅₀ values for the Greenhouse-1 (GH-1) strain when left untreated and in the presence and absence of immigrant permethrin-resistant *A. fallacis* over a one-year period. (percent A.I. permethrin).
for resistance management and IPM programs (Croft and Hoyt 1978, Croft 1982). If SPs were used more extensively on a routine basis (a use not currently recommended for IPM), then large regional populations of SP resistant predators would probably develop in 3–5 years (Strickler and Croft 1981, 1982; Hull and Starner 1983); however, it is feared that pest resistances in a species like the codling moth Cydia pomonella L. could also develop due to more extensive use (Croft and Hoyt 1978). A more desirable compromise might be to use the SP’s twice during the season; once in early season to control such troublesome pests as the spotted tentiform leafminer (Phyllocnistis blancardella Fabricius) and tarnished plant bug (Lygus lineolaris Palisot de Beauvois) and once later after the principal predator-prey mite interactions have occurred in mid to late season (i.e. during early August). At this time, second generation codling moth and apple maggot (Rhagoletis pomonella Walsh) populations could be suppressed with the SP’s. This late-season spray should also be timed, if possible, to affect susceptible immigrant populations of A. fallacis which usually disperse into the orchard in great numbers in late August and September (Johnson and Croft 1981). The early and late spray would thus bracket the intense period of susceptible predator influx and insure that SP resistance in predatory mites was maximally maintained in the orchard, hopefully without inducing high levels of SP resistance in other orchard pests.

Another possibility for improving and managing SP resistance in A. fallacis would be to select out a single-gene, more dominant basis for this trait. Geneticists have suggested that by using high SP concentrations (equivalent to field rates) from the beginning of selection trials, rather than slow incremental increases in concentration as were used in these studies (see Strickler and Croft 1982), a more stable resistance of hybridization could be obtained. Further research is needed to evaluate this hypothesis as well as to survey field populations for more stable SP resistance traits which may be developed as these compounds are more widely used.

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Appreciation is expressed to several of my co-workers at Michigan State University who contributed to this research: Karen Strickler, Steven Wagner, Jeffrey Scott, Terry Davis, Thomas Mowry, Mark Whalon, and Christopher Mullin.

LITERATURE CITED

ENTOMOLOGICAL NOTES

FIRST RECORD OF THE MOSQUITOES AEDES DUPREEI, PSOROPHORA HORRIDA, AND PSOROPHORA MATHESONI (DIPTERA: CULICIDAE) IN ST. JOSEPH COUNTY, INDIANA

Adult females of Aedes (Ochlerotatus) dupreei (Coquillett), Psorophora (Janthinosoma) horrida (Dyar and Knab), and Psorophora (Janthinosoma) mathesoni (Belkin and Heinemann) were collected on 18 and 19 June 1981, in an oak woodlot in South Bend, Indiana. These constitute new species records for St. Joseph County (Shroyer et al. 1977, Taylor 1981). The single Ae. dupreei was collected with a battery-powered suction device used to sample mosquitoes resting in the herbaceous understory of the woodlot (Nasci 1981). The two Psorophora species were collected in human-baited collections. In addition, one Ps. horrida larva was collected in a temporary pool in the center of the woodlot.

All three mosquitoes are woodland species, their larvae developing in forest pools formed in depressions covered with heavy leaf litter. These species are considered rare in northern Indiana because rainfall does not usually occur in sufficient quantity to create free-standing water on forest floors during mid-summer (Siverly 1972). Rainfall during the three weeks preceding capture of the specimens was extremely heavy, causing flooding in sections of northern Indiana, including a portion of the woodlot in which the collections were made.

Ae. dupreei is distributed from the southeastern United States north to New Jersey and west to Kansas and Texas (Carpenter and La Casse 1955). In Indiana it has been recorded only in Spencer and Posey counties in the southern portion of the state (Siverly 1972). This report extends the distribution of the species in Indiana northward 480 km.

The two Psorophora species are found throughout the southeast United States, north to Pennsylvania, and west to Texas (Carpenter and La Casse 1955). They have been reported in several counties in the southern third of Indiana (Siverly 1972). This is the first record of these species in the northern portion of the state.

LITERATURE CITED


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The mild, snowless winter weather of late December 1982 and early January 1983 made it easy to obtain litter and soil samples for extraction of overwintering ground beetles. Collections of this nature are desirable in order to positively confirm the hibernating status of Michigan carabid beetles. As an added benefit, the collections also produced several specimens of rare species which had not been previously collected by other methods (blacklighting and hand collecting) in the same areas during the spring and summer of 1982.

In order to capture the beetles, various quantities of leaf litter, soil (up to a depth of 15 cm), and rotten wood were placed into plastic bags and taken to the laboratory. The beetles were separated from the leaf litter by placing the contents of each bag into a large container filled with warm water. The beetles floated to the surface of the water and were easily picked out with forceps.

All of the following collections were made in Michigan. On the days the collections were made there was no snow cover and virtually no soil frost. The ambient air temperature ranged between 2° and 15°C. Numbers in parentheses are the number of individuals collected.

Clinton County, Rose Lake Wildlife Research Area (T.5N, R.1W, S.26); habitat: leaf litter, rotten wood, and organic soil near edge of Rose Lake; 23 Dec. 1982: Platynus decentis Say (1), Agonum palustre Goulet (1), A. melanarium Dejean (10), A. propinquum Gemmingen & Harold (3), A. gratiosum Mannerheim (26), Bradyceillus neglectus LeConte (1), Anisodactylus kirbyi Lindroth (2), Pterostichus luctuosus Dejean (12), and P. patruelis Dejean (2).

Clinton County, Rose Lake Wildlife Research Area (T.5N, R.1W, S.23); habitat: leaf litter in lowland woods; 24 Dec. 1982: Platynus decentis (1), Pterostichus mutus Say (4), and Lebia viridis Dejean (1).

Ingham County, Delhi Township (TAN, R.2W, S.2); habitat: leaf litter and sand-mixed clay in floodplain of Sycamore Creek; 24 Dec. 1982: Agonum extensicolle Say (16), A. puncticeps Casey (5), A. sordens Kirby (1), A. palustre (4), A. melanarium (3), Acupalpus rectangulus Chaudoir (1), Bembidion castor Lindroth (4), B. graciliforme Hayward (3), B. patruelis Dejean (1), B. frontale LeConte (71), Lebia viridis (1), and Dyschirius pilosus LeConte (1).

Clare County and Osceola County line, Muskegon River at Rte. M 115; habitat: leaf litter and sand at margin of an oxbow lagoon; 6 Jan. 1983: Omophron tesselatum Say (1), O. americanum Dejean (8) (Omophron taken from pure sand at a depth of less than 20 cm), and Bembidion frontale (2).

Osceola County, 6.5 km E of Tustin (T.20N, R.9W, S.22); habitat: leaf litter and soil at margin of small woodland pond; 6 Jan. 1983: Bembidion muscicola Hayward (4).

Ingham County, Delhi Township. (T.4N, R.2W, S.2); habitat: leaf litter and soil from floodplain of Sycamore Creek; 10 Jan. 1983: Platynus decentis (1), Agonum puncticeps (8), A. palustre (2), Loricera pilicornis Fabricius (1), Bembidion frontale (79) and Acupalpus canadensis Casey (1).

These collections from five Michigan localities yielded 282 specimens and illustrate imaginal hibernation for 25 species of Michigan ground beetles.

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INFORMATION FOR AUTHORS

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Manuscripts must be typed, double-spaced, with wide margins on white 8½ x 11" or equivalent size paper, and submitted in duplicate. Footnotes, legends, and captions for illustrations should be typed on separate sheets of paper. Titles should be concise, identifying the order and family discussed. The author of each species mentioned must be given fully at least once in the text. A common name for each species or group should be given at least once when such a name exists. The format of references should follow that used in recent issues. Photographs should be glossy. Drawings, charts, graphs, and maps must be scaled to permit proper reduction without loss of detail. Contributors should follow the recommendations of the Council of Biology Editors Style Manual, 4th ed.

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