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THE DISTRIBUTION AND SPREAD OF HYADAPHIS TATARICA (HOMOPTERA: APHIDIDAE) IN THE NORTH-CENTRAL STATES
WITH NOTES ON ITS HOSTS, BIOLOGY, AND ORIGIN

David Voegtlin

Hyadaphis tataricae (Aizenberg), an aphid known from eastern Europe, is rapidly becoming a pest on ornamental honeysuckles (Lonicera spp.) throughout the north-central states. The source of the infestation is not known but it could have been introduced from eastern Canada where it has been present since 1976 (Boisvert et al. 1981), or by separate introduction from eastern Europe. The first observations in the United States were made in the north-eastern corner of Illinois (Lake County) in 1979 (Voegtlin 1981). Observations of damage levels in that area support the hypothesis that its introduction to the north-central states originated there.

Although the aphid is small (< 2 mm) the witches' brooms caused by its feeding on honeysuckle are obvious and easily seen from a distance. In the fall of 1980, this aphid had been collected from six sites indicating a limited distribution (Voegtlin 1981). Since the presence or absence of this species can be easily determined, a study of its 1980 distribution and subsequent spread was undertaken during the 1981 season.

METHODS

Attempts to delineate the 1980 distribution and subsequent spread of H. tataricae in 1981 consisted of personal surveys circumscribing the known infested area and of contacting horticultural inspectors and state entomologists in the north-central states. During the personal survey trips the search for infestations entailed driving from town to town looking for honeysuckle plants and examining them for the presence of H. tataricae. In locations where no evidence of infestation was found on the first honeysuckle seen, a minimum of two additional plants was located and examined. If no aphids were found on these, the locality was considered to be free of the aphid. In general, many more than three honeysuckle plants were available as most plants located were in hedgerows. The witches' brooms are so obvious that once a honeysuckle plant was located, the presence or absence of the aphid was easily assessed.

A short trip was made through north-central Illinois on 15 and 16 April 1981 and another through north-western Indiana, north-eastern Illinois and south-eastern Wisconsin on 10–12 May 1981. These two trips were made to determine the extent of the 1980 distribution. This was determined at each locality by the presence or absence of the previous years’ witches' brooms (Fig. 1). Localities where the aphid was found, but no evidence of 1980's witches' brooms could be seen were considered to be newly infested in 1981. The localities where 1980 infestations were confirmed are shown on Figure 2. Two subsequent surveys on 13–25 July and 14–16 September 1981 circumscribed the distributional area established during the previous surveys.

Specimens of H. tataricae were collected from each locality where infestations were observed and samples of the host honeysuckle were pressed for later determination. All plant specimens are deposited in the herbarium of the Illinois Natural History Survey. In addition, aphid verifications were provided for many people who sent in preserved specimens from throughout the north-central states. These samples have proved useful for taxonomic examination and provided phenological data for the various forms of H. tataricae.

Contact with state entomologists and horticultural inspectors was made through a mailing

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1 Illinois Natural History Survey, 607 E. Peabody Drive, Champaign, IL 61820.
containing a short summary of the known biological information for *H. tataricae*, a picture of a witches' brooms on honeysuckle, a map of its known distribution in the north-central states, and a postcard questionnaire. This information was further distributed in newsletters and bulletins by various state and private organizations. The response was varied but many records of infestations, especially near the extremes of the distribution as shown on Figure 2, were obtained from returned questionnaires.

RESULTS AND DISCUSSION

The distribution records of *H. tataricae* through 1981 are shown on Figure 2. The circles containing stars represent those counties for which there were confirmed records in the fall of 1980. Counties with open circles represent additional 1980 infestations as determined by the presence of witches’ brooms in the spring and summer of 1981. The gray area represents the approximate 1980 distribution and the black dots are in counties where *H. tataricae* was found for the first time in 1981. *H. tataricae* could not be found in counties with open squares. Observations over the past two years suggest that the number of witches’ brooms per plant increases each year. Grigorov (1965) noted an increase in damage over a 3–4-year period in Bulgaria. In Illinois a few witches’ brooms may be formed on new growth, during the first year of infestation. These are usually on the upper third of the plant and in hedges rows all the plants may not be attacked. During the second year all of the bushes in a hedgerow will have damage and some will have up to half of their growing tips infested. Based on observations in north-eastern Illinois, virtually every growing tip on the plant is attacked during the third year and the witches’ brooms change the color and shape of the plants making them nearly unrecognizable as honeysuckle. Progressive damage categorization makes it possible to estimate the length of time *H. tataricae* has been present in any given area, at least over the first two or three years.

It became increasingly apparent during the July 1981 survey that the aphid was spreading by means other than the natural movement of alatae. Traveling north-west from the Chicago
area towards Minneapolis-St. Paul, the aphid infestations became increasingly scarce across Wisconsin until it could no longer be found, but in Minneapolis-St. Paul the honeysuckles were again heavily infested. From damage levels observed in these cities it was obvious that the aphid had been there in 1980. The source of this infestation is unknown but the movement of infested nursery stock is a probable explanation.

The spread of *H. tataricae* through Iowa seems to have occurred very rapidly. Much of this spread seems to be man-aided as the distribution pattern is closely aligned with two major highway systems (Interstates 80 and 35). Movement of infested plants along these routes could easily have inoculated the immediate vicinity with alatae. The collection records from south-western Iowa and south-eastern Nebraska both were found in nurseries and assumed to have resulted from the transfer of infested stock.

In *Michigan H. tataricae* occurred in the Detroit area prior to 1981 (Murray Hanna, pers. comm.) and the level of damage observed in Port Huron suggests that the aphid must have also been there in 1980. The source of the aphids for the eastern portion of Michigan was likely from Ontario, Canada, where the aphid had been found earlier (Boisvert, pers.
While traveling west across Michigan from Port Huron to Holland in July 1981, observable aphid damage became increasingly scarce toward the center of the state but increased again toward the western border. Plants seen in Holland were as heavily damaged as those in Port Huron. From Holland south, in the counties bordering Lake Michigan, the aphid was abundant. Movement of the aphid into this area could have been by flight of alatae across southern Lake Michigan or from northwestern Indiana.

Many of the interstate highways throughout the north-central states are landscaped with honeysuckle, especially in and near cities. Interstate 57 in Illinois is intermittently lined with hedgerows of honeysuckle, thus functioning as a "host highway" for aphid movement.

From the 1981 observations it is difficult to determine if the rapidity of natural dispersal is occurring in a similar magnitude in all directions because of the possibility of extensive man-aided dispersion. Dispersal southward in Illinois and Indiana seems to have been slow compared to the movement westward. Range expansion of 100–150 km southward is about the maximum detected. The southern records in Illinois, Indiana, and Ohio were obtained only after extensive examination of many honeysuckle plants. In the southern counties of Iowa (square symbols on Figure 2) the aphid was scarce with only one collection record taken on the September 1981 survey. North of this area the aphid was abundant and easily located. The reasons for the apparent paucity of southern records could be many. The prevailing summer winds are from the south-west and there seems to be less honeysuckle planted in south-central Illinois and Indiana than in northern regions of both states, although quantitative data were not taken to confirm this. Grigorov (1965) stated that the aphid did poorly in the hot summer months in Bulgaria; thus this species may well be limited in its southern distribution by hot summer weather.

**BIOLOGICAL OBSERVATIONS**

**Host finding by alatae.** The vagility of this species might be demonstrated from the summer observations in central Illinois. In some of the smaller towns a thorough street by street survey was made for honeysuckle and often only one or a few plants could be located. These towns are surrounded by fields of corn and soybean and in some cases were at least 50 km from the nearest known source of *H. tataricae* alatae yet the aphid was found on many of these isolated honeysuckles. This phenomenon could be due to an intense saturation of the air with alatae or one must conclude that these aphids are very adept at locating their hosts. No evidence of recent honeysuckle plantings, i.e. movement into the area of infested plants, was found in these towns.

**Host Records.** A list of the hosts on which witches' brooms and specimens of *H. tataricae* were collected during the survey trips is shown on Table 1. All of these hosts are in the *Lonicera tatarica* complex (Green 1966) and all but *L. muscaviensis* Rehder are double or triple hybrids involving *L. tatarica* L.

**Phenology in the North-central States.** Collections made during the 1981 season indicate that *H. tataricae* eggs hatch early in the spring and populations can be found until late fall. Nymphal fundatrices were collected in the Chicago area during the first week of April 1981.

Table 1. Determination of honeysuckle specimens on which *H. tataricae* was collected during 1981. Plants were collected from Ohio, Michigan, Indiana, Illinois, Minnesota, and Iowa. Determinations were made by William Hess of the Morton Arboretum, Lisle, Illinois.

<table>
<thead>
<tr>
<th>Hosts of <em>H. tataricae</em></th>
<th>Number of Collections</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Lonicera tatarica</em> L.</td>
<td>9</td>
</tr>
<tr>
<td><em>Lonicera × muscaviensis</em> Rehder</td>
<td>3</td>
</tr>
<tr>
<td><em>Lonicera × muenderiensis</em> Rehder</td>
<td>2</td>
</tr>
<tr>
<td><em>Lonicera × minutiflora</em> Zabel</td>
<td>11</td>
</tr>
<tr>
<td><em>Lonicera × bella</em> Zabel</td>
<td>52</td>
</tr>
</tbody>
</table>
Egg hatch is probably earlier in the more southerly areas of its distribution. The last live fall collection was taken in the first week of November in Champaign, Illinois. Alate viviparae were present in collections from late April to early September. Apterous viviparae were present from mid-April to November. The first males were collected in Beardstown, Cass County, and Galesburg, Knox County, Illinois on 14 July 1981. No oviparae were collected until late August and early September. The occurrence of males so early in two of the southern records is surprising since other collections in the same vicinity at the same time did not have males. Males were generally abundant in collections from mid-September to November.

POSSIBLE ORIGIN OF *H. TATARICA*E

The home of *H. tataricae* is unknown, but eastern Europe is probably not its origin. There are several reasons for this hypothesis. First, it was not described until 1935 from specimens taken in and near Moscow (Aizenberg 1935). Prior to 1935 there were active aphid taxonomists in Russia (e.g. A. K. Mordvilko, author of over 100 papers on aphids from 1892 to 1938) who certainly would have been aware of this aphid. Second, this aphid has not yet been found in western Europe although according to Mueller and Buhr (1965) and Hille Ris Lambers (pers. comm.) it is spreading westward in Europe. Grigorov (1965) noted its spread into Bulgaria over a 5-year period from 1960 to 1964. An aphid native to eastern Europe would certainly have dispersed across Europe prior to now. Third, the abundance and intensity of the damage caused by this aphid in western Russia (Shaposhnikov 1964) suggests strongly that it has no natural biological control agents there.

Green (1966) stated that *Lonicera tatarica* grows wild from the Altai Mountains of the Mongolian Republic to the Ural Mountains, and as far west as the Volga River in southern Russia. Hille Ris Lambers (1966) considered *H. tataricae* to be a synonym of *Hyadaphis coriandri* (Das) which is found from India to East Africa; later (Eastop and Hille Ris Lambers 1976) retained *H. tataricae* as a separate species. A reasonable hypothesis is that *H. tataricae* is native to the area where its host plant is found, i.e., northern and western Asia.

ACKNOWLEDGEMENTS

This research was supported by a grant from the University of Illinois Research Board, Urbana-Champaign campus. I would like to thank the many people who provided distributional records by mail and telephone, in particular Carl Carlson, Iowa State Entomologist, Murray Hanna, Michigan State Entomologist, and Virgil Knapp, a horticultural inspector and entomologist in Indiana. My thanks to Drs. Donald Webb, Michael Irwin and George Godfrey for their critical review of this manuscript and Lloyd LeMere for assistance with the distribution map. A special thanks to Dr. William Hess of the Morton Arboretum for identification of the honeysuckle specimens.

LITERATURE CITED


THE DISTRIBUTION OF NATURAL ENEMIES OF THE CORN LEAF
APHID (HOMOPTERA: APHIDIDAE) ON FIELD CORN¹

S. W. Wagner² and W. G. Ruesink³

The corn leaf aphid (CLA), *Rhopalosiphum maidis* (Fitch), is found on field corn in the midwest United States each year. Except for infrequent and scattered outbreaks, CLA populations remain at low levels. Injury to corn occurs during tasseling (Snelling et al. 1941) and is caused by CLAs which are the progeny of colonizers that arrived 2–3 weeks earlier when the corn was in the whorl stage (Bryson 1934, Falter 1963). Yield reductions averaging up to 54% on heavily infested plants have been reported (Bigger 1958, Everly 1960, Randell 1967).

Various workers have shown that CLA biotype (Painter and Pathak 1962), corn variety (Gernert 1917, Everly 1971, Long et al. 1977) and planting date (McColloch 1921, Falter 1963) can influence CLA population levels. The impact of natural enemies on CLA populations has usually been assumed to be negligible.

This study was undertaken to learn which species of potential natural enemies, especially predators, were most abundant in corn fields in central Illinois and whether any of these was temporally and spatially synchronized with the CLA. All of the research was done in Champaign County, Illinois.

METHODS

Aphid and natural enemy populations on field corn were sampled during 1977 by non-destructive visual searches. Three groups, each consisting of 20 plants (four sets of five consecutive plants), were visually monitored between four and seven times during the whorl and tasseling stages. Each plant was marked and monitored at ca. 4-day intervals from whorl stage until CLA populations declined after tasseling. At each date, data were taken concerning selected predator and phytophagous insect species, abundance, location, and field corn maturity. Group 1 was located in Field 1, which tasseled 7 July. Groups 2 and 3 were both in Field 2: Group 2 tasseled 29 July, while Group 3 tasseled 16 August. For data analysis, the corn plant was divided into the upper plant (UP) and lower plant (LP). The UP consisted of either the tassel plus the upper two leaves or the whorl. The LP consisted of that portion of the corn plant from the ground to the whorl or to the second leaf from the top of the corn plant.

Parasitoids were reared from aphid mummies collected from corn in the vicinity of the three corn groups being monitored. A representative collection of parasitoids was identified by E. E. Grissell and Paul M. Marsh of the Systematic Entomology Laboratory, USDA, Agricultural Research Service, Beltsville, Maryland. The remainder of the specimens were identified by comparison and were deposited in the Illinois Natural History Survey insect collection.

Whorls cannot be sampled without destroying them, so another sampling procedure was initiated in 1977 to complement the data gathered by visual searches. Until tasseling occurred, whorls of five consecutive plants in the vicinity of each group of five marked plants were removed, placed in a plastic bag, and stored at 5°C. The whorl was disassembled into a 70% ethanol bath, shaken vigorously, and the leaves and tassel were then rinsed with 70% v/v ethanol.
ethanol. All 70% ethanol was then filtered through ca. 100 mesh/inch organdy. The organdy was then inspected with a binocular microscope, and the number of CLAs and adult Orius insidiosus was recorded.

In the summer of 1978, plants in three fields of corn in the whorl stage of development were also censused. The whorl was removed and the insects associated with each leaf were noted as the leaf was removed from the whorl. Adult O. insidiosus (Say) (Hemiptera: Anthocoridae) and thrips were collected with an aspirator and preserved. O. insidiosus specimens were sexed and the thrips were identified to species. These data were gathered to determine whether thrips might serve as temporary prey for O. insidiosus prior to the arrival of the CLA.

RESULTS

The visual census of the three field corn groups from whorl through tasseling showed that CLA averaged 0 to 262 per plant depending on the corn groups and were located primarily on the UP (Table 1). Adult O. insidiosus averaged between 0.95 and 6.13 per UP during the whorl stage. Neuropteran larvae averaged 0 to 0.67 per plant and were located on the LP and larval coccinellids averaged between 0.05 and 1.10 per plant and were also found on the LP. Frankliniella tenuicornis Uzel (Thysanoptera: Thripidae) were always present in the whorl and in the leaf sheath. Schizaphis graminum (Rodani) (Homoptera: Aphididae), the greenbug, averaged from 0.4 to 14.3 per plant and was always located on the LP. Other insect species were found infrequently with average densities of at most a few per 20 plants and were also found on the LP.

CLA populations peaked within a week of tassel emergence: X(SD) of 128(91), 38(79), and 236(479) respectively, for the three groups. CLA populations on the lower plant (LP) peaked at the same time as the UP population or a few days later and had peak values of 5.07(0), 1.4(2.4), and 25.9(97.7) for the three groups.

Populations of adult O. insidiosus on the UP peaked within 5 days of tassel emergence while populations on the LP peaked 3-11 days after tassel emergence. The relative distribution of this predator shifted from the UP prior to tasseling to the LP after tasseling. Correlations of CLA and adult O. insidiosus numbers on individual plants within a sampling date for the UP were significant once each at both 0.05 and 0.01 level and were not significant on 16 dates. Alternately, analysis of the distribution of the CLA, O. insidiosus and F. tenuicornis from the destructive sampling of whorls indicated that their distribution is random with respect to one another (X², 2 x 2 contingency table, P > 0.05, n = 176, 57 plants in 1977 and 119 plants in 1978). O. insidiosus adults were observed feeding on CLAs on four occasions and once on thrips, probably F. tenuicornis.

Observations during the summers of 1977 and 1978 indicated that F. tenuicornis colonized plants prior to the whorl stage. Individuals remain under the leaf sheath or in the whorl until tasseling when populations decline and are found in the ear shucks.

Coccinellid and neuropteran distributions were almost exclusively limited to the LP for all life stages. The only exception to this was Hippodamia convergens Guerin-Meneville (Coleoptera: Coccinellidae) adults with 63.2% located on the UP. In contrast, 93.2% of the Coleomegilla maculata (DeGeer) (Coleoptera: Coccinellidae) adults were on the LP which is a significantly different distribution (X² analysis of 2 x 2 contingency table, P < 0.0005) and in keeping with the results of Ewert and Chiang (1967).

The density of potential predators did not correlate well with aphid density except in one case: chrysopid egg density was significantly correlated with non-CLA populations on the LP (P < 0.01, r = 0.60, n = 18). Otherwise, neither eggs nor larvae of either coccinellids or neuropterans could be related to LP aphid density. On the premise that predator populations should lag behind prey populations, the analysis was repeated comparing predator density with the number of aphids found on the preceding sampling date, but in this case none of the correlation coefficients was significantly greater than zero.

Eight species of parasitoids emerged from the aphid mummies that were collected and returned to the laboratory (Table 2). Known primary parasitoids composed 18.7% of those
Table 1. Average population levels on three groups of plants monitored periodically, and in whorls of plants located near the groups, during the summer of 1977.

<table>
<thead>
<tr>
<th>Group</th>
<th>Date</th>
<th>Tassel Emergence</th>
<th>Sampling Method and Number</th>
<th>Orlus Adults UP</th>
<th>Orlus Adults LP</th>
<th>CI/A UP</th>
<th>CI/A LP</th>
<th>Greenbug UP</th>
<th>Greenbug LP</th>
<th>Other Aphids Eggs</th>
<th>Other Aphids Larvae</th>
<th>Neuroptera Eggs</th>
<th>Neuroptera Larvae</th>
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<tbody>
<tr>
<td>1</td>
<td>7-02</td>
<td>Before</td>
<td>E 23</td>
<td>1.04</td>
<td>54.80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.24</td>
<td>0.00</td>
<td>0.90</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td>7-10</td>
<td>After</td>
<td>E 21</td>
<td>0.95 0.62</td>
<td>89.14 5.00</td>
<td>3.50</td>
<td>3.52</td>
<td>0.40</td>
<td>0.25</td>
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<tr>
<td></td>
<td>7-14</td>
<td>After</td>
<td>E 20</td>
<td>0.75 0.25</td>
<td>127.90 5.00</td>
<td>14.30</td>
<td>2.70</td>
<td>1.80</td>
<td>0.25</td>
<td>0.00</td>
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<td>0.00</td>
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<td></td>
<td>7-18</td>
<td>After</td>
<td>E 20</td>
<td>0.75 1.65</td>
<td>48.80 0.05</td>
<td>8.15</td>
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<td>2</td>
<td>7-12</td>
<td>Before</td>
<td>E 20</td>
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<td>11.8</td>
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<td>0.90</td>
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<td>1.10 0.25</td>
<td>0.20 0.00</td>
<td>4.00</td>
<td>0.90</td>
<td>0.55</td>
<td>0.25</td>
<td>0.95</td>
<td>0.05</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>7-20</td>
<td>Before</td>
<td>W 14</td>
<td>2.14</td>
<td>4.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.10</td>
<td>1.30</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>7-24</td>
<td>Before</td>
<td>E 20</td>
<td>1.10 0.35</td>
<td>27.35 0.05</td>
<td>2.85</td>
<td>0.70</td>
<td>0.85</td>
<td>0.10</td>
<td>1.30</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>7-25</td>
<td>Before</td>
<td>W 16</td>
<td>4.31</td>
<td>24.94</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.10</td>
<td>8.65</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>8-01</td>
<td>After</td>
<td>E 20</td>
<td>5.90 7.05</td>
<td>24.40 1.40</td>
<td>1.45</td>
<td>0.10</td>
<td>0.95</td>
<td>0.05</td>
<td>2.05</td>
<td>0.10</td>
<td>0.00</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>8-06</td>
<td>After</td>
<td>E 20</td>
<td>2.95 2.70</td>
<td>0.00 0.65</td>
<td>0.50</td>
<td>0.05</td>
<td>0.85</td>
<td>0.00</td>
<td>8.65</td>
<td>0.25</td>
<td>0.00</td>
<td>0.15</td>
</tr>
<tr>
<td>3</td>
<td>8-8</td>
<td>Before</td>
<td>E 20</td>
<td>5.90 2.80</td>
<td>234.90 0.00</td>
<td>1.20</td>
<td>0.20</td>
<td>0.40</td>
<td>0.00</td>
<td>1.15</td>
<td>0.25</td>
<td>0.00</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>8-10</td>
<td>Before</td>
<td>E 20</td>
<td>6.13 4.07</td>
<td>236.27 25.87</td>
<td>0.67</td>
<td>0.07</td>
<td>0.33</td>
<td>0.67</td>
<td>5.27</td>
<td>0.07</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>8-13</td>
<td>Before</td>
<td>E 15</td>
<td>6.13 4.07</td>
<td>236.27 25.87</td>
<td>0.67</td>
<td>0.07</td>
<td>0.33</td>
<td>0.67</td>
<td>5.27</td>
<td>0.07</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>8-19</td>
<td>Before</td>
<td>E 20</td>
<td>4.60 4.35</td>
<td>187.45 13.95</td>
<td>0.90</td>
<td>3.00</td>
<td>0.00</td>
<td>0.00</td>
<td>6.35</td>
<td>0.25</td>
<td>0.00</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>8-24</td>
<td>After</td>
<td>E 20</td>
<td>1.65 3.55</td>
<td>87.15 5.30</td>
<td>0.40</td>
<td>0.40</td>
<td>0.10</td>
<td>0.05</td>
<td>4.60</td>
<td>0.35</td>
<td>0.00</td>
<td>0.35</td>
</tr>
</tbody>
</table>

a) 1 = field 1, tasseled 7-7; 2 = field 2, tasseled 7-29; 3 = field 2, delayed germination tasseled 8-16.

b) Entire plant was visually sampled (see Methods); W, only whorl was sampled (see Methods).
Table 2. Hymenopterous parasitoids reared from unidentified aphid mummies collected from corn at Urbana, Illinois, in 1977.

<table>
<thead>
<tr>
<th>Parasitoid</th>
<th>Number of mummies</th>
<th>Percent of total</th>
<th>Trophic affinity(a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Braconidae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aphidius sp.</td>
<td>17</td>
<td>18.7</td>
<td>1()</td>
</tr>
<tr>
<td>Eulophidae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tetrastichus minutus (Howard)</td>
<td>14</td>
<td>15.4</td>
<td>II()</td>
</tr>
<tr>
<td>Encyritidae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aphidencyrtus aphidivorus (Mary)</td>
<td>3</td>
<td>3.3</td>
<td>II()</td>
</tr>
<tr>
<td>Genus sp.</td>
<td>1</td>
<td>1.1</td>
<td>?</td>
</tr>
<tr>
<td>Pteromalidae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asaphes sp.</td>
<td>11</td>
<td>12.1</td>
<td>?</td>
</tr>
<tr>
<td>Pachneuron siphonophorae (Ashmead)</td>
<td>42</td>
<td>46.2</td>
<td>II()</td>
</tr>
<tr>
<td>P. altiscutum (Cook)</td>
<td>1</td>
<td>1.1</td>
<td>?</td>
</tr>
<tr>
<td>Megaspilidae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dendrocerus niger (Howard)</td>
<td>2</td>
<td>2.2</td>
<td>?</td>
</tr>
</tbody>
</table>

\(a\) I\(\) = primary parasite of aphid, II\(\) = secondary parasite of aphid.

emerging, while three species composing 64.9% of those emerging were secondary parasitoids. The trophic relationships of the remaining 16.5% are not known. Mummies on the monitored plants were located on the LP, often in clusters of greenbug. The number of mummies/plant were similar both between the different fields (2 miles apart) and on corn of differing age within the same field. While no data were gathered on percent parasitism, based on the low number of mummies found, it would appear that far less than 1% of the aphids were parasitized. Aphid flights were very low in 1977.

DISCUSSION

The results of these field observations indicate that potential CLA natural enemies other than O. insidiosus were generally restricted to the LP and thus could have little effect on CLA populations colonizing corn. The only exception to this was H. convergens adults, but any significant impact on CLA dynamics by this species was precluded by low numbers (maximum population = 0.2/plant). Ewert and Chiang (1967) and Havnvik and Frye (1969) noted associations between CLAs and both H. convergens and H. tridecimpunctata, but neither indicated that these species control CLAs.

Between-plant distribution of O. insidiosus is only slightly affected, if at all, by the between-plant distribution of CLA according to our analysis. This distribution of O. insidiosus adults is consistent with Isenhour's (1977) description of a floating adult Orius population. He argued that adults constantly sample the environment, moving from plant to plant within the corn and soybean fields under study. This behavior would tend to bring the predator into contact with newly arrived CLAs, when aphid populations are small and predation would have its greatest impact.

The pre-tasseling adult O. insidiosus density of ca. 1/plant found in this study and by others (Barber 1936, Dicke and Jarvis 1962) indicates that this predator is often present in corn fields in the eastern U.S. at levels which could impact CLA populations. While Dicke and Jarvis (1962) and Havnvik and Frye (1969) suggested that O. insidiosus may have controlled CLA populations in their studies, the actual impact remains uncertain because feeding studies have not been conducted.
LITERATURE CITED

Barber, G. W. 1936. Orlia insidiosus (Say), an important natural enemy of the corn earworm. USDA Tech. Bull. 504.


Everly, R. T. 1960. Loss in corn yield associated with the abundance of the corn leaf aphid, Rhopalosiphum maidis, in Indiana. J. Econ. Entomol. 53:924-932.


EFFECTS OF VARIOUS SPLIT DEVELOPMENTAL PHOTOPHASES AND CONSTANT LIGHT DURING EACH 24 HOUR PERIOD ON ADULT MORPHOLOGY IN EUCHISTUS TRISTIGMUS TRISTIGMUS (HEMIPTERA: PENTATOMIDAE)

J. E. McPherson and S. M. Paskewitz

ABSTRACT

Rearing immatures of Euschistus tristigmus tristigmus in a range of split photophases during each 24 h period and in constant light showed that the adult dimorphic response in shoulder shape and number of midventral spots could be produced; individuals reared in photoperiods in which each scotophase was at least 2 h in length developed into the tristigmus (short-day) form.

Euschistus tristigmus ranges from northern Canada to southern Mexico (Van Duzee 1904) and contains two subspecies, luridus Dallas and tristigmus (Say) (= pyrrhocerus (Herrich-Schaeffer)). E. t. tristigmus exhibits adult dimorphism. McPherson (1975a) has shown it to be bivoltine and seasonally dimorphic; adults with spinose shoulders and 0-2 midventral abdominal spots (pyrrhocerus or long-day form) are found during the summer months and adults with subtriangular shoulders and 3-4 spots (tristigmus or short-day form) are found during the fall and spring. Adult dimorphism results from developmental photoperiod (McPherson 1974, 1975b) with a threshold photoperiod of about 14.5L:9.5D (light:dark) involved in the dimorphic response (McPherson 1979a); animals reared in photophases above and below the threshold develop into the pyrrhocerus and tristigmus form adults, respectively.

To determine if the photophase during each 24 h period had to be continuous (e.g., 16 h) or could be split (e.g., 8 h, 8 h) and still produce the same morph, McPherson (1979b) reared animals under 8L:16D, 8L:4D:8L:4D, and 16L:8D photoperiods. The 8L:4D:8L:4D photoperiod exposed the animals to only 8 h of continuous light but a total of 16 h of light/24 h. He found that those reared under 8L:16D and 8L:4D:8L:4D became tristigmus adults (short-day form) and those in 16L:8D, pyrrhocerus adults (long-day form). Thus, during each 24 h period, it is the length of each photophase, rather than the combined lengths of all photophases, that determines the adult morph. Also, since photophases of 16 h and 4 h were involved in the production of the tristigmus form and 8 h the production of the pyrrhocerus form, it appeared that the scotophase was functioning only to break the photophase and the length of the scotophase was unimportant down to 4 h. This raised another question. What was the length of the scotophase below which the animals would no longer respond but, instead, develop into pyrrhocerus adults? The results of an experiment to determine this are presented here.

METHODS AND MATERIALS

Fifty males and 50 females from F1 generation stock were placed in an incubator (23.9 ± 1.1°C) under a 24L:0D photoperiod; the stock was established with individuals collected June–July 1981 in the LaRue-Pine Hills Ecological Area, Union County, in southern Illinois. They were maintained in mason jars (five of each sex/jar) provided with cheesecloth.

1Department of Zoology, Southern Illinois University, Carbondale, IL 62901.
as an oviposition site, a paper toweling strip, and filter paper, and fed green snap beans (*Phaseolus vulgaris* L.), as described by McPherson (1971).

Each resulting egg cluster was placed in one of the following five photoperiods and the individuals reared to adults as described by McPherson (1971): 8L:4D:8L:4D, 9L:3D:9L:3D, 10L:2D:10L:2D, 11L:1D:11L:1D, and 24L:0D. All individuals were reared in 23.9 ± 1.1°C and in about 250 ft-c during the light phases (Sylvania, 15W Daylight, F15ST8/D).

Adult characters compared were shoulder shape (ratio of length/width) and number of midventral abdominal spots (McPherson 1974). These characters had previously been shown to be dimorphic between animals reared in long- and short-day photoperiods (McPherson 1979a). Shoulder ratios were compared with Duncan's multiple range test (Table I). Numbers of spots were compared with Fisher's exact probability test and generally in sequential pairs of increasing photophases; for example, individuals reared in 9L:3D:9L:3D were compared with those reared in 8L:4D:8L:4D and 10L:2D:10L:2D (Table 2). The 0.01 level of significance was chosen for all comparisons.

**RESULTS AND DISCUSSION**

There was no significant difference in shoulder ratios between males or females reared in 8L:4D:8L:4D, 9L:3D:9L:3D, and 10L:2D:10L:2D; all had shoulder ratios less than 1.00 (subtriangular shoulder-tristigmus form) (Table 1). Males or females reared in 11L:1D:11L:1D had shoulder ratios greater than 1.00 (spinose shoulder = pyrrhocerus form) and were not significantly different from those reared in 24L:0D. There was also no significant difference in number of spots between males or females reared in 8L:4D:8L:4D, 9L:3D:9L:3D, and 10L:2D:10L:2D; most had 3–4 spots (= tristigmus form) (males 85–95%; females 90–95%) (Table 2). Males or females reared in 11L:1D:11L:1D usually had 0–2 spots (= pyrrhocerus form) (males 80%; females 85–90%) and were not significantly different from those reared in 24L:0D.

These results show that there is a critical developmental scotophase between 2 and 1 h below which the animals do not respond; as adults, therefore, they appear as though reared in constant light (i.e., develop into the pyrrhocerus form). Thus, scotophase, as shown in the earlier experiment (McPherson 1979b), does function to break the photophase but can be overridden by the photophase if the scotophase is not of sufficient duration (i.e., near 1.5 h).

**LITERATURE CITED**


Van Duzee, E. P. 1904. Annotated list of the Pentatomidae recorded from America north of Mexico, with descriptions of some new species. Trans. Amer. Entomol. Soc. 30:1–80.
<table>
<thead>
<tr>
<th>Photoperiod</th>
<th>Sex</th>
<th>No.</th>
<th>Shoulder (X)</th>
<th>Sex</th>
<th>No.</th>
<th>Shoulder (X)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8L:4D:8L:4D</td>
<td>♂</td>
<td>20</td>
<td>0.94 A</td>
<td>♂</td>
<td>20</td>
<td>0.94 A</td>
</tr>
<tr>
<td>9L:3D:9L:3D</td>
<td>♂</td>
<td>20</td>
<td>0.93 A</td>
<td>♂</td>
<td>20</td>
<td>0.95 A</td>
</tr>
<tr>
<td>10L:2D:10L:2D</td>
<td>♂</td>
<td>20</td>
<td>0.93 A</td>
<td>♂</td>
<td>20</td>
<td>0.94 A</td>
</tr>
<tr>
<td>11L:1D:11L:1D</td>
<td>♂</td>
<td>20</td>
<td>1.07 B</td>
<td>♂</td>
<td>20</td>
<td>1.11 B</td>
</tr>
<tr>
<td>24L:9D</td>
<td>♂</td>
<td>20</td>
<td>1.09 B</td>
<td>♂</td>
<td>20</td>
<td>1.10 B</td>
</tr>
</tbody>
</table>

*Means followed by same letter within columns are not significantly different at the 0.01 level of probability by Duncan's multiple range test.

Table 2. Comparison of number of midventral abdominal spots between *E. t. tristigmus* adults reared in various split photophases and constant light.

<table>
<thead>
<tr>
<th>Photoperiod</th>
<th>Sex</th>
<th>0-2</th>
<th>3-4</th>
<th>Prob.</th>
<th>Sex</th>
<th>0-2</th>
<th>3-4</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>8L:4D:8L:4D</td>
<td>♂</td>
<td>3</td>
<td>17</td>
<td>0.67</td>
<td>♂</td>
<td>2</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>9L:3D:9L:3D</td>
<td>♂</td>
<td>3</td>
<td>17</td>
<td>0.67</td>
<td>♂</td>
<td>1</td>
<td>19</td>
<td>0.50</td>
</tr>
<tr>
<td>10L:2D:10L:2D</td>
<td>♂</td>
<td>1</td>
<td>19</td>
<td>0.30</td>
<td>♂</td>
<td>1</td>
<td>19</td>
<td>0.76</td>
</tr>
<tr>
<td>11L:1D:11L:1D</td>
<td>♂</td>
<td>1</td>
<td>19</td>
<td>0.30</td>
<td>♂</td>
<td>1</td>
<td>19</td>
<td>0.76</td>
</tr>
<tr>
<td>11L:1D:11L:1D</td>
<td>♂</td>
<td>16</td>
<td>4</td>
<td>0.00</td>
<td>♂</td>
<td>18</td>
<td>2</td>
<td>0.00</td>
</tr>
<tr>
<td>24L:9D</td>
<td>♂</td>
<td>16</td>
<td>4</td>
<td>0.65</td>
<td>♂</td>
<td>17</td>
<td>3</td>
<td>0.50</td>
</tr>
<tr>
<td>8L:4D:8L:4D</td>
<td>♂</td>
<td>3</td>
<td>17</td>
<td>0.65</td>
<td>♂</td>
<td>2</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>24L:9D</td>
<td>♂</td>
<td>16</td>
<td>4</td>
<td>0.00</td>
<td>♂</td>
<td>17</td>
<td>3</td>
<td>0.00</td>
</tr>
</tbody>
</table>

*aFisher's exact probability test.*
THE FEMALE OF GRAPHODERUS MANITOBENSIS WITH NOTES ON IDENTIFICATION OF FEMALE GRAPHODERUS (COLEOPTERA: DYTISCIDAE)

Bryn H. Tracy and William L. Hilsenhoff

ABSTRACT

Ten male and 11 female Graphoderus manitobensis were collected in April and May, 1980 and 1981 from a pond 16 km west of Madison, WI. Females can be distinguished from female G. fascicollis (Harris) by their much narrower metasternal wings and more pronounced corrugated sculpturing on the pronotum. The sculpturing and markings on the pronotum, width of the metasternal wings, and projections at the base of the ovipositor are used to identify females of G. manitobensis and three closely related species.

Wallis (1933) described Graphoderus manitobensis from a single male collected 21 June 1911 at Winnipeg, Manitoba, but the female remained unknown and no additional males were ever collected (Wallis 1973). However, in 1980 and 1981, 10 males and 11 females were collected between 3 April and 24 May from McKenna Pond, a shallow, 0.8 ha, semi-permanent, heavily-vegetated pond owned by the University of Wisconsin and located 16 km west of Madison, WI. Female G. manitobensis were identified after comparison with the 10 males and 47 G. fascicollis (Harris) in the University of Wisconsin Insect Collection. Frequently in the literature G. fascicollis is erroneously called G. fasciatocollis. This paper describes the female of G. manitobensis and provides a means for separating it from G. fascicollis and other species of Graphoderus Aube. All G. manitobensis from this study are deposited in the University of Wisconsin Insect Collection.

DESCRIPTION OF FEMALE GRAPHODERUS MANITOBENSIS

Except for the modified pro- and mesotarsi and their claws, which are secondary male sexual characteristics, the description by Wallis (1933) for the male of G. manitobensis applies to females. But females differ from males in other respects. They have more pronounced corrugated macrosculpturing on the pronotum, which is longitudinal toward the lateral margin and oblique toward the middle. The basolateral elytral punctures are more pronounced, and in some the punctures coalesce into abbreviated, irregular, black grooves. Lastly, along the dorsal anterolateral margins of the basal segment of the ovipositor are two small, sclerotized, apically rounded to bluntly pointed projections. The posterior black fascia on the pronotum of both sexes, although reaching the posterior margin, is attenuated laterally, and does not quite reach the lateral margin as described by Wallis.

NOTES ON IDENTIFICATION OF GRAPHODERUS

The most recent key to North American Graphoderus Aube is by Wallis (1939). Graphoderus liberus (Say) is easily recognized by its distinctive coloration, but the other

1Research supported by the College of Agricultural and Life Sciences and the Graduate School at the University of Wisconsin-Madison.

2Department of Entomology, University of Wisconsin, Madison, WI 53706.
four species are marked similarly. Males are easily identified with Wallis’s key by differences in the number of pallettes on the pro- and mesotarsi, and differences in the genitalia can also be used (Wallis, unpub. manuscript). Identification of females is based on pronotal markings, and is sometimes difficult, with *G. manitobensis* females keying to *G. fascicollis*. The following additions to couplet 4 in Wallis’s key will separate females of these two species:

4. Width of metasternal wing 0.5–0.6 mm; ratio of metasternal wing width to metacoxal plate length greater than 0.13 ........................................... *G. fascicollis* (Harris)

   Width of metasternal wing 0.3–0.4 mm; ratio of metasternal wing width to metacoxal plate length less than 0.13 ........................................... *G. manitobensis* Wallis.

The width of the metasternal wing is the narrowest width between the mesocoxae and metacoxal plate. The length of the metacoxal plate is measured along the same line (Larson 1975). Additional characters in Table 1 can be used to verify identifications of female *Graphoderus*.

### Table 1. Separation of female *Graphoderus*.

<table>
<thead>
<tr>
<th></th>
<th><em>perplexus</em></th>
<th><em>occidentalis</em></th>
<th><em>fascicollis</em></th>
<th><em>manitobensis</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrugated macrosculpturing on pronotum</td>
<td>distinct</td>
<td>obsolete</td>
<td>distinct</td>
<td>pronounced</td>
</tr>
<tr>
<td>Width of metasternal wing (mm)</td>
<td>0.35–0.40</td>
<td>0.50–0.60</td>
<td>0.50–0.60</td>
<td>0.30–0.40</td>
</tr>
<tr>
<td>Separation of posterior black fascia from base of pronotum</td>
<td>narrow testaceous</td>
<td>none</td>
<td>very narrow rufous laterally</td>
<td>none</td>
</tr>
<tr>
<td>Separation of anterior black fascia from apex of pronotum</td>
<td>broad testaceous</td>
<td>none</td>
<td>broad rufopiceous</td>
<td>none</td>
</tr>
<tr>
<td>Dorsal projections at antero-lateral margins of basal segment of ovipositer</td>
<td>pointed</td>
<td>reduced</td>
<td>truncate to notched</td>
<td>bluntly pointed</td>
</tr>
</tbody>
</table>

\(^a\)Occasionally extremely narrow or absent at center.

\(^b\)Present in all Wisconsin specimens, but in some *G. fascicollis* the black fascia extends to the margin (Wallis 1939).

\(^c\)Anterior bead may be rufopiceous.

**LITERATURE CITED**


---------. MS. The Haliplidae, Dytiscidae and Gyrinidae of Minnesota and Manitoba. 187 pp + 10 plates. Located at Dept. of Entomology, Univ. of Alberta.
PROJECTED RED PINE YIELDS FROM ALDRIN-TREATED AND UNTREATED STANDS DAMAGED BY WHITE GRUB (COLEOPTERA: SCARABAEIDAE) AND OTHER AGENTS AT STAND AGE TEN YEARS

Richard F. Fowler,1 Louis F. Wilson,2 and Allen L. Lundgren2

ABSTRACT

White grubs affect pine plantations by killing some trees and by reducing vigor and growth of others. Light to moderate mortality only slightly affects timber yields and financial returns if the level of trees remains at the number required for full utilization of the site. Reduced height growth, however, lowers apparent site quality and substantially affects yields and financial returns. The 10-year projections suggest that greater product volumes, financial returns, and higher interest rates on the investment will be gained by grub control before tree growth is reduced.

During the first few years after planting, red pines, Pinus resinosa Ait., are vulnerable to several injurious agents including white grubs, the larvae of May beetles, Phyllophaga spp. (Kittredge 1929). To protect seedlings from white grubs, more than 12,000 acres of National Forest land in the Lake States were treated with aldrin. Almost 10,000 of these acres were on the Hiawatha National Forest in Michigan (Fowler 1973).

To assess white grub injury and to determine the effectiveness of different aldrin treatments on white grub populations, studies were begun on the Hiawatha National Forest in 196-. White grubs killed many trees and suppressed others in the research areas. More than half of the total tree mortality during the first five years after planting, however, was attributed to disease organisms, improper planting practices, and other agents (Fowler and Wilson 1971a, 1974). The overall impact of the white grubs and other agents was assessed and then growth and yield projections of the red pine were made after five years (Fowler and Wilson 1975). Growth and yield projection made from the trees after 10 years are presented here; direct comparisons to the five-year projections are not possible due to changes made in some of the assumptions in the 10-year growth and yield program projections.

MATERIALS AND METHODS

Four white grub infested research areas (designated Bird, Raco, Townhall, and Townline Lake) were machine-planted with 3-0 and 2-1 nursery stock red pine in 1967 on the Hiawatha National Forest. Because terrain and obstacles differed, initial tree stocking ranged from 450 to 1037 trees per acre in the four study plantations. The Townline Lake area had the lowest stocking because it was a conversion of a poorly stocked hardwood stand.

Three aldrin treatments were evaluated by using a randomized complete block design replicated five times in each planting. Aldrin was applied both as a liquid solution and as a granular formulation by a dispenser on the planting machines, and as a liquid solution with a

1Northeastern Area, State and Private Forestry, USDA Forest Service.
2North Central Forest Experiment Station, USDA Forest Service, St. Paul, MN 55108.
3This publication reports research involving pesticides. It does not contain recommendations for their use nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate state or federal agencies before they can be recommended.
backpack pump and wand. Further details of the results of the tests are found in Fowler and Wilson (1971b, 1974).

For the first three years after planting, the trees were monitored for height growth, causes of injury, and mortality. Height growth and mortality of the pines were also measured in the research plots after five years, and then growth and yield projections were made from the five-year data. After the 10th growing season, tree height and mortality were again recorded for all trees in all study plots. Site index values were calculated from the height of three dominant or codominant trees from each plot. Growth and yield projections were then made from 10-year data. The Raco granular aldrin treatment was excluded from the 10-year projections because of heavy mortality from Scleroderris canker, Gremmeniella abietina.

GROWTH AND YIELD PROGRAM

Growth and yield volumes and values for the study plantings were projected by using a computer program called REDPINE. The management provisions in the Timber Management Plan of the Hiawatha National Forest were used in the projections. Basic inputs to the program included (1) nature of each stand (new plantations); (2) site index of each stand (from Table 1); (3) age of trees at the time of establishment (3 years at planting); and (4) number of trees an acre alive at 10 years after planting (from Table 2).

At the start, all plantations were considered to be age 0 and the planting stock to be age 3. Projections were made at five-year intervals, from stand-age 0 to rotation-age 120 years. The stands were thinned to 90 square feet basal area, beginning at age 30 when possible, and every 10 years thereafter to age 100. Final harvest was made at age 120. The model assumes a varying distribution of tree diameters within the stand (Lundgren 1981).

Cubic-foot volume is the total stem volume under bark, not limited by a merchantable top. Board foot volume is the volume of sawtimber in trees 9.0 inches d.b.h. and larger using the International 0.25-inch rule. Cordwood volume includes all merchantable volume in trees 5.0 to 9.0 inches d.b.h.

White grubs and most other injurious agents kill trees in a contagious distribution and not randomly, usually resulting in distinct pockets of dead trees. The dead trees, however, were not sufficiently clumped in the study plots to cause concern, and we assumed that the little uneven distribution would be evened out during early thinnings.

The economic analysis of the alternative treatments was made using the investment analysis program RETURN (Lundgren and Schweitzer 1971, Schweitzer et al. 1967). Assumed planting costs were $94 per acre direct and $38 per acre indirect. Sales administration costs were $0.0029 per cubic foot harvested. The costs of the chemical and application were not included in the basic inputs into the computer program. Cost of the chemical was less than $1 per acre, and except for occasional filling of the dispensing apparatus in the planting machine, no extra time or effort was expended in applying the chemical when the granular aldrin was used. Liquid applications added to the cost.

Stumpage values of expected products used were $20 per thousand board feet (MBF) for sawtimber. Cordwood values were $5 per cord for Townhall and Raco and $7.92 per cord for Bird and Townline Lake. These are 1975 values used to keep the five-year and 10-year projections similar.

The Internal Rate of Return (IRR) was computed for each stand for a wide range of rotation ages. The IRR is a measure frequently used to indicate when a stand should be harvested in order to maximize financial returns. It is the rate of interest earned over an investment period on all invested capital and the rate of interest that would make the sum of all compounded costs equal to the sum of all compounded incomes (Lundgren 1966).

4Developed by A. L. Lundgren. The computer program, not yet published, is based on growth and yield equations developed by Buckman (1962) and Wambach (1967). The growth model is briefly described by Lundgren (1981).
RESULTS AND DISCUSSION

Site index values calculated from 10-year heights differed somewhat from the five-year values, which were estimated from soil characteristics alone because of small tree size (Table 1). Site index values were reasonably close between the five- and 10-year data for Bird and Townhall, but the five-year indexes for Raco and Townline Lake appeared to overestimate the site. Also, mean 10-year site index calculations from the aldrin-treated plots were consistently and significantly ($P < 0.05$) higher than those from the untreated plots. The significantly higher index values and taller trees in the treated plots suggest that the aldrin affected the outcome. We know that aldrin killed many of the grubs and thus lessened root injury in the treated areas. The response from this lessened injury apparently is greater height growth. Also, site indexes calculated for the aldrin-treated plots would thus be the most realistic for each research area as height growth of trees in the untreated plots is affected by grub feeding injury.

Between the fifth and 10th years, tree mortality averaged 1–11% in the aldrin-treated plots and 2–12% in the untreated plots (Table 2). One aldrin-treated plot at Raco, which was eliminated from analysis, had 17% mortality but most of that was caused by Scleroderris canker. No mortality between the fifth and 10th years was attributed to white grub feeding as we had predicted previously (Fowler and Wilson 1975). A few trees weakened by grubs during the first five years may have died during the latter period, but as losses were proportionately the same for treated and untreated plots, the effect from grubs must have been small.

### Table 1. Five- and 10-year site index values for aldrin-treated and untreated plots for white grub research areas, Hiawatha National Forest.

<table>
<thead>
<tr>
<th>Research area</th>
<th>Site index $^a$</th>
<th>Site index $^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5th year</td>
<td>10th year</td>
</tr>
<tr>
<td></td>
<td>Treated and</td>
<td>Treated</td>
</tr>
<tr>
<td></td>
<td>untreated plots</td>
<td>plots</td>
</tr>
<tr>
<td>Bird</td>
<td>55</td>
<td>59</td>
</tr>
<tr>
<td>Raco</td>
<td>55</td>
<td>46</td>
</tr>
<tr>
<td>Townhall</td>
<td>65</td>
<td>70</td>
</tr>
<tr>
<td>Townline Lake</td>
<td>65</td>
<td>58</td>
</tr>
</tbody>
</table>

$^a$Estimated by soil characteristics of each research area.

$^b$Calculated from height of three dominant or codominant trees in each lot. Treatments were pooled because there were no significant differences in tree heights among treatments.

### Table 2. Mean number of trees per acre for aldrin-treated and untreated plots for white grub research areas at plantation ages 5 and 10 years.

<table>
<thead>
<tr>
<th>Research area</th>
<th>Trees per acre (treated)</th>
<th>Percent loss</th>
<th>Trees per acre (untreated)</th>
<th>Percent loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 yrs</td>
<td>10 yrs</td>
<td>5 yrs</td>
<td>10 yrs</td>
</tr>
<tr>
<td>Bird</td>
<td>628</td>
<td>615</td>
<td>2</td>
<td>459</td>
</tr>
<tr>
<td>Raco</td>
<td>737</td>
<td>656$^a$</td>
<td>11</td>
<td>609</td>
</tr>
<tr>
<td>Townhall</td>
<td>829</td>
<td>821</td>
<td>1</td>
<td>745</td>
</tr>
<tr>
<td>Townline Lake</td>
<td>346</td>
<td>332</td>
<td>4</td>
<td>252</td>
</tr>
</tbody>
</table>

$^a$Pooled data for only two aldrin treatment plots instead of three. Data from the granular aldrin treatment were omitted because of excessive mortality from Scleroderris canker.
Table 3. Volume yields of cordwood and sawtimber over a 120-year rotation in aldrin-treated and untreated plots for white grub research areas, using site index values for both treated and untreated plots.

<table>
<thead>
<tr>
<th>Age</th>
<th>Volume removed</th>
<th></th>
<th>Volume removed</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Treated</td>
<td>Untreated</td>
<td>Treated</td>
<td>Untreated</td>
</tr>
<tr>
<td></td>
<td>Cords MBF</td>
<td>Cords MBF</td>
<td>Cords MBF</td>
<td>Cords MBF</td>
</tr>
<tr>
<td>30</td>
<td>8.0</td>
<td>0.04</td>
<td>1.1</td>
<td>0.01</td>
</tr>
<tr>
<td>40</td>
<td>7.0</td>
<td>1.24</td>
<td>5.7</td>
<td>0.87</td>
</tr>
<tr>
<td>50</td>
<td>3.4</td>
<td>3.59</td>
<td>3.2</td>
<td>2.44</td>
</tr>
<tr>
<td>60</td>
<td>0.0</td>
<td>6.31</td>
<td>0.3</td>
<td>4.48</td>
</tr>
<tr>
<td>70</td>
<td>0.0</td>
<td>6.42</td>
<td>0.0</td>
<td>4.93</td>
</tr>
<tr>
<td>80</td>
<td>0.0</td>
<td>5.53</td>
<td>0.0</td>
<td>4.41</td>
</tr>
<tr>
<td>90</td>
<td>0.0</td>
<td>4.76</td>
<td>0.0</td>
<td>3.86</td>
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<tr>
<td>100</td>
<td>0.0</td>
<td>4.11</td>
<td>0.0</td>
<td>3.88</td>
</tr>
<tr>
<td>120</td>
<td>0.0</td>
<td>31.30</td>
<td>0.0</td>
<td>27.08</td>
</tr>
<tr>
<td>Total</td>
<td>18.4</td>
<td>63.30</td>
<td>10.3</td>
<td>51.46</td>
</tr>
<tr>
<td>%dif</td>
<td>79</td>
<td>23</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age</th>
<th>Volume removed</th>
<th></th>
<th>Volume removed</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Treated</td>
<td>Untreated</td>
<td>Treated</td>
<td>Untreated</td>
</tr>
<tr>
<td></td>
<td>Cords MBF</td>
<td>Cords MBF</td>
<td>Cords MBF</td>
<td>Cords MBF</td>
</tr>
<tr>
<td>30</td>
<td>18.7</td>
<td>0.17</td>
<td>8.6</td>
<td>0.00</td>
</tr>
<tr>
<td>40</td>
<td>8.5</td>
<td>2.05</td>
<td>7.8</td>
<td>1.13</td>
</tr>
<tr>
<td>50</td>
<td>2.8</td>
<td>5.95</td>
<td>4.1</td>
<td>3.51</td>
</tr>
<tr>
<td>60</td>
<td>0.0</td>
<td>9.00</td>
<td>0.0</td>
<td>6.55</td>
</tr>
<tr>
<td>70</td>
<td>0.0</td>
<td>8.39</td>
<td>0.0</td>
<td>6.88</td>
</tr>
<tr>
<td>80</td>
<td>0.0</td>
<td>7.00</td>
<td>0.0</td>
<td>5.90</td>
</tr>
<tr>
<td>90</td>
<td>0.0</td>
<td>5.92</td>
<td>0.0</td>
<td>5.05</td>
</tr>
<tr>
<td>100</td>
<td>0.0</td>
<td>5.07</td>
<td>0.0</td>
<td>4.35</td>
</tr>
<tr>
<td>110</td>
<td>0.0</td>
<td>37.72</td>
<td>0.0</td>
<td>32.33</td>
</tr>
<tr>
<td>Total</td>
<td>30.0</td>
<td>81.27</td>
<td>20.5</td>
<td>65.70</td>
</tr>
<tr>
<td>%dif</td>
<td>46</td>
<td>24</td>
<td></td>
<td>178</td>
</tr>
</tbody>
</table>

Volume yields of sawtimber and cordwood were projected over the length of the 120-year rotation by using calculated site index values from aldrin-treated and untreated plots (Table 3). In all research areas more sawtimber and cordwood were produced in the aldrin-treated than in the untreated plots. The increase in sawtimber ranged from 14 to 60%; the cordwood increase ranged from 36 to 178%. The untreated Raco and Townline Lake plots could not be thinned at age 30 because of insufficient basal area.

Projected stumpage values were estimated for the products produced over the 120-year rotation (Table 4). Total values for aldrin-treated trees ranged from 16 to 57% higher than those for untreated trees.

The calculated internal rates of return (IRR) reached maximum at age 80 for the treated areas except for Raco where the maximum was reached at age 110 (Table 5). The IRR's reached maximum at age 90 for the untreated areas except for Raco where again it was reached at age 110. Based on an economic rotation then, all the stands except Raco could be

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*aThousands of board feet.

bThe percentage difference is the increase in volume of the treated product over the corresponding untreated product.
Table 4. Stumpage value\(^a\) of red pine cordwood and sawlogs over a 120-year rotation in aldrin-treated and untreated plots for white grub research areas, using site index values for both treated (T) and untreated (U) plots for growth projections.

<table>
<thead>
<tr>
<th>Research area</th>
<th>Site index</th>
<th>Cordwood</th>
<th>Sawlog</th>
<th>Total</th>
<th>% diff.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T</td>
<td>U</td>
<td>T</td>
<td>U</td>
<td>T</td>
</tr>
<tr>
<td>Bird</td>
<td>59</td>
<td>51</td>
<td>146</td>
<td>82</td>
<td>1266</td>
</tr>
<tr>
<td>Raco(^b)</td>
<td>46</td>
<td>39</td>
<td>86</td>
<td>63</td>
<td>772</td>
</tr>
<tr>
<td>Townhall</td>
<td>70</td>
<td>61</td>
<td>150</td>
<td>103</td>
<td>1625</td>
</tr>
<tr>
<td>Townline Lake</td>
<td>58</td>
<td>53</td>
<td>51</td>
<td>18</td>
<td>1297</td>
</tr>
</tbody>
</table>

\(^a\)1975 prices.

\(^b\)One aldrin treatment omitted from the pooled data because losses from disease were heavier than in other plots, yielding a significant difference in number of trees per acre.

Table 5. Internal rates of return over a range of rotation ages for aldrin-treated and untreated lots by research areas and 10-year site index values.

<table>
<thead>
<tr>
<th>Rotation age</th>
<th>Internal rate of return (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Treated</td>
</tr>
<tr>
<td>BIRD</td>
<td></td>
</tr>
<tr>
<td>SI 59</td>
<td>3.04</td>
</tr>
<tr>
<td>SI 51</td>
<td>3.21</td>
</tr>
<tr>
<td>SI 51</td>
<td>3.24</td>
</tr>
<tr>
<td>SI 46</td>
<td>3.24</td>
</tr>
<tr>
<td>SI 39</td>
<td>3.22</td>
</tr>
<tr>
<td>SI 39</td>
<td>3.19</td>
</tr>
<tr>
<td>SI 39</td>
<td>3.16</td>
</tr>
</tbody>
</table>

| RACO         |         |           |         |           |
| SI 46        | 2.91    | 2.46      | 2.91    | 2.66      |
| SI 39        | 3.04    | 2.66      | 3.07    | 2.72      |
| SI 39        | 3.07    | 2.68      | 3.05    | 2.73      |
| SI 39        | 3.03    | 2.71      | 3.06    | 2.71      |
| SI 39        | 3.00    | 2.68      | 3.08    | 2.70      |
| SI 39        | 2.96    | 2.65      | 3.06    | 2.65      |
| SI 39        | 2.99    | 2.62      | 3.00    | 2.62      |

| TOWNHALL     |         |           |         |           |
| SI 58        | 3.60    | 2.72      | 2.79    | 2.91      |
| SI 53        | 3.72    | 3.05      | 3.07    | 3.04      |
| SI 53        | 3.71    | 3.06      | 3.08    | 3.05      |
| SI 53        | 3.69    | 3.04      | 3.06    | 3.03      |
| SI 53        | 3.66    | 3.03      | 3.03    | 3.00      |
| SI 53        | 3.63    | 2.99      | 3.00    | 2.96      |

| TOWNLINE LAKE|         |           |         |           |
| SI 58        | 2.91    | 2.46      | 2.91    | 2.66      |
| SI 53        | 3.04    | 2.66      | 3.07    | 2.72      |
| SI 53        | 3.07    | 2.68      | 3.05    | 2.73      |
| SI 53        | 3.03    | 2.71      | 3.06    | 2.71      |
| SI 53        | 3.00    | 2.68      | 3.08    | 2.70      |
| SI 53        | 2.96    | 2.65      | 3.06    | 2.65      |
| SI 53        | 2.99    | 2.62      | 3.00    | 2.62      |

harvested at least 30 years earlier than the planned rotation of 120 years. And early aldrin treatments for white grubs could reduce the rotation age by 10 years. For untreated areas the maximum IRR's ranged from 1.44% at Raco to 3.08% at Townhall. Aldrin treatments raised the IRR's to 2.08% at Raco to 3.73% at Townhall. These rotation ages and IRR percentages, except for the Raco area, compare favorably with the five-year projections presented by Fowler and Wilson (1975).
CONCLUSION

White grubs affect pine plantations in at least two ways; they kill some trees and reduce the vigor and subsequent growth of others. Provided the number of living trees is not reduced below the level required for relatively full utilization of the site (perhaps as few as 200 to 300 trees per acre), the effect of mortality alone is small on timber yields and financial returns in red pine plantations. White grubs, in reducing the vigor and hence the height growth of red pine trees, lower the apparent site quality and substantially affect yields and financial returns.

Based on the projections presented here and an assumption that the relationships will continue to rotation age, greater product volumes, financial returns, and higher interest rates on the investment will be gained by preventing the grubs from destroying part of the root system and decreasing tree growth.

LITERATURE CITED


----. 1974. Injury to aldrin-treated and untreated red pine by white grubs (Coleoptera: Scarabaeidae) and other agents during first five years after planting. Great Lakes Entomol. 7:81-88.


THE DISTRIBUTION OF XYLOSANDRUS GERMANUS IN AMERICA NORTH OF MEXICO (COLEOPTERA: SCOLYTIDAE)¹

B. C. Weber² and J. E. McPherson³

Xylosandrus germanus (Blandford) (= Xyleborus germanus), a sexually dimorphic beetle, was first described in 1894 from specimens collected in Japan; it is now also known from Korea, the Kuril Islands, Vietnam, China, Taiwan, central Europe, and the U.S. (Nobuchi 1981). It was first discovered in the U.S. in a greenhouse on Long Island, New York (Felt 1932). Since then, this beetle has been occasionally reported from the eastern half of the U.S. (e.g., Bright 1968) but, as yet, has not been reported from Canada. It appears to be increasing in economic importance in the U.S. (Weber 1982) and has already damaged young plantation black walnut (Juglans nigra L.) in Indiana (Anonymous 1979) and tulip poplar (Liriodendron tulipifera L.) in Ohio (Anderson and Hoillard 1978). Because its reported distribution in North America is based upon scattered records, and because of its potential pest status, we have updated the distribution of X. germanus in America north of Mexico.

METHODS AND MATERIALS

The distribution of X. germanus was determined by examining literature reports; by examining and extracting label information from about 300 specimens in collections at the Illinois Natural History Survey (17 specimens), the National Museum of Natural History (9), North Carolina State University (25), the Northeastern Forest Experiment Station (30), Ohio State University (54), Purdue University (70), Southern Illinois University at Carbondale (2), University of Georgia (17), University of Minnesota (72), and University of Missouri (8); by field-collecting about 600 specimens in North Carolina, Ohio, Tennessee, Indiana, and Illinois; and by examining three specimens sent from South Carolina and Kentucky by state protection personnel.

RESULTS AND DISCUSSION

X. germanus ranges from Connecticut and New York south to Georgia, and west to Missouri and Louisiana (Fig. 1). Specific localities are given in Table 1.

Two specimens in the collection of the National Museum of Natural History were collected at ports of entry, one in Baltimore, Maryland, and the other in Portland (Maine?—state not given on label), in dunnage boards and on wooden crates, respectively, that originated from Japan. Another specimen was collected in Oakland, California, in timber imported from Japan (Nobuchi, pers. comm.). Because no further specimens have been reported from Maryland, Maine, or California, the species has apparently not become established in these states and, thus, these records are not included in Figure 1 or Table 1.

X. germanus has not been reported, to date, from Florida, Alabama, Mississippi, Arkansas, Iowa, Minnesota, Wisconsin, or southeastern Ontario in Canada, but, based on its presently known distribution (Fig. 1), it probably occurs in these areas as well.

¹Part of a dissertation submitted to Southern Illinois University by the senior author in partial fulfillment of the requirements of the Ph.D. degree in Zoology.
²North Central Forest Experiment Station, Forestry Sciences Laboratory, Southern Illinois University, Carbondale, IL 62901.
³Department of Zoology, Southern Illinois University, Carbondale, IL 62901.

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Table 1. Distribution records of *X. germanus* in America north of Mexico.

<table>
<thead>
<tr>
<th>Location</th>
<th>Records</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONNECTICUT</td>
<td>New Haven Co., Bright 1968</td>
</tr>
<tr>
<td>GEORGIA</td>
<td>Clark, Macon Co., Weber 1982</td>
</tr>
<tr>
<td>MICHIGAN</td>
<td>Washenaw Co., Kirkendall (in litt.).</td>
</tr>
</tbody>
</table>

ACKNOWLEDGEMENTS

We thank Dr. S. W. Wilson, California State University, Chico, for obtaining collection records for *X. germanus* from the National Museum of Natural History, and the following individuals for allowing us to examine the scolytid collections at their respective institutions: Drs. G. W. Byers, University of Kansas, Lawrence; E. Cook, University of Minnesota, St. Paul; M. Deyrup, Purdue University, West Lafayette, Indiana; M. Kosztarab, Virginia Polytechnic Institute and State University, Blacksburg; J. C. Morse, Clemson University, Clemson, South Carolina; J. Peacock, Northeastern Forest Experiment Station, Delaware, Ohio; A. Provonsa, Purdue University, West Lafayette, Indiana; C. Smith, University of Georgia, Athens; and C. A. Triplehorn, Ohio State University, Columbus. Scolytid collections were also examined at Auburn University, Auburn, Alabama; Illinois Natural History Survey, Champaign; Michigan State University. East Lansing; Mississippi State University, Mississippi State; North Carolina State University, Raleigh; and the University of Wisconsin, Madison. We also thank Drs. L. Kirkendall, University of Michigan, Ann Arbor, for providing distribution records from Michigan, and A. Nobuchi, Forestry and Forest Products Research Institute, Ibaraki, Japan, for providing information about the specimens collected in California. We appreciate the identifications of scolytids by Drs. S. L. Wood, Brigham Young University, Provo, Utah, and D. E. Bright, Biosystematics Research Institute, Ottawa, Canada.
Fig. 1. Distribution of *X. germanus* in America north of Mexico.

LITERATURE CITED


Hoffmann, C. H. 1941. Biological observations on *Xylosandrus germanus* (Bldfd.). *J. Econ. Entomol.* 34:38-42.


Xylosandrus germanus (Blandford) (= Xyleborus germanus) is an ambrosia beetle that is found in Japan, Korea, the Kuril Islands, Vietnam, China, Taiwan, central Europe, and the United States (Nobuchi 1981). It attacks apparently healthy plants and those that are dying or recently dead (Weber 1982). Kaneko (1967) reported X. germanus to be a serious pest on tea (Thea sp.) plants in Japan, and Heidenreich (1960) reported it on oak (Quercus sp.) trees in Germany. This beetle seems to be increasing in economic importance on black walnut (Juglans nigra L.) and other hardwood species in the U.S. (Weber 1982).

During a study by the senior author on the biology of X. germanus, we found little published biological information from research on this beetle in the U.S.; most studies had been conducted in foreign countries. We also found that in most of the literature, it was not possible to tell from the titles that the publications contained information about X. germanus. Therefore, to help other researchers who may be interested in X. germanus, we have compiled an annotated bibliography of the world literature on this beetle. The bibliography, current through January 1982, includes all articles that are listed in the Zoological Record and the Bibliography of Agriculture and several that are not included in those abstracting publications. We were not able to obtain copies of about 30 articles listed by Nobuchi (1981); most of these were published in Japan between 1938 and 1965.

Anderson, D. M. 1974. First record of Xyleborus semiopacus in the United States (Coleoptera, Scolytidae). Coop. Econ. Insect Rep. 24:863–864. X. germanus was included in a listing of other Xyleborine ambrosia beetles that have been introduced into the U.S.

Anderson, R. L. and W. H. Hoffard. 1978. Fusarium canker-ambrosia beetle complex on tulip poplar in Ohio. Plant Dis. Rep. 62:751. A 6-year-old tulip poplar plantation was attacked in spring 1978 by X. germanus and Xyleborus savi ambrosia beetles. Cankers caused by Fusarium solani were associated with dieback in the beetle-attacked trees. About 36% of the trees in the 5-acre plantation were affected. Affected trees averaged about 2 inches in diameter.

Anonymous. 1972. A list of plant diseases, insect pests, and weeds in Korea. Korean Soc. Plant Prot. 424 p. X. germanus was included in the insect fauna of Korea and was called the smaller alnus bark beetle. Host plants were also listed.

Anonymous. 1979. Summary of forest pests for 1979. Indiana For. Pest Informer, February. 25 p. Three black walnut plantations in Dubois, Green, and Washington counties, Indiana, were damaged by X. germanus and Fusarium cankers (dates of attack not given). Sanitation of affected trees was the recommended control procedure.

Baker, W. L. 1972. Eastern forest insects. USDA For. Serv. Misc. Publ. No. 1175:1–642. X. germanus was reported from stumps and logs of elm and other hardwoods in New York City and the Ohio River Valley and noted as capable of transmitting Dutch elm disease.

were included.

Kansas Acad. Sci. 66:213-236. The term "mycangia" was coined to describe sac-like
structures for carrying the ambrosial fungi of scolytids. Although the ambrosial fungi of
some ambrosia beetles were described and discussed, the ambrosial fungus of *X. germanus*
was unnamed. *Ceratocystis ulmi* (Buisman) was associated with *X. germanus*
adults collected from American elm in Pennsylvania.

Batra, L. R. 1967. Ambrosia fungi: a taxonomic revision and nutritional studies of some
species. Mycologia 59:976-1017. The ambrosial fungus of *X. germanus* in Germany and in
Japan was named as *Ambrosiella hartigii* Batra and described.

*germanus* Blandford, was named and the female described. It was listed as common
Japan.

Pflanzenarzt 11(3):41. *X. germanus* was given the status of a quarantined pest in Switzer­
land to prevent its introduction into that country from Germany.

Bright, D. E. 1968. Review of the tribe Xyleborini in America north of Mexico (Coleoptera:
Scolytidae). Canadian Entomol. 100:1288-1323. Keys to species of *Xyllosandrus* (includ­
ing *X. germanus*) and *Xyleborus* ambrosia beetles were provided. A brief review of the
literature and distribution maps were included.

dam) 23:53-59. *X. germanus* was included in a list of the known species in the genus
*Xyllosandrus* and was (incorrectly) stated to be the type of the genus.

Buchanan, W. D. 1940. Ambrosia beetle *Xyllosandrus germanus* transmits Dutch elm
disease under controlled conditions. J. Econ. Entomol. 33:819-820. *Ceratostomella (=*
*Ceratocystis*) *ulmi* Buisman was isolated from 0.24% of all *X. germanus* adults collected
from elm trees. In a laboratory experiment, adults transmitted *C. ulmi* to five out of six
caged elm trees.

NY. 759 p. *X. germanus* was listed as a possible but unimportant vector of Dutch elm
disease.

Coop. Assoc., Corvallis, OR. 513 p. *X. germanus* was included as a species recently
introduced into North America.

Collins, C. W. 1941. Studies of elm insects associated with Dutch elm disease fungus. J.
Econ. Entomol. 34:369-372. Studies on Dutch elm disease and its vectors, including
*X. germanus*, were reviewed.

Distribution of *X. germanus* was given as Connecticut, New York, New Jersey, and Ohio.
Beetles reportedly attacked branches, peeled and unpeeled logs, and stumps of elm trees.

Deyrup, M. 1978. Impact of bark and ambrosia beetles (Scolytidae) on Indiana hardwoods.
germanus* was reported as one of the most serious scolytid pests of Indiana hardwoods. It
was found to be abundant in live black walnut and *Rhododendron* sp.

germanus* was listed as injurious to mulberry.

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was found to be abundant in live black walnut and *Rhododendron* sp.

Coop. Assoc., Corvallis, OR. 513 p. *X. germanus* was included as a species recently
introduced into North America.
1979 and was the most frequently collected ambrosia beetle species. Several new host plants were reported.


Felt. E. P. 1932. A new pest in greenhouse grown grape stems. J. Econ. Entomol. 25:418. The occurrence of X. germanus in the U.S. was reported for the first time. The beetle was found in a greenhouse on Long Island, New York.

Felt. E. P. and W. S. Bromley. 1937. A new ambrosia beetle, Xyloborus germanus Blandf., in America. Bartlett Tree Res. Lab. Bull. 2:20. X. germanus was collected in January 1932 from grape stems with diameters of 3.7 to 5.0 cm. Hundreds of beetles were reared from stem sections that had a total length of about 1 m. The infested grape stems were apparently not severely damaged nor were the vines seriously injured.

Francke-Groschmann, H. 1956. Hautdriisen als Trager der Pilzsymbiose bei Ambrosiakiifern. Z. Morphol. Ökol. Tiere 45:275-308. The spore storage organs (mycangia) of X. germanus were described for the first time and noted to be in the intersegmental membrane between the pro- and mesonota.

Francke-Groschmann. H. 1963. Some new aspects in forest entomology. Annu. Rev. Entomol. 8:415-438. The mycangia of X. germanus were again described. The ambrosial fungus of X. germanus (unnamed) was isolated from the mycangia. It was reported as closely related to Trichosporium ferrugineum Mathiesen-Käärik, the ambrosial fungus of Trypodendron spp. ambrosia beetles, and was living in symbiosis with Monilia candida Hartig.


Gauss. R. 1960. Ist Xylosandrlls germanus Blandf. ein Primärschädling? Anz. Schädlingskd. 33:129-172. The presence of X. germanus in Germany on Acer pseudoplatanus L. was associated with Fusarium and Phomopsis fungi. Only one generation of beetles per year was observed. Gallery characteristics and other aspects of the biology of X. germanus were compared to those of X. dispar (Fabricius). A wasp, Tetrastichus sp., and a mite, Histiogaster hylocoeti Koch, were found in galleries but their relationships to X. germanus were not known. No other parasites were found.

Groschke. F. 1952. Der "Schwarze Nutzholzborkenkäfer" Xylosandrlls germanus Blandf., ein neuer Schädling in Deutschland. Z. Angew. Entomol. 34:297-302. The occurrence of X. germanus in Germany was reported for the first time. The known literature up to that time was reviewed.

Groschke. F. 1953. Der "Schwarze Nutzholzborkenkäfer," eine neue Gefahr für Forstwirtschaft. Obst- und Weinbau. Anz. Schädlingskd. 26:81-84. X. germanus attacked weakened trees in forests and was considered a secondary pest. In fruit orchards and vineyards, however, it was considered an agricultural pest of some importance.

Heidenreich. E. 1960. Primärbefall durch Xylosandrlls germanus an Jungeichen. Anz. Schädlingskd. 33:5-10. In 1959, 7-year-old red oak trees were attacked, with 10-30 borer holes per tree up to a height of 2.5 m. Dissected galleries yielded 12-20 offspring per female. Two generations per year were reported; the first generation caused the most damage. The first attack period occurred about mid-May, and a second attack period occurred about mid-June. Females were considered to be poor fliers and strongly temperature-dependent. X. germanus was determined to be a primary pest on young oak trees.


Heidenreich. E. 1964. Ökologische Bedingungen für Primärbefall durch Xylosandrlls germanus. Z. Angew. Entomol. 54:131-140. In 1961, young red oak trees were again attacked, particularly late-leafing trees. X. germanus preferred moist, shaded stumps and logs as the
best sites to grow its ambrosial fungus. Females reportedly were able to fly as far as 300 m to find new hosts.


Hoffmann, C. H. 1941. Biological observations on Xylosandrus germanus (Bldfd.). J. Econ. Entomol. 34:38-42. Distribution of X. germanus was given as New York, New Jersey, West Virginia, and Ohio; hosts included oak, elm, red maple, beech, hickory, and poison ivy. Two instances of attack in apparently healthy trees were noted. Gallery structure was briefly described. Two, or three, generations were reported in New Jersey; the beetles first attacked trees in early May. All stages of development were present from June to September. Various other aspects, including moisture content of host plants and associate insects, were also discussed.

Inouye, M. 1955. Wichtige, in Hokkaido (Japan) durch schädliche Forstinsekten verursachte Probleme. Anz. Schadlingskd. 28:161-162. X. germanus was found in Todo fir in Hokkaido, Japan, after a severe ice storm on 10 May 1954.

Jones, T. H. and C. S. Moses. 1943. Isolation of Ceratostomella from insects attracted to felled elm trees. J. Agric. Res. 66:77-85. Ceratostomella (= Ceratocystis) ulmi Buisman was isolated from 0.2% of X. germanus beetles collected from elm.


1953. Neues über den eingeschleppten "Schwarzen Nutzholzborkenkäfer." Holz-Zentralbl. 79:1194. Attack patterns on birch, beech, and spruce in Germany were described. Under certain conditions, X. germanus was reported capable of becoming a serious pest because it introduced fungi into a tree at the time of attack. Girdling of a tree was possible if the attack was strong enough. Control recommendations included the removal of fallen trees before 1 April.


1954. Nutzholzsädlinge an Eiche und ihre Bekämpfung. Merck Bl. 4:1-14. X. germanus was included in a list of important pests of oak; signs of attack and other host plants were also listed. It was ranked the third most frequent pest of oaks in 1953. Mechanical and chemical controls were discussed.

1958. Kleine Mitteilungen Nummer 1610 Scolytidae. Entomol. Bl. Biol. Syst. Käfer 54:64. X. germanus was reported as one of four species of scolytids that attack both deciduous and coniferous trees in Germany.

1963. Kleine Mitteilungen Nummer 1748 Xylosandrus germanus. Entomol. Bl. Biol. Syst. Käfer 59:125. X. germanus was reported to overwinter in its brood galleries. Females became active soon after they were brought inside on 17 February 1963, after a very cold winter.

1965. Ein Beitrag zur südbadischen Käferfauna. Mitt. Bad. Landesver. Naturk. Naturschutz 8:565-568. Bark and ambrosia beetles of southern Germany were briefly reviewed. X. germanus was reported to be occasionally abundant because of the mild climate.

1966. Ein weiterer Beitrag zur südbadischen Käferfauna. Mitt. Bad. Landesver. Naturk. Naturschutz 9:329-334. Larvae of X. germanus were collected in Germany in a dying cherry tree on 28 July 1966; the species was also collected from beech, oak, and fir trees from altitudes up to 600 m.


Decheniana 20:22-28. X. germanus was reported on both deciduous and coniferous trees in Germany.

Kaneko, T. 1965. Biology of some scolytid ambrosia beetles attacking tea plants. I. Growth and development of two species of scolytid beetles reared on sterilized tea plants. Japanese J. Appl. Entomol. Zool. 9:211-216. X. germanus and X. compactus (Eichhoff) were reared on tea plants in the laboratory. X. germanus preferred roots about 15-20 mm in diameter. Development time was a minimum of 15 days at 20°C. Adult sex ratios were 9:1 (♀:♂) in the first generation and 8:1 in the second. The numbers of eggs per adult female ranged from 33-50. Other aspects of the biology were also discussed.

Kaneko, T. 1967. Shot hole borer of tea plant in Japan. Japanese Agric. Res. Quart. 2:19-21. X. germanus was noted as a serious pest of tea in Japan, attacking roots 0-50 cm below ground. Other hosts were Morus alba L., Castanea crenata Siebold & Zuccarini, and Diospyros kaki Thunberg. X. germanus was reported to have two generations/year and to overwinter in roots. Drenching tea plants in cyclodiene insecticides to control X. germanus proved unsuccessful. The hypothesis was advanced that X. germanus adults pick up their ambrosial fungus by everting their mycangia and scraping the sides of the galleries.

Kaneko, T. and K. Takagi. 1965. Biology of some scolytid ambrosia beetles attacking tea plants. IV. Parthenogenesis of Xyleborus germanus Blan. in relation to the germanus ambrosia fungus. Japanese J. Appl. Entomol. Zool. 9:303-304. X. germanus was reported as haplo-diploid: unmated females produced only male progeny in laboratory cultures. The sex ratio was 10 females: 1 male.


1931. Revision des familles des Ipides et Platypides (Coleopteres) de L’Ile de Quelpart. Annot. Zool. Japonenses 13:39-61. X. germanus was collected from the three host plant species in Korea listed above (Murayama 1930). Scolytid associates were also listed.


1936. Notes sur les Scolytides (Coleopteres) de Honshu et Kiushu, Japan. Tenthredo 1:121-149. Collection dates, host plants, and distribution records for X. germanus in Japan were summarized.

1939. X. germanus was collected from the three host plant species in Korea listed above (Murayama 1930). Scolytid associates were also listed.


1936. Notes sur les Scolytides (Coleopteres) de Honshu et Kiushu, Japan. Tenthredo 1:121-149. Collection dates, host plants, and distribution records for X. germanus in Japan were summarized.


Niisima, Y. 1909. Scolytiden Hokkaidos unter Berücksichtigung ihrer Bedeutung für Forstschäden. J. Coll. Agric., Tohoku Imperial Univ. (Sapporo, Japan) 3:109-179. X. germanus was collected in Sapporo (northern) and central Japan.


---. 1913. Neue Borkenkaefer nebst Frasspflanzen. Trans. Sapporo Natur. Hist. Soc. 5:1-16. Several specimens of X. germanus were collected from dead alder stems in fall 1911. More specimens were collected from tea plants in summer 1913.

Nobuchi, A. 1966. Bark beetles injurious to pine in Japan. Gov. For. Exp. Sta. Bull. 185:1-50. X. germanus was collected from two species of pine, and was included in a key to all scolytids injurious to pine, in Japan. All other host plants were also listed.

---. 1967. Formosan Scolytoidae (Coleoptera). Gov. For. Exp. Sta. Bull. 207:11-30. X. germanus was included in a list of scolytids collected in Formosa (Taiwan) and had been intercepted from logs imported from Formosa into Japan.

---. 1969. A comparative morphological study of the proventriculus in the adult of the superfamily Scolytoidae (Coleoptera). Gov. For. Exp. Sta. Bull. 224:39-110. The proventriculi of 100 genera of scolytids, including that of X. germanus, were described and illustrated. Possible phylogenetic relationships among the genera were also discussed.

---. 1972. The biology of Japanese Scolytidae and Platypodidae. Rev. Plant Prot. Res. 5:61-75. X. germanus was noted as a pest of actual or potential importance on conifer and broadleaf trees in Japan. It was reported to attack standing green trees and to breed for generations in living wood. Canker-causing and wood-rotting fungi were introduced by the beetles into their host trees. No parasites of X. germanus were recorded.


---. 1979. Studies on Scolytidae XVI. Bark and ambrosia beetles collected by Dr. Kintaro Baba (Coleoptera: Scolytidae and Platypodidae). J. Japanese Entomol. Soc. 50:115-121. X. germanus was commonly collected in hardwood and coniferous tree species. Collecting dates and locations were given.


Norris, D. M. 1979. The mutualistic fungi of Xyleborini beetles. p. 53-63 in L. R. Batra (ed.). Insect-fungus symbiosis. Allanheld, Osmun Publishing Co., Montclair, NJ. Fusarium solani (Martius) and other Fusarium species were given as the dominant fungal symbiotes of X. germanus. Ceratocystis ulmi (Buisman) was also listed as an ambrosial fungus of X. germanus.

Schneider, I. 1975. Untersuchungen über die biologische Bedeutung der Mycetangien bei einigen Ambrosiakäfern. Mater. Org. (Berlin) 3:489-497. *X. germanus* was noted to overwinter in wood but not to diapause.

Schneider, I. and M. H. Farrier. 1969. New hosts, distribution, and biological notes on an imported ambrosia beetle, *Xylosandrus germanus* (Coleoptera: Scolytidae). Canadian Entomol. 101:412-415. *X. germanus* was reported from *Nyssa aquatica* L., *Taxodium distichum* (L.), and *Prunus serotina* Ehrhart in North Carolina. The hosts and the state were new records. The U.S. literature was reviewed briefly.

Takagi, K. and T. Kaneko. 1965. Biological observation on the scolytid tea root borer (*Xyleborus germanus* Blanford [sic]) and tea stem borer (*Xyleborus compactus* Eichhoff)—some notes on their ambrosia fungi. Japanese Tea Res. Sta. Stud. Tea 31:54-58. The mycangium of an adult *X. germanus* was pictured in cross-section. Also shown were the fungus mat inside the mycangia and the 2-3 celled ambrosial fungus.

------. 1965. Biology of some scolytid ambrosia beetles attacking tea plants. II. Spore storage organ of tea root borer, *Xyleborus germanus* Blanford (sic). Japanese J. Appl. Entomol. Zool. 9:247-248. The mycangia were pictured and described. Ambrosial spores inside the mycangia were described as globular in shape and 11–12 μ in diameter. Spores cultivated from galleries were also globular but 15–18 μ in diameter.

------. 1965. Biology of some scolytid ambrosia beetles attacking tea plants. III. Sporulation of *Xyleborus germanus* ambrosia fungus. Japanese J. Appl. Entomol. Zool. 9:298–300. The ambrosial fungus of *X. germanus* was unnamed but described as living parasitically on plants and causing root rot of tea plants. The fungus had three growth types: mycelial type A (in plants), and type B (in the mycangium).


Ueno, H. On the bionomics and control of the wood boring beetles (Ipidae, Coleoptera) attacking persimmons in Japan. Japanese J. Appl. Entomol. Zool. 4:166–172. *X. germanus* was the most common of eight wood boring pest species of persimmon in Japan from 1958 to 1960. Most attacked trees wilted and died. Stems and branches were attacked in late April or early May.

------. 1962. On the bionomics and control of the wood boring beetles (Ipidae, Coleoptera) attacking persimmons in Japan. (Abstr.) Rev. Appl. Entomol. 50:450. This is the abstract of the previous paper that reported *X. germanus* as a pest of persimmon trees in Japan.

USDA. 1968. A scolytid beetle (*Xylosandrus germanus*)—Missouri. Coop. Econ. Insect Rep. 18:821. *X. germanus* adults were collected from the roots of dogwood nursery stock on 12 June 1968 in Cape Girardeau County; this report was a new state and a new host record.


------. 1972. A scolytid beetle (*Xylosandrus germanus*)—Virginia. Coop. Econ. Insect Rep. 22:640. *X. germanus* adults were collected from a redbud limb on 6 June 1971 in Pittsylvania County; this report was a new state and a new host record.


------. 1978. A scolytid beetle (*Xylosandrus germanus*)—Louisiana. Coop. Plant Pest Rep. 3:350. *X. germanus* adults were collected from a small pecan tree on 10 May 1978 in Pointe Coupee Parish; this report was a new state and a new host record.


1978. Protection committee report. Walnut Council News. 5(3):3. X. germanus was included in a brief discussion of insect problems on black walnut in 1978. Three Indiana plantations, ranging in age from 4–8 years and consisting of trees ranging in height from 0.9 to 7.6 m, were attacked in spring 1978.

1978. Xylosandrus germanus (Blandford) (Coleoptera: Scolytidae), a new pest of black walnut. (Abstr.) 23rd Southern For. Insect Work Conf., Minutes, p. 35. X. germanus was reported from 11 states and 18 genera of host plants in the U.S. It was associated with Fusarium canker dieback in young black walnut trees.

1979. Xylosandrus germanus (Blandford) (Coleoptera: Scolytidae), a new pest of black walnut: a review of its distribution, host plants, and environmental conditions of attack. p. 63–68 in Walnut insects and diseases. USDA. For. Servo Gen. Tech. Rep. NC-52. The world literature on X. germanus was reviewed, including host plants throughout the world. The potential impact to black walnut was discussed.

1980. Xylosandrus germanus (Blandford) (Coleoptera: Scolytidae): an ambrosia beetle pest of young hardwood plantations in the United States. (Abstr.) XVI Internat. Congr. Entomol. Abstracts, Kyoto, Japan, p. 301. X. germanus was reported from 22 genera of host plants and found throughout most of the eastern U.S. Tulip poplar and black walnut plantations, ranging in age from 1 to 7 years, were attacked by a Fusarium canker/X. germanus complex that caused top dieback, cankers; and basal sprouting. Impact included death of trees, loss of growth, and increased time spent in plantation management.

1981. Ambrosia beetles in your black walnut plantation—how serious are they? N. Nut Grow. Assoc. Ann. Rept. 72:68–74. The biology of X. germanus on black walnut was briefly summarized. Signs and symptoms of attack were given as pinholes, basal sprouts, wilted leaves, and top dieback. Although tree survival was little affected by X. germanus attacks on black walnut, growth losses were reported as potentially serious depending on the age of the trees when attacked and the management goals of the plantation. Some management and silvicultural control recommendations were included.

1982. The biology of the ambrosia beetle Xylosandrus germanus (Blandford) (Coleoptera: Scolytidae) and its effects on black walnut. Ph.D. thesis, Southern Illinois Univ., Carbondale. 222 p. Information on the life history of X. germanus in North Carolina and Illinois, particularly as associated with black walnut (Juglans nigra L.), was presented and included flight activity, gallery patterns, life cycle, predators, parasites and other associates, geographic distribution, host plants, laboratory rearing, behavior, and ambrosial and other fungi. Descriptions of the egg and larval instars were included. Particular emphasis was placed on the relation between X. germanus attack and disease symptoms in black walnut trees, on differences in susceptibility of trees to attack and dieback, and on the ability of trees to recover from attack.


Weise, E. 1963. Xylosandrus germanus Blandf. Entomol. Bl. Biol. Syst. Käfer 59:125. X. germanus was observed on 11 October 1962 near Freiburg, Germany, in fir and copper beech stands. When overwintering adult females were brought inside on 17 February 1963, they immediately became active.

Wichmann, H. E. 1955. Im Europäischen Grosraum eingeschleppte Borkenkafer. Z. Angew. Entomol. 37:92–109. X. germanus was felt to have originated in the Far East in Japan, China, Korea, and Formosa. The paper includes a list of the known host plant genera.

1955. Zur derzeitigen Verbreitung des Japanischen Nutzholzborkenkäfers Xylosandrus germanus Blandf. im Bundesgebiete. Z. Angew. Entomol. 37:250–258. At least 12 species of trees in Germany were reported as hosts of X. germanus.

1957. Einschleppungsgeschichte und Verbreitung des Xylosandrus germanus Blandf. in Westdeutschland (nebst einem Anhang: Xyleborus adunbratus Blandf.) Z.
Angew. Entomol. 40:82–99. *X. germanus* was reported from 34 new localities in Germany, mainly near Karlsruhe and Heilbronn, and was believed to have only a moderate capacity for dispersal and one generation per year. *X. germanus* was felt to be of no economic importance.

Wood, S. L. 1977. Introduced and exported American Scolytidae (Coleoptera). Great Basin Natur. 37:67–74. *X. germanus* was included in a list of scolytids introduced into the U.S., and reported as breeding in branches and stumps of a wide variety of hosts. It was said to be of possible local economic concern.

ADULT FEMALE SPRUCE BUDWORM, CHORISTONEURA FUMIFERANA (LEPIDOPTERA: TORTRICIDAE), DRY WEIGHT IN RELATIONSHIP TO PUPAL FRESH WEIGHT AND CASE DIAMETER

W. J. Mattson, C. N. Koller, and S. S. Slocum

The weights of adult insects are often measured in production and population studies in order to estimate such variables as growth rates, food conversion efficiencies, fecundity, and others. For the eastern spruce budworm, *Choristoneura fumiferana* (Clemens), both pupal fresh weights and pupal case diameters have been measured as indicators of adult fecundity and adult dry weights (Miller 1957). However, there are no reports explicitly showing the relationship between these metric pupal variables and adult dry weights. This is the goal of this note.

METHODS

Budworm pupae and adults for this study were derived from two sources: (1) second instar, lab stock larvae from the Great Lakes Forest Research Centre in St. Ste. Marie, Ontario, which were reared on a variety of natural hosts in Minnesota (eg. *Picea glauca* (Moench) Voss, *Picea mariana* (Mill.) B.S.P., and *Abies balsamea* (L.) Mill.) and artificial diet, and (2) wild, late stage larvae collected from *A. balsamea*, and *P. glauca* in New Hampshire and then reared to pupation on artificial diet. Pupae were weighed fresh within 24 h after pupation. Adults, likewise, were collected within 24 h after emergence and then frozen in preparation for freeze drying to constant weight. Diameter (*D*₁) and height (*H*) of the first abdominal segment immediately below the wing pads were measured on the dorsal side of the empty pupal case. We also measured the diameter (*D*₂) of this segment from the lateral perspective as did Miller (1957).

RESULTS

Adult female dry weight (FWT) was clearly a linear function of fresh pupal weight (PPWT) (Fig. 1):

- **Lab stock:** FWT<sub>mg</sub> = -0.915 + 0.244 PPWT<sub>mg</sub> \( r^2 = .99 \), \( n = 129 \), Sx.y = 1.234
- **Eastern wild:** FWT<sub>mg</sub> = -7.009 + 0.293 PPWT<sub>mg</sub> \( r^2 = .88 \), \( n = 101 \), Sx.y = 2.423

However, the two regressions have significantly different intercepts as well as slopes. Examination of Figure 1 shows that this difference results from the fact that the small (< 75 mg) eastern wild pupae produced smaller adults than similarly small lab stock pupae. However, at higher pupal weights (> 75 mg) both groups yielded adults of about the same size. Without more data it is impossible to explain the source of the apparent differences. It is possible, however, that different budworm populations may differ in their adult-pupal weight ratios, and that a universal equation relating these two variables may not exist.

Adult female dry weight (FWT) was clearly a nonlinear function of pupal case diameter (*D*₁) (Fig. 2). This is not unexpected because dimensional analysis suggests that weight or volume of an object ought to be proportional to the cube of one of its linear dimensions.

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1 USDA Forest Service, North Central Forest Experiment Station, 1992 Folwell Ave., St. Paul, MN 55108.

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Lab Stock: \[ \text{Ln}(\text{FWT}) = -0.9275 + 2.6747 \text{Ln} (\text{D}_1)_{\text{mm}} \] \[ r^2 = .95, \ n = 316, \ \text{S}x.y = 0.099 \]

The regression coefficient (2.67) for the transformed variables (natural logs) is remarkably close to the coefficient (2.62) of the nonspecific or generalized weight (W)-length (L) regression for insects that was developed by Rogers et al. (1976): \[ W = k L^{2.62} \] Neither \( D_2 \) nor \( H \), either singly or in combination with one another or with \( D_1 \) were significantly better in explaining variation in FWT than \( D_1 \) alone. We did not save the pupal cases from the eastern wild stock collection.

We offer the results from this study for use in converting existing measures of pupal fresh weight and case diameters to adult dry weights. Since there may not be a single equation applicable to all populations of the eastern spruce budworm for converting pupal metric variables into adult weights, we offer our results as a benchmark and a stimulus for wider testing of these relationships in different parts of the budworm range.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the technical assistance provided by Ms. Anita Foss and Messrs G. W. Erickson, and T. J. Van't Hof. We also thank Dr. N. Lorimer and Ms. L.
Fig. 2. Adult female spruce budworm dry weight (mg) plotted against dorsal diameter (mm) of the cast pupal case.

Bauer for the eastern wild budworm, and the Great Lakes Forest Research Centre for the lab stock budworm. This research was supported in part by the CANUSA-East Spruce Budworm Program, USDA Forest Service, 870 Reed Road, Broomall, PA.

LITERATURE CITED


BIOLOGICAL CHARACTERISTICS THAT MAKE THE LESSER PEACHTREE BORER (LEPIDOPTERA: SESIIDAE) A PEST ON PEACH TREES

R. H. Meyer

ABSTRACT

The lesser peachtree borer, Synanthedon pictipes, is a native insect with well distributed hosts near peach orchards, which has high mobility between sylvatic and domestic hosts. It is able to take advantage of the susceptibility of the peach tree to periodic freeze injury and disease cankers. The moth stage is present through most of the growing season and effectively conceals the eggs singly at the most favorable sites for larval success.

The lesser peachtree borer (LPTB), Synanthedon pictipes (Grote & Robinson), is a pest both on single fruit trees in home plantings and in peach and cherry orchards. While most major pests of stone fruits can be controlled by current methods, the LPTB remains expensive to control and shortens the useful life and production of peach and cherry trees. Experiments in applying chemical controls (Meyer 1962, 1965), peach harvest surveys, and direct observation on peach trees have provided a knowledge of LPTB biology. Results of experiments in applying and evaluating new chemicals during 1973 and 1974 were applied to peach insect control recommendations, and their results were observed through 1981. The observed biological characteristics coordinated with those given in the literature describe why the LPTB remains a major pest on peach trees.

LITERATURE REVIEW AND OBSERVATIONS

Being a native insect, the LPTB has enough hosts (Girault 1907) to maintain abundant insect populations (Wong et al. 1971). Sharp et al. (1978) in Florida generally found greater populations in orchards, but the males moved freely between the orchards and nearby wooded areas. Many midwestern orchards are situated near wooded areas, and even though they may be isolated from other orchards, trees soon become infested as they mature. King (1917) noted that LPTB prefers to oviposit on disease cankers, winter injuries, sun scalding, narrow angle and split limb crotches, and mechanical wounds. Smith and Harris (1952) indicated a positive correlation between high tree vigor and dead trees due to winter kill, increased gumming (tree sap exudate), and LPTB injury. Cytospora canker is widely present in Illinois (Gairola and Powell 1970) and is also aided by winter injury in becoming established in young orchards (Luepschen 1976). The canker as well as winter injury provide favorable egg laying sites. When the canker wounds are closed off against further advance by callus tissue (Hildebrand 1947), the larvae in turn aid the canker by boring openings to new wood. This has often been observed by tracing borer tunnels through successive callus layers.

The LPTB, which overwinters as partially grown and mature larvae, probably has as much or greater tolerance of cold temperature as the peach tree. Pupal skins were observed where moths had emerged from limbs on trees killed by severely cold winters. Immature
larvae remain near live bark through the winter and feed when temperature gets high enough to permit activity. After a winter freeze which kills an area of bark around an infested wound, larval tunnels can be found from the pre-freeze feeding areas to the edge of the live bark after the freeze. These tunnels are usually perpendicular to the former live bark edge and proceed straight to the live bark.

Bobb (1959) watched moths seeking egg-laying sites and found that fresh gumming was very attractive to them. Most of the eggs are placed near wounds on roughened bark. Armstrong (1943) placed many eggs on smooth healthy bark during several seasons and found that newly hatched larvae could not survive. Vigorous bark, which is more attractive to egg laying moths than non-vigorous live bark, exudes a very sticky gum soon after wounds are made. The outer bark has a greater propensity for gumming than the inner bark. The larvae prefer the inner bark for food. After finding many young larvae in a variety of situations, it is evident that the larvae must find a location where they can get under the protection of dead bark and be close enough to live bark to feed upon it. First instar larvae have been found trapped in fresh gum. Mature larvae have been found on branches as small as 1 cm in diameter. Usually there is a dead twig, a canker, or a mechanical damage at the center of such wounds, which provided the essentials for successful infestation.

Moths crawl into wounds and probe for cracks with their abdomen to hide the eggs. Eggs were found under bark and deep in cracks often not visible at the surface. Larvae can usually be located by the frass or "sawdust" they produce. The presence of frass in gum usually determines whether LPTB are present in the wound. The size of frass particles also indicates the relative size of the larva. Fresh frass is lighter and brighter in color and darkens with age. The larvae actively push frass out of their tunnels and may crawl all the way out and turn around to go back in when doing so. First instar larvae produce very small particles, and when they feed in cracks in old bark it is often dry and easily blown by wind.

OBSERVATIONS IN 1973 AND 1974

In conjunction with experiments in applying and evaluating new chemicals for LPTB control, seasonal observations were made in three adjacent peach tree blocks of about 20 ha at Belleville, Illinois, during the autumn of 1973 and through 1974. Larvae were excised from entire trees with knives. In 1974, larval instars were recorded in all samples as listed in Table 1. Average instar sizes for second through sixth instar as indicated by Bobb (1959) were carried in an alcohol vial to aid identification in the field. Pupal skins were also counted as described by Yonce et al. (1977) on all trees examined for larvae during the spring season of 1974.

Table 1. The seasonal distribution of larvae instars and pupae of the lesser peachtree borer in peach trees at Belleville, IL, 1974.

<table>
<thead>
<tr>
<th>Sample dates</th>
<th>Pupal skins</th>
<th>Larval instars</th>
<th>Total live insects</th>
</tr>
</thead>
<tbody>
<tr>
<td>22/5</td>
<td>25</td>
<td>6 5 4 3 2 1</td>
<td>70</td>
</tr>
<tr>
<td>3/6</td>
<td>28</td>
<td>9 5 12 9 17 12</td>
<td>42</td>
</tr>
<tr>
<td>18-21/6</td>
<td>25</td>
<td>19 25 25 13 8 3</td>
<td>331</td>
</tr>
<tr>
<td>29/6</td>
<td>22</td>
<td>27 21 26 12 5 1</td>
<td>264</td>
</tr>
<tr>
<td>9/7</td>
<td>13</td>
<td>39 16 26 10 4 1</td>
<td>132</td>
</tr>
<tr>
<td>22/7</td>
<td>5</td>
<td>42 19 21 11 2 0</td>
<td>375</td>
</tr>
<tr>
<td>6-8/8</td>
<td>13</td>
<td>37 22 19 7 1 1</td>
<td>1660</td>
</tr>
<tr>
<td>19-21/8</td>
<td>26</td>
<td>30 26 12 3 2 1</td>
<td>646</td>
</tr>
<tr>
<td>8-10/10</td>
<td>0</td>
<td>37 22 19 15 6 1</td>
<td>336</td>
</tr>
<tr>
<td>23-25/10</td>
<td>0</td>
<td>29 22 24 16 8 1</td>
<td>747</td>
</tr>
<tr>
<td>10/12</td>
<td>0</td>
<td>32 20 24 23 1 0</td>
<td>257</td>
</tr>
</tbody>
</table>

aNumber of pupal skins as percentage of total skins and live insects.
bNumber as percentage of total living pupae and larvae.
Bobb (1961) had commented on the difficulty of finding early instars in making accurate assessments of LPTB populations. On 3 June, an intensive search was made of three average sized mature peach trees for both early instar larvae and eggs. The bark near wounds was cut off and examined under a low power microscope. All cracks and dead tissue that was near live tissue were broken open. All rough bark was examined using magnifying glasses. LPTB populations had reached high levels by autumn of 1973. On unsprayed trees there was an average of 224 larvae per tree with a single tree having 405. The high populations may have attracted predators. In late autumn 47% of the larvae were mature, but by late January woodpeckers had removed two-thirds of them. The remaining third were under heavy bark, gum, or between crotches or other unaccessible places. Only those larvae that had prepared a cell for pupation were dug out by the birds. Almost none in accessible locations were missed by the birds. In the 22 May and 3 June 1974 samples (Table 1), 11.5% of the larvae were dead, filled with hardened fungus growth. Populations of LPTB remained lower in 1974 than in 1973 with untreated trees averaging 20-65 with a single high of 77 on one tree. Bird predation on 10 December 1974 was also lower at 7% and 3% of the larvae were found dead. Little parasitism was observed except in the two August 1974 samples where parasites had emerged from 20 of the 406 pupae found (4.9%).

The distribution of LPTB at the various sampling dates in Table 1 shows the typical two-peak emergence pattern for the latitude (Bobb 1959, Sharp et al. 1978, Yonce et al. 1977). Farther north, there may be only one peak (Wong et al. 1971), but there are always some moths present, and therefore continuous hatch of larvae occurs throughout the season. In coordinating first emergence with the stage of growth of the peach tree (Reis et al. 1976), LPTB moths appear during the time shucks are falling off the young peach fruit. Weather conditions may cause early season development of both plants and insects to vary up to two weeks from an average calendar date. The peak of LPTB moth emergence usually follows in four weeks (Bobb 1966). By the first sampling date of Table 1, the peak of moth emergence was soon to occur, but no young larval stages were found. On 3 June, all young stages were found probably due to more intensive searching. While 29 eggs were found on the three trees which was 41% of all the insects found, the method was considered too time-consuming and harmful to the trees. The intensive search helped to know where to look and what to watch for to find more early instar larvae. On the last sampling date, special care was taken to search for young instars, but no first instar larvae were found. On 30 September 1975, 337 LPTB were excised in trees of this same orchard. A similar pattern of instars were found as in the 8–10 October date of Table 1. One pupa was also found, and a moth was observed laying an egg.

During the last half of 1974, the number of wounds per tree was counted on six peach cultivars (Table 2). The cultivar ‘Redhaven’ is conspicuous in having many more wounds per tree than the other cultivars, yet the trees survive as long as the other cultivars. This is often easily observed in many orchards where ‘Redhaven’ is planted next to other cultivars of the same tree age. The number of LPTB per wound was found to be a good sampling technique as many more trees could be sampled in the same amount of time rather than

<table>
<thead>
<tr>
<th>Peach cultivar</th>
<th>Number examined</th>
<th>Live insects</th>
<th>Wounds ( ^a ) per tree</th>
<th>Borers per</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>Wounds</td>
<td></td>
<td>Tree</td>
</tr>
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<td>Culhaven</td>
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<td>291</td>
<td>310</td>
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<tr>
<td>Blake</td>
<td>11</td>
<td>261</td>
<td>125</td>
<td>23.7</td>
</tr>
<tr>
<td>Redskin</td>
<td>26</td>
<td>619</td>
<td>401</td>
<td>23.8</td>
</tr>
<tr>
<td>Glohaven</td>
<td>30</td>
<td>819</td>
<td>874</td>
<td>27.3</td>
</tr>
<tr>
<td>Cresthaven</td>
<td>30</td>
<td>893</td>
<td>1065</td>
<td>29.8</td>
</tr>
<tr>
<td>Redhaven</td>
<td>32</td>
<td>1573</td>
<td>963</td>
<td>49.2</td>
</tr>
</tbody>
</table>

\( ^a \) Means for all cultivars except ‘Redhaven’ not significantly different (Duncan’s Multiple Range Test, \( P > 0.1 \)).
sampling whole trees. Some fruit growers have found that sampling a few wounds at several
locations in their orchards gives both a larval age structure to know when to expect peak
moth emergence and a continuing check on fluctuation of population levels.

SUMMARY OF PEST CHARACTERISTICS

A range of acceptable native host trees located near most peach orchards or even single
trees, plus the active flying range of the moth and its mobility between native and cultivated
hosts makes infestation possible on most trees. The natural susceptibility of peach trees to
periodic freeze injury coupled with the complementary attack of both Cytospora canker and
LPTB greatly increase the attractiveness of maturing peach trees to LPTB moths for egg
laying sites. Egg placement singly in the most protected locations near gummy wounds
apparently not only reduces the chances of predation and contact from chemical sprays, but
also places the newly hatched larvae in the most favorable situation to remain protected near
food. While moths do crawl about on open surfaces of the tree which makes them suscepti­
ble to chemical sprays, their continuous presence from the time the young peach appears
until well after harvest gives at least some of them the opportunity to penetrate all but the
most persistent protection. The interplay of these characteristics have kept the LPTB a
formidable pest on peach trees.

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Murray Hanna

ABSTRACT

Gypsy moth, *Lymantria dispar*, was first discovered in Michigan in 1954. Aerial spraying operations were conducted to eradicate gypsy moth infestations with synthetic insecticides (DDT, carbaryl, and diflubenzuron).

Riley (1870) documented the first occurrence of gypsy moth (*Lymantria dispar* L.), in North America. Perhaps *L. dispar* has been introduced into North America on more than one occasion, and there may be genetic differences among populations. In New England, where this insect has been established for more than a century, periodic widespread outbreaks result in substantial aesthetic, economic, and material losses. Gerardi and Grimm (1979) extensively reviewed the history, biology, damage, and control of gypsy moth in the United States from introduction until about 1976. Doane and McManus (1981) compiled almost all important recent research toward integrated management of gypsy moth.

The Michigan Department of Agriculture, Plant Industry Division (MDA-PID) is responsible for preventing the establishment and spread of gypsy moth in Michigan. The United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine (USDA-APHIS-PP&Q) endeavors to prevent or retard artificial spread of gypsy moth in the United States and Canada and to eradicate isolated infestations when feasible. A Federal Bee Indemnification Program administered by the USDA, Agricultural Stabilization and Conservation Service (ASCS), which provided for reimbursement to bee owners who sustained bee losses due to Federal-State treatment programs, was terminated about four months after gypsy moth aerial spraying had been completed in 1979. The USDA-APHIS-PP&Q and MDA-PID, under state authority, act together in quarantine and eradication efforts in Michigan.

INTRODUCTION INTO MICHIGAN

How long gypsy moth has occurred in Michigan is not known. Certainly it has been here for 30 years, probably for 40 years, and possibly for 50 years or more. It most likely has been introduced many times. During the summer of 1952, an unidentified individual left an unlabeled jar of larvae at the office of Walter F. Morofsky at Michigan State University in East Lansing. The sample went unnoticed until after the larvae had pupated and adult moths had emerged. Morofsky knew the specimens were gypsy moths, but he was unable to determine where the larvae had been collected. The insect was not reported in Michigan in 1953. Confirmation of a breeding colony of gypsy moths in Ingham County, Michigan, was obtained in 1954 when a resident on Jolly Road in Lansing informed the City Forester on 19 May that unfamiliar caterpillars were crawling on his house, garage, shrubs, and neighboring elm trees. Specimens of the larvae were identified as *L. dispar*.

Regulatory personnel and city employees conducted hurried visual surveys to determine the extent of the infestation while conditions were yet favorable to attempt eradication. Scouting for defoliation and other signs of infestation was done from vehicles along roads in

1Michigan Department of Agriculture, Lansing, MI 48913.
East Lansing and Lansing in Ingham County, and in rural sections of eastern Eaton County. When survey was terminated on 5 June, it was estimated that the gypsy moth infestation extended over an area of 108 square miles encompassing the northwest corner of Ingham County and the adjacent portions of Clinton and Eaton counties.

EARLY ERADICATION EFFORTS

In 1954 Michigan was the westernmost state in which breeding colonies of gypsy moth had been found. A proposal to eradicate gypsy moth by applying synthetic insecticide from the air was promptly funded by the State Legislature and supported by interested residents of the community. Eradication then meant permanent elimination of gypsy moths from the state (it now means the reduction of existing gypsy moth populations in an area of operations to below detectable survey levels for an unspecified time into the future). A multi-engined aircraft was selected for safe operation at low altitude over densely populated areas. Single-engined aircraft, which could be maneuvered to avoid direct application of insecticide to cultivated fields and open water, were used in lightly populated rural areas. Aerial spraying was started on 6 June and completed on 10 June. About 84% of the 69,400 acre eradication plot consisted of favorable gypsy moth habitat. A total of 58,000 pounds of DDT was applied in these three Michigan counties to eradicate gypsy moth in 1954. O'Dell (1955) presented a detailed account of the activity.

In the years 1954–1959, DDT was used with complete confidence. Environmental concerns about misapplication of DDT eventually began to surface, and it should be noted that the insecticide was applied sparingly along the shoreline of Duck Lake in Calhoun County in 1960. By 1962 concern about adverse effects of persistent insecticide on human health and the environment abounded. The 1962 eradication plot in Onondaga Township of Ingham County encompassed a dairy farm. In an effort to avoid accidental contamination of milk, for which no legal tolerance of DDT had been established, carbaryl was used near pastures and forage crops; DDT was used in the usual way elsewhere. Notwithstanding this extra precaution, the farmer in the treatment area obtained a legal judgment against the USDA for loss sustained when milk was condemned due to the DDT contamination. DDT was never used again to eradicate gypsy moth in Michigan.

Gypsy moth pheromone trap survey results for the years 1962–1965 were negative (Hanna 1981). In the spring of 1966, the MDA enthusiastically prepared a publicity folder titled, "Oh Where Oh Where did the Gypsy Moth Go?", to report to the Michigan taxpayer on the successful eradication of an insect pest at a combined State-Federal cost of $946,248. In the summer of 1966, before the folder became widely distributed, a property owner at Duck Lake in Calhoun County reported that gypsy moth caterpillars were feeding on oak and willow trees. The infestation occurred in an eradication plot that had been treated with DDT in 1960. By the time the infestation was reported, it was too late in the season to attempt eradication, but carbaryl was used in spring 1967. This time the risk of not applying enough insecticide was avoided.

RECENT PROGRAMS

More details have been summarized here about the years 1954–1972 because comparable information is far more readily available from state agencies beginning with 1973. The MDA gives notice of plans to eradicate gypsy moth to residents and property owners by personal service, mail, or newspaper publication. Such notice identifies the date of application, insecticide to be applied, and the area to be treated. The MDA and USDA hold public meetings, usually with help from the Michigan Cooperative Extension Service, to explain eradication operations to those directly concerned. Since 1973, the Michigan Environmental Review Board (MERB) has been provided written details of proposed action, probable environmental impact, probable adverse environmental effects, evaluation of alternatives which would avoid adverse environmental effects, and modifications to minimize environmental effects.
State of Michigan Environmental Impact Statements for Gypsy Moth, Gypsy Moth Management Policy Statements, and Gypsy Moth Management Program Reports for any year are public documents which are accessible through the MERB, MDA, or State of Michigan Record Center for a period of perhaps 10 years, after which they may be traced in the State Archives. Management strategies, which may have kept gypsy moth populations from dangerously exceeding economic thresholds thus far in Michigan, may be of interest to people in other places where it will inevitably become established.

Gypsy moth defoliation in all of Michigan has never exceeded 25 acres in any one year. Regulatory interventions with synthetic insecticide in 1954–1981 were correlated with gypsy moth survey results. No eradication operations were conducted in Michigan in 1958, 1961, 1963–1966 or 1968–1972 because no gypsy moth infestations were detected in the years immediately preceding.

Gypsy moth was collected in seven counties of Michigan in 1977, and plans were made for the aerial application of synthetic insecticide in 1978. On 3 May 1978, the MDA and USDA held a public meeting to discuss plans for applying diflubenzuron to 103,200 acres of infested gypsy moth habitat in portions of Clare, Gratiot, Isabella, Mecosta, Montcalm, and Saginaw counties. A majority of citizens in attendance objected strenuously to the proposed use of synthetic insecticide. Representatives of the Organic Growers of Michigan organization met later that same night at a private home near Lake, Michigan, to organize a protest group named Citizens Against Chemical Contamination. These two organizations later became plaintiffs against the MDA and the Director of MDA in the Circuit Court of the County of Ingham, and were successful in obtaining a Temporary Restraining Order on 25 May 1978 which resulted in cancellation of gypsy moth eradication plans in 1978.

Among regulatory interventions attempted over the years in Michigan as possible alternatives to aerial application of synthetic insecticide were

(1) state quarantine enforcement
(2) departmental regulation enforcement
(3) mass trapping
(4) disparlure mating disruption
(5) 

Table 1. Insecticide treatments to eradicate gypsy moth in Michigan, 1954–1981.

<table>
<thead>
<tr>
<th>County</th>
<th>No. years treated</th>
<th>Acres treated</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td>DDT</td>
<td>Carbaryl</td>
<td>Diflubenzuron</td>
<td>Total</td>
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<tr>
<td>Berrien</td>
<td>1</td>
<td>—</td>
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<td>—</td>
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<td>Wayne</td>
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<td>405</td>
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gypsy moth nucleopolyhedrosis virus application (6) Bacillus thuringiensis bacterial application (7) exotic parasite release and (8) laboratory-reared sterile-male gypsy moth release. The only state quarantine enforced became effective 15 January 1973 and was rescinded effective 1 March 1976.

The dispersal of gypsy moth in Michigan, either by natural means (Mason 1975) or as a result of human activity (Spears 1974), went largely undetected until advanced pheromone trapping techniques became available. *L. dispar* males were captured in pheromone traps in three new counties in 1972. A small number of egg masses were found on firewood in a yard near where male moths had been caught in Isabella County. By tracing the source of the firewood, a well established infestation of gypsy moth was discovered in a 30-acre woodlot in Section 20 of Fremont Township in Isabella County. Either because gypsy moth populations had increased, or as a result of improved trapping technique, gypsy moth males were captured in 17 more new counties in 1973. Wallner (1974) reported that the pheromone trap survey in 1973 indicated at least 600,000 acres in Michigan were probably lightly infested with gypsy moth.

![Fig. 1. Gypsy moth eradication operations, 1954-1962, employing DDT.](image-url)
Table 1 lists the counties of Michigan in which synthetic insecticide was applied to eradicate gypsy moth, number of years treated, insecticides used, and acres treated. Figures 1 and 2 show by county, aerial spraying operations conducted to eradicate gypsy moth in the years 1954–1981, with insecticide used and acres treated. Eradication was a major component of gypsy moth management in Michigan in the years 1954–1981. Perhaps widespread aerial spraying of forests, woodlots, and wooded residential areas by regulatory agencies to eradicate gypsy moth, with relatively few valid claims of bee losses reimbursed by ASCS and with only the one reported dairy judgment regarding potential harm to human health or the environment, has provided both short-term and long-term benefits to the people of Michigan which well justify the investment.

For 28 years the management of gypsy moth in Michigan has been nearly the exclusive concern of federal and state government. Ecological factors may have been most important and may continue to keep gypsy moth populations from exceeding economic thresholds in certain places in Michigan. But gypsy moth will never completely go away by itself. And
right or wrong, whenever or wherever gypsy moth infestations interfere with business or comfort, citizens will demand relief. The time is coming when communities may want to decide for themselves whether or not to manage gypsy moth at the local level with local resources. Morse and Simmons (1978) used results of computer-simulated control strategies to devise alternatives to the gypsy moth eradication program in Michigan. Thomas E. Moore (pers. comm.) has proposed a system to create computer-generated models of gypsy moth population dynamics based on shared biological, ecological, environmental, and meteorological data accumulated in Michigan over a period of some 25–30 years.

Hanna (1981) summarized data from over 300,000 gypsy moth pheromone traps spanning 27 years, and identified the 47 counties of Michigan where gypsy moth had been collected in the years 1954–1980. Hillsdale, Jackson, Lapeer, Lenawee, Oscoda and Presque Isle counties were new 1981 records for gypsy moth based on male moths captured in pheromone traps. Combined records of the MDA, USDA, Michigan Department of Natural Resources, and National Campers and Hikers Association showed that gypsy moth was collected again in 1981 in Berrien, Clare, Clinton, Eaton, Gratiot, Ingham, Ionia, Isabella, Kalamazoo, Macomb, Mecosta, Midland, Montcalm, Newaygo, Oakland, Saginaw, Shiawassee, Van Buren, Washtenaw and Wayne counties, all of which were counties where eradication operations had previously been conducted.

Regulatory interventions with synthetic insecticide in 22 counties had temporarily modified the environment of some 400,000 acres of Michigan woodlands inhabited by gypsy moth since 1954. MDA and USDA staff members engaged in regulatory activity occasionally have recorded observations on occurrence, development, quality, and persistence of gypsy moth populations in diverse habitats. Good weather data are available for Michigan. No other state has a comparable historical perspective against which to test predictive models of weather impact, the one agent which simultaneously and unpredictably affects host plants, target organisms and their competitors, predators and diseases, and intervention efforts. It is unfortunate that at least two people who were most familiar with gypsy moth eradication operations are already dead. My recollection on the property where gypsy moth was first discovered and of the localities where eradication operations have been conducted is surely fading. If existing historical gypsy moth population data for Michigan are to be combined with comprehensive Michigan weather data for the same period to provide a basis for predicting impact on forest environments, it had best be done soon, before more useful information becomes irretrievably lost.

ACKNOWLEDGMENT

I thank Thomas E. Moore of the Museum of Zoology, The University of Michigan, Ann Arbor, for instructive discussions and criticism.

LITERATURE CITED


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NOTES ON SHIFTING DISTRIBUTION PATTERNS AND SURVIVAL OF IMMATURE DANAUS PLEXIPPUS (LEPIDOPTERA: DANAIDAE) ON THE FOOD PLANT ASCLEPIAS SYRIACA

Susan Sullivan Borkin

ABSTRACT

Abundance and distribution of immature stages of the monarch butterfly, Danaus plexippus, on the food plant Asclepias syriaca were examined at a site in southeastern Wisconsin over one growing season. Estimated mortality for eggs and larvae was substantial (88%). Dispersal of larvae between individual food plants, along with egg and larval mortality factors, may result in low population density. Although the mechanism triggering larval dispersal is unknown, several alternative hypotheses are proposed for further examination.

The monarch butterfly, Danaus plexippus (L.), is widely distributed over North America. Considerable information has accumulated regarding its biology (e.g. Urquhart 1960; Urquhart and Urquhart 1976a, 1976b; Brower et al. 1977; Rawlins and Lederhouse, 1981), and ecological chemistry (Brower 1969, Roeske et al. 1976, Fink and Brower, 1981). Nonetheless, there are few quantified data on the population biology of the species, particularly as related to the immature stages. This paper summarizes a preliminary investigation of abundance and distribution of eggs and larvae on individual food plants and changes in these parameters through one growing season. A striking result of this study is the documentation of very low densities of eggs and larvae on food plants mitigated by the interplay of mortality and dispersal.

STUDY SITE AND METHODS

The study was conducted during 1979 at the University of Wisconsin Field Station, near Saukville, Ozaukee County, Wisconsin (43°37' N, 88°1' W). The site selected for observation was approximately 650 m² of old-field habitat with an abundance of common milkweed (Asclepias syriaca L.) interspersed among sweet clover (Melilotus officinalis L.), goldenrod (Solidago sp.), and various grasses. A large portion of the land surrounding the study site was mowed on 17 July 1979 for reasons unrelated to this investigation. However, the production of new A. syriaca growth in this mowed area during late July and early August provided an opportunity to compare exploitation of young and old milkweed plants by D. plexippus. The study site was therefore expanded to about 3300 m² beginning 11 August to include a portion of the mowed land.

A census of eggs and larvae was taken during daylight hours at weekly intervals beginning 2 June, the week prior to the first sightings of D. plexippus adults at the Field Station, through 15 September when the abundance of immatures declined dramatically. The aerial portions of milkweed plants (stem, leaves, and inflorescence) were examined for all stages of the butterfly. About 400 milkweed plants were examined on each sampling date in the unmowed portion of the study site; and an additional 250 plants on 11 August, 450 plants on 18, 25 and 31 August, and 650 plants on 8 and 15 September were examined in the mowed area.

1Invertebrate Zoology Section, Milwaukee Public Museum, Milwaukee, WI 53233.
Numbered survey stakes were used to indicate the milkweed plants on which eggs or larvae were found. The number of eggs, number of instars of larvae, and their locations on each plant were recorded. Instar was determined on the basis of morphological differences in head capsule size, body length, and coloration. On subsequent sampling dates, the presence of any new eggs, empty or partially eaten egg shells, larvae, and areas of feeding damage were recorded. The census was maintained in this manner until no immatures were found on the plant. The stake was then removed. The height, number and color of leaves (green versus yellow), and other obvious signs of aging and herbivore damage were noted for the tagged plants.

One fourth and 25 fifth instar larvae were collected from the site and allowed to complete their development in the laboratory to estimate the incidence of tachinid fly parasitism. In addition, eggs from another locality were reared in the laboratory on selected milkweed plants from the study site to determine if the plants were capable of supporting *D. plexippus* development.

RESULTS

A total of 219 samples, representing 269 eggs and 156 first through fourth instar larvae, were monitored during the study. Some milkweeds are included more than once in the total since they were marked on more than one occasion. Larvae may also have been counted

![Graph](image_url)

Fig. 1. Population index of *Danaus plexippus* eggs and larvae per 400 milkweed stems in the unmowed and mowed areas of the study site.
more than once as a result of dispersal occurring between sampling dates. An additional 26 larvae, all but one fifth instars, were brought into the laboratory to complete their development. The repeated searches of milkweeds failed to turn up any D. plexippus pupae. (The complete census history data are available on request from the author.)

Population Index

Population estimates based on the relative abundance of eggs and larvae on each sampling date are summarized in Figure 1. The data from the mowed portion of the site have been adjusted by ratio to correspond to a base figure of 400 plants searched. This enables comparison with the numbers of immatures found in the unmowed area.

The population index shows a strong peak in the number of eggs found during the second week of June corresponding to the arrival of migrating D. plexippus at the site. The peak in number of larvae occurring one week later was comprised mostly of first and second instars. The second peak of immatures is less pronounced than the first but extends over a longer period of time, from mid-July to late August, and represents overlapping broods. It is clearly distinguishable from the first peak based on the numbers of larvae found as first and second versus later instars. The population index also shows a shift in the distribution of immatures, from the unmowed portion of the site to the milkweeds in the mowed area, during mid- to late August. The milkweeds in the unmowed area had begun to yellow, the leaves were tough, and there was extensive herbivore damage. Those in the mowed area were green and succulent in comparison. Table 1 gives the distribution of larvae found in each area during these time periods. By September, there was a sharp decline in the D. plexippus population at the site, even though milkweeds were still available and temperatures were favorable for development. The first freeze in the area occurred 14 October.

Distribution of eggs and larvae

Of the total 269 eggs censused in this investigation, 152 (57%) were found distributed singly on the milkweed plants. A single egg was discovered on a blade of grass that was resting across a milkweed leaf. The remaining 116 eggs were found in combinations of up to three eggs per leaf, but no more than four eggs were found on any one plant. Approximately two-thirds of the total number of eggs were placed on the undersides of leaves. The rest were found on the dorsal leaf surfaces and a few on the stalk and flowers.

Larvae were observed feeding and resting on the food plant. Only first and second instars were observed molting. The majority of first and early second instar larvae were found concealed among the newly developing leaves. When two or more larvae occupied the same plant, they were generally found on different leaves, although on one occasion two fifth instars were seen feeding on single leaf. No observations were recorded of intraspecific aggression.

Table 1. The distribution of Danaus plexippus larvae according to study site area for the time periods indicated.

<table>
<thead>
<tr>
<th>Site Area</th>
<th>Dates</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unmowed</td>
<td>9/6-15/7</td>
<td>44</td>
<td>27</td>
<td>6</td>
<td>1</td>
<td>9</td>
<td>87 (45%)</td>
</tr>
<tr>
<td>Unmowed</td>
<td>19/7-15/9</td>
<td>23</td>
<td>12</td>
<td>5</td>
<td>2</td>
<td>13</td>
<td>55 (29%)</td>
</tr>
<tr>
<td>Mowed</td>
<td>11/8-15/9</td>
<td>19</td>
<td>14</td>
<td>3</td>
<td>1</td>
<td>14</td>
<td>51 (26%)</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>86 (45%)</td>
<td>53 (27%)</td>
<td>14 (7%)</td>
<td>4 (2%)</td>
<td>36 (20%)</td>
<td>193</td>
</tr>
</tbody>
</table>
Census history of eggs and larvae

Egg survivorship was assessed using two criteria. The first was the presence or absence of early instar larvae on each marked plant corresponding to the number of eggs recorded for that plant the previous week. The second was the condition of the egg shell if present, coupled with the presence or absence of typical first instar feeding damage. The pattern of feeding damage, a small circular or semi-circular area usually located close to where the egg had been, is characteristic for early instars of D. plexippus. Newly hatched larvae exhibit variability in the extent to which the evacuated egg shell is consumed, but the basal plate is not eaten. Partially devoured egg shells and the basal plates were therefore used as indications that eggs had survived until hatching. In most cases, the results were also supported by feeding damage. The second criterion has the advantage over the first in that it allows a measure of egg survivorship that is independent of the survival of the resulting larvae. Although egg cannibalism is known to occur under overcrowded conditions (Brower 1961), it was not found to be a significant factor in this study based on the survivorship of eggs found in combination of two or more per plant (Table 2).

First or second instar larvae were found on successive sampling dates for 81 eggs. Where no larvae were found, egg shells and feeding damage on the milkweeds indicated that survivorship was probable for an additional 74 eggs. Combined, these figures give an estimate of 58% survivorship for the eggs monitored in this study (30% when based only on the number of larva found). Nine eggs darkened and shriveled, possibly due to some microbial pathogen or parasitism. The remaining 105 eggs were unaccounted for. Some disappeared along with portions of the milkweed plants on which they were laid as a result of the activity of insect and non-insect herbivores. A comparison of the survivorship of eggs from the first brood with eggs found in the unmowed area after June 30th indicates no significant difference for survival ($\chi^2$ test, $P > 0.75$). Likewise, there is no significant difference in survival for eggs from the first brood compared with eggs found in the mowed area ($P > 0.1$).

One of the more intriguing results obtained in this study was that not one larva monitored completed its development on the milkweed plant where it was first recorded. Out of 155 first through fourth instars, only 17 were resighted the successive sampling date on the same plant where originally recorded and 16 were either second or early third instars at the time they were resighted. No larva was resighted on the same plant after more than one week. Table 1 illustrates a second interesting feature of the data, that is, the consistently small proportion of third and fourth instar larvae found relative to the number of fifth instars.

An example of the movement pattern for a larva which was disturbed and dropped off of its food plant is shown in Figure 2. However, I witnessed at least six examples of larvae crawling off of the food plant without disturbance. Larvae from the second instar on were observed wandering off of what appeared to be suitable milkweed plants where at least some amount of feeding had occurred. Often, a larva was found feeding on a milkweed that had

<table>
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<th></th>
<th>Single egg per Asclepias stem</th>
<th>Two or more eggs per Asclepias stem</th>
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<tr>
<td>Total No. eggs</td>
<td>153</td>
<td>116</td>
</tr>
<tr>
<td>Larvae found</td>
<td>35 (23%)</td>
<td>46 (40%)</td>
</tr>
<tr>
<td>Survivorship probable</td>
<td>50 (33%)</td>
<td>24 (21%)</td>
</tr>
<tr>
<td>Egg survivorship</td>
<td>85 (56%)</td>
<td>70 (61%)</td>
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<tr>
<td>Egg survivorship based</td>
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<td></td>
</tr>
<tr>
<td>only on larvae found</td>
<td>35 (23%)</td>
<td>46 (40%)</td>
</tr>
</tbody>
</table>

aDifference not significant ($\chi^2$ test, $P > 0.25$).

bDifference significant ($P < 0.01$).
been abandoned previously by another larva. I successfully reared *D. plexippus* in the laboratory from egg to imago on such plants. All of the plants tested were found to be capable of supporting development.

Of the 26 larvae that were collected and allowed to complete development in the laboratory, three (11.5%) were found to be parasitized by the tachinid, *Lespesia archippivora* (Riley). One observation was made of this tachinid in the field, attempting to oviposit on a fifth instar larva. Upon contact, the larva jerked violently from side to side, repelling the fly. The larva then dropped to the ground and crawled rapidly away from the plant. It was collected and subsequently reared through the imago. I was not able to determine whether the fly was unsuccessful in depositing an egg or some aspect of host suitability (Vinson and Iwantsch 1980) prevented development of the parasitoid.

Only one instance of predation was witnessed in the field, that of a pentatomid bug feeding on a fifth instar larva. However, other potential predators such as immature neuropterans, ants, and several species of spiders were commonly found on the milkweeds. The overall estimate of survivorship for *D. plexippus* prior to pupation is 12% in this study based on the total number of eggs and fifth instar larvae found and taking known instances of parasitism into account.

**DISCUSSION**

Essentially this was a descriptive study. The purpose was to investigate how *D. plexippus* exploits available larval food plants by examining abundance and distribution of immatures on the plants at one locality over a growing season. The data show that (1) only a small
percentage of the food plants were occupied at any given time and new growth was preferred
for oviposition sites and feeding by early instar larvae, (2) eggs were killed in significant
numbers throughout the growing season, and (3) the number of larvae decreased with the
progression in instars, presumably as a result of mortality factors. The data also support the
concept that at northern latitudes colonization of milkweeds by *D. plexippus* occurs by way
of population expansion. That is, females migrate northward after overwintering and oviposits
en route. The June oviposition pulse illustrated in Figure 1 represents a single brood
 corresponding to the arrival of migrating females at the site. The pulse beginning in mid-July
represents overlapping broods, evidence of continuing northern movement by adults that
developed farther south.

In addition to the population parameters just listed, it was found that individual larvae
moved considerably between food plants during development even though the plants were
not severely defoliated or otherwise noticeably changed. Similar results have been reported
by Urquhart (1960) and Rawlins and Lederhouse (1981). The cause of this dispersal has not
been determined, but it requires the expenditure of energy, and some mortality undoubtedly
occurs as a direct or indirect result of the movement. For example, larvae may experience
considerable difficulty in relocating a food plant, as the experiments of Dethier (1959b) and
Urquhart (1960) and observations from this study (Figure 2) show. For these reasons, the
proximal cues and resulting selective pressures in displacement of *D. plexippus* larvae from
their food plants are of great interest.

Several alternative hypotheses can be proposed to explain the observed behavior. One is
the "physiology" hypothesis, where dispersal occurs as a response to some change in the
physiological condition of the larvae. For instance, a proximal cue could be related to
feeding and selection pressures related to the suitability of the micro-habitat. Rawlins and
Lederhouse (1981) found that feeding behavior in *D. plexippus* larvae is influenced by
ambient temperature, and that active larvae tend to be feeding and in the shade. They also
found that wandering off the food plant is most prevalent during midday. If this movement
were for thermoregulation, one might expect the larvae to remain near the bases of the host
plants and move back up the stems at a later time, as Sherman and Watt (1973) found for
*Colla* larvae. Such behavior was not observed in this study nor by Rawlins and Lederhouse.

A second hypothesis is the "predator-parasitoid," where larvae disperse to escape para-
sitoids and other predators. Although such mortality has not been quantified, casual obser-
vations made over the past few years reveal that several species of hemipterans, spiders,
lacewing larvae, and vespid wasps prey on *D. plexippus*. The aposematic coloration of *D.
plexippus* larvae may serve as an adequate defense against vertebrate predators; nonetheless
the results of this study indicate that mortality, likely due to invertebrate predators, is
substantial. Young and Moffett (1979) found a number of arthropods kill the eggs and young
larvae of *Mechantitis isthmia*, which is also considered an unpalatable species. The data
support this hypothesis in part. The tachinid species found parasitizing *D. plexippus*
deposits its eggs directly on the body of the host and is widespread in the United States with
many lepidopterous hosts (Cole 1969) and movement off the host plant was noted for larvae
that had been disturbed. However, larvae were also observed leaving the host plant without
apparent cause. It seems unlikely that this hypothesis would account for the fact that not one
larva completed development on its original host plant.

A third hypothesis is that of "food plant quality," where dispersal occurs as a response to
some change in the physiological condition of the food plant which cannot be detected
visually by researchers. The data favor this hypothesis over the preceding two. Female *D.
plexippus* are highly precise in selecting a larval food plant for egg placement (Dethier 1959a,
Rothschild and Schoonhoven 1977). Whether due to random selection or, more likely, to
specific visual and chemical cues, some milkweeds in this study which appeared healthy
(green, succulent foliage) were never utilized as oviposition sites while other milkweeds in
poor condition (yellow, and with extensive herbivore damage) were found with one or more
eggs. The mid-August shift in oviposition sites to the regenerated growth in the mowed area
indicates a strong preference by females for young, tender plants on which to deposit their
eggs, and the majority of first and second instar larvae were found on newly developing
leaves. There may be a selective advantage for young larvae to feed on new growth (Coley
1980, Futuyma and Wasserman 1980, Scriber and Slansky 1981). Often food selection does not correspond with the nutritional properties of a plant (Chew 1980, Dethier 1980). Secondary plant substances may be important as attractants or feeding stimulants. Roeske et al. (1976) found the presence of secondary plant substances varies intraspecifically in Asclepias syriaca even among plants from the same locality. Although D. plexippus were successfully reared on plants that larvae had deserted, the biochemistry of the plants may have been altered when they were brought into the laboratory (J. E. Rawlins, in litt.). No measure was obtained of larval feeding preference or fitness of the resulting adults.

Any one or a combination of these proposed hypotheses can account for the shifting larval distribution patterns that were observed. Clearly, further experimental studies are required to determine the mechanism and adaptive significance, if any, of this behavior. Nonetheless, the results from this preliminary investigation suggest that in addition to egg and larval mortality factors, larval dispersal between food plants is important in the population dynamics of D. plexippus.

ACKNOWLEDGMENTS

This study was conducted as part of a Master’s degree program. I gratefully acknowledge A. M. Young for guidance throughout the project. I also thank J. E. Rawlins for reviewing the manuscript; M. Ficken, University of Wisconsin-Milwaukee, for suggestions and use of the Field Station facilities; C. W. Sabrosky, USDA Systematic Entomology Laboratory, for the tachinid determination, and A. Borkin for encouragement.

LITERATURE CITED


SUSCEPTIBILITY OF WHITE SPRUCE SEED SOURCES TO YELLOWHEADED SPRUCE SAWFLY, PIKONEMA ALASKENSIS, (HYMENOPTERA: TENTHREDINIDAE)  

Michael D. Connor, 2 Mark W. Houseweart, 3 and Herbert M. Kulman 4  

ABSTRACT  

A field caging technique was used to test the susceptibility of 25 white spruce, Picea glauca (Moench) Voss, seed sources to attack by Pikonema alaskensis (Rohwer). No significant differences were found in the number of eggs laid, number of desiccated eggs, or number of egg slits. Percent oviposition differed significantly within a tree, the south side having more eggs. Bud size differed significantly within trees and between trees but not between seed sources. The number of sawfly eggs laid on a bud could not be related to bud size. There was no significant difference in susceptibility of the seed sources studied to Pikonema alaskensis.  

The yellowheaded spruce sawfly, Pikonema alaskensis (Rohwer), is a Nearctic species occurring transcontinentally in Canada and northern United States, coinciding with the range of white spruce, Picea glauca (Moench) Voss. Plantations, nurseries, shelterbelts, and ornamentals are especially susceptible. Plantations are usually not attacked until 3–5 years after planting (Nash 1939). Some mortality does occur, but growth loss is the greatest economic impact caused by this sawfly (Kulman 1971).  

The biology of P. alaskensis is well documented from Maine studies (Nash 1939). The bionomics and natural mortality agents of yellowheaded spruce sawfly in Minnesota have been reported by Houseweart and Kulman (1976a, 1976b) and Schoenfelder et al. (1978). Studies of tree resistance to sawfly attack are limited. Wilson (1966) reported ponderosa pine, Pinus ponderosa Laws., from seed collected in the Deschutes region of Oregon was lightly attacked by European pine sawfly, Neodiprion sertifer (Geoff), in Michigan, possibly indicating resistance. Wright et al. (1967) examined Scotch pine, Pinus sylvestris L., and found variety uralensis was attacked less by European pine sawfly than other varieties of comparable heights. Pauley and Mohn (1971) studied defoliation by P. alaskensis in a northeast Minnesota provenance test of 23 white spruce seed sources. They reported no consistent evidence in frequency of attack between white spruce seed sources. Nienstaedt and Teich (1972) reported preferential feeding by yellowheaded spruce sawfly occurred on trees from 28 seed sources growing in northeast Minnesota. Differences apparently occurred only when sawfly infestations were low because no differences were found in another Minnesota test of the same provenances heavily infested by the sawfly.  

Pointing (1957) stated that emergence of P. alaskensis and expanding shoot growth were well synchronized. Eggs were not found on shoots where bud scale caps covered greater than 60% of the needles. At the other extreme, fully expanded shoots had needles which diverged considerably and were so flexible that penetration by the female’s ovipositor was impossible.  

Cook (1978) reported no yellowheaded spruce sawfly eggs were found on shoots < 100 mm 3 in volume and few were found on shoots with a volume > 1000 mm 3. Since
adults are short lived, 3–14 days, the synchronization of emergence with bud flush is critical. Differences in initiation of bud flush in white spruce clones have been shown to be as great as 21 days (Nienstaedt and King 1969). Differences this great between seed sources may make some sources unsuitable for oviposition.

The objectives of this study were to determine (1) if there were differences in the ability of females to oviposit on different white spruce seed sources, (2) if there were differences in the ability of larvae to feed and survive on different white spruce seed sources, and (3) if differences exist, were they related to bud size or volume.

MATERIALS AND METHODS

Twenty-five white spruce seed sources and one black spruce, *Picea mariana* (Mill.) B.S.P., source were planted north of Grand Rapids, Minnesota, in 1962 as a provenance study. Seed sources were planted in a randomized complete-block design with four-tree plots in each of 10 blocks. Tree spacing was 2.4 m by 2.4 m. Three replicates from the plantation were randomly chosen for the study. The first three trees in each source were utilized. If any of the first three trees was unusually small or deformed, it was skipped and the fourth tree utilized.

Yellowheaded spruce sawfly larvae were collected in 1975 near Grand Rapids and reared in the laboratory using a technique developed by Houseweart and Kulman (1976b). Approximately 4000 cocoons were overwintered using schedules patterned after those developed by Houseweart et al. (1977), as yielding the least mortality in laboratory rearing. Two groups of 2000 each were used with staggered schedules of 1.5 weeks to result in different emergence times. This allowed for variable weather conditions, so field introductions would coincide with the naturally emerging sawfly flight period.

In May 1976, dacron marquisette (27 threads/cm) cages supported by a 14 gauge wire frame were tied to an east and south branch of three trees from each of the 26 seed sources for each of three replicates (total of 468 bags). The sawfly prefers sunlit areas, so cages were not placed at a uniform height, but rather where shading would be minimal. Therefore, cage height varied between trees due to placement at mid-upper crown regardless of total tree height. However, within a tree both cages were placed at approximately the same height. Before placing cages on the trees, branches were sprayed with pyrethrum to ensure no predators or parasites were present. Sawflies were placed in cages between 18 to 23 May 1976. Males were observed flying around cages containing females on 19 May, and field populations of females were seen ovipositing on 21 May, confirming that the females were caged at the proper time. Cages were checked daily for dead females. After females died, they were removed from the cages, placed in KAAD for 48 h, and then stored in 95% ethyl alcohol until dissection for counts of unlaid eggs. After removal of female sawflies the branches were examined for the number of eggs laid, desiccated eggs, number of oviposition slits without eggs, and number of buds available for oviposition. Potential fecundity and percent oviposition were calculated.

On 21 and 23 May, length and width of flushed buds adjacent to sleeve cages and approximately the same size as those in the sleeve cage were measured using a hand micrometer. Approximate volume of the shoots was calculated using the formula for a cylinder.

Destructive sampling was used to sample third and fifth instar larvae to determine larval mortality. Instar determinations were made from head capsule measurements as determined by VanDerwerker and Kulman (1974).

Data were analyzed by ANOVA using an interactive computer program, IVAN (Weisberg and Koehler 1976).

RESULTS AND DISCUSSION

There were no significant differences ($P > 0.10$) in the number of eggs laid by yellowheaded spruce sawfly on different white spruce seed sources (Table 1). However, there was a wide range in the average number of eggs laid on each seed source (Table 2). The percent natural defoliation is given in Table 3 to provide an index of feeding on the various sources.
Table 1. Analysis of variance table for the number of yellowheaded spruce sawfly eggs laid on caged branches of 25 white spruce seed sources (df = degrees of freedom, SS = sum of squares, MS = mean square).

<table>
<thead>
<tr>
<th>Source of variability</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>24</td>
<td>20,607.0</td>
<td>858.6</td>
<td>1.15</td>
</tr>
<tr>
<td>Replicate</td>
<td>2</td>
<td>4,523.1</td>
<td>2261.5</td>
<td>6.51a</td>
</tr>
<tr>
<td>Source × replicate</td>
<td>48</td>
<td>35,268.0</td>
<td>734.8</td>
<td>2.12a</td>
</tr>
<tr>
<td>Among trees</td>
<td>150</td>
<td>71,693.2</td>
<td>478.0</td>
<td>1.38b</td>
</tr>
<tr>
<td>Direction</td>
<td>1</td>
<td>887.6</td>
<td>887.6</td>
<td>2.55</td>
</tr>
<tr>
<td>Source × direction</td>
<td>24</td>
<td>7,444.6</td>
<td>310.2</td>
<td>0.89</td>
</tr>
<tr>
<td>Error</td>
<td>200</td>
<td>69,486.7</td>
<td>347.4</td>
<td>—</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>449</td>
<td>209,910</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

aSignificant at the 0.01 level.
bSignificant at the 0.05 level.

Table 2. Average number of eggs of the yellowheaded spruce sawfly laid on caged branches of 25 white spruce seed sources.

<table>
<thead>
<tr>
<th>Source and location</th>
<th>Mean number of eggs (replications combined)</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1661 Quebec</td>
<td>23.3</td>
<td>3.2</td>
</tr>
<tr>
<td>1654 Alaska</td>
<td>23.3</td>
<td>4.9</td>
</tr>
<tr>
<td>1659 N. Brunswick</td>
<td>25.6</td>
<td>3.6</td>
</tr>
<tr>
<td>1664 Manitoba</td>
<td>26.9</td>
<td>5.6</td>
</tr>
<tr>
<td>1676 Michigan</td>
<td>28.5</td>
<td>4.7</td>
</tr>
<tr>
<td>1662 Ontario</td>
<td>28.7</td>
<td>4.5</td>
</tr>
<tr>
<td>1645 Wisconsin</td>
<td>29.9</td>
<td>3.7</td>
</tr>
<tr>
<td>1653 Alaska</td>
<td>30.7</td>
<td>4.5</td>
</tr>
<tr>
<td>1631 Manitoba</td>
<td>31.9</td>
<td>3.8</td>
</tr>
<tr>
<td>1658 Labrador</td>
<td>34.4</td>
<td>3.8</td>
</tr>
<tr>
<td>3511 Minnesota</td>
<td>34.6</td>
<td>4.7</td>
</tr>
<tr>
<td>1649 N. Hampshire</td>
<td>35.1</td>
<td>5.0</td>
</tr>
<tr>
<td>1660 Quebec</td>
<td>35.2</td>
<td>5.2</td>
</tr>
<tr>
<td>1686 Ontario</td>
<td>35.3</td>
<td>5.1</td>
</tr>
<tr>
<td>1655 Maine</td>
<td>35.6</td>
<td>3.7</td>
</tr>
<tr>
<td>1647 Minnesota</td>
<td>36.6</td>
<td>7.0</td>
</tr>
<tr>
<td>1687 Ontario</td>
<td>37.2</td>
<td>5.8</td>
</tr>
<tr>
<td>1665 Saskatchewan</td>
<td>37.6</td>
<td>6.7</td>
</tr>
<tr>
<td>1628 S. Dakota</td>
<td>38.5</td>
<td>3.9</td>
</tr>
<tr>
<td>1630 Montana</td>
<td>41.1</td>
<td>4.8</td>
</tr>
<tr>
<td>1669 Minnesota</td>
<td>42.4</td>
<td>4.5</td>
</tr>
<tr>
<td>1657 Labrador</td>
<td>43.5</td>
<td>5.4</td>
</tr>
<tr>
<td>1644 N.Y.</td>
<td>43.7</td>
<td>6.2</td>
</tr>
<tr>
<td>1663 Ontario</td>
<td>45.5</td>
<td>6.3</td>
</tr>
<tr>
<td>1677 B.C.</td>
<td>49.2</td>
<td>5.5</td>
</tr>
</tbody>
</table>
There were no significant differences in the number of dessicated eggs or number of ovipositional slits without eggs by seed source, tree, or direction. Percent oviposition was significantly different ($P < 0.025$) due to direction. The average percentage of eggs laid for the east and south direction was 73.6% and 67.9%, respectively.

If differences in bud size occurred among seed sources the result could be differences in the number of eggs laid by sawflies. However, bud width and length differed significantly ($P < 0.005$) only by direction. Bud volume differed significantly between trees ($P < 0.10$) and by direction ($P < 0.005$), the southerly direction having larger buds. Wilkinson (1977) reported only a 5-day variation in budbreak of 37 half-sib families of white spruce in southern Maine. He also reported that differences between individual trees were greater than those between families. Possibly a relationship exists between bud size and number of eggs laid, but since variation between and within trees is greater than variation between seed sources the result is no detected difference in number of eggs laid on different sources.

From Pointing’s (1957) observations, yellowheaded spruce sawfly was expected to lay few eggs on small buds, most eggs on an optimum bud size, and few eggs on large buds with diverged needles. Although Cook (1978) found this to be true, this was not the case when the sawfly was caged on branches. Eggs were laid on a bud $10 \text{ mm}^3$ at the time of oviposition. The largest buds measured were $2168$ and $2072 \text{ mm}^3$ and 5 and 27 eggs, respectively, were laid on adjacent caged buds. Possibly, under natural conditions in a stand of trees with variable-sized buds, sawflies would select the most suitable tree. However, when caged and restricted to a particular tree, the sawfly will lay eggs even on very small buds. It is also

Table 3. Percent of natural defoliation of 25 white spruce seed sources by the yellowheaded spruce sawfly in August 1975, at Grand Rapids and Cloquet, Minnesota.

<table>
<thead>
<tr>
<th>Seed source</th>
<th>Mean % defoliation</th>
<th>Std. error</th>
<th>Seed source</th>
<th>Mean % defoliation</th>
<th>Std. error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1657</td>
<td>0.3</td>
<td>0.2</td>
<td>1657</td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>1669</td>
<td>0.4</td>
<td>0.2</td>
<td>1653</td>
<td>2.8</td>
<td>1.9</td>
</tr>
<tr>
<td>1644</td>
<td>0.9</td>
<td>0.4</td>
<td>1645</td>
<td>3.1</td>
<td>1.7</td>
</tr>
<tr>
<td>1687</td>
<td>1.0</td>
<td>0.5</td>
<td>1655</td>
<td>3.1</td>
<td>1.9</td>
</tr>
<tr>
<td>1665</td>
<td>1.2</td>
<td>0.4</td>
<td>1665</td>
<td>3.9</td>
<td>2.6</td>
</tr>
<tr>
<td>1659</td>
<td>1.4</td>
<td>0.5</td>
<td>1669</td>
<td>5.3</td>
<td>2.3</td>
</tr>
<tr>
<td>1647</td>
<td>1.9</td>
<td>0.6</td>
<td>1631</td>
<td>5.6</td>
<td>1.5</td>
</tr>
<tr>
<td>1660</td>
<td>1.9</td>
<td>0.6</td>
<td>1628</td>
<td>5.8</td>
<td>2.4</td>
</tr>
<tr>
<td>1628</td>
<td>1.9</td>
<td>0.7</td>
<td>1644</td>
<td>6.5</td>
<td>1.9</td>
</tr>
<tr>
<td>1662</td>
<td>2.1</td>
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<td>2.8</td>
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<tr>
<td>1645</td>
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<td>0.8</td>
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<td>6.8</td>
<td>2.9</td>
</tr>
<tr>
<td>1658</td>
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<td>0.8</td>
<td>1659</td>
<td>7.4</td>
<td>3.8</td>
</tr>
<tr>
<td>1676</td>
<td>2.6</td>
<td>0.8</td>
<td>1687</td>
<td>8.6</td>
<td>1.4</td>
</tr>
<tr>
<td>1686</td>
<td>2.9</td>
<td>1.5</td>
<td>1686</td>
<td>9.1</td>
<td>3.7</td>
</tr>
<tr>
<td>3511</td>
<td>2.9</td>
<td>0.8</td>
<td>1647</td>
<td>9.2</td>
<td>2.3</td>
</tr>
<tr>
<td>1631</td>
<td>3.3</td>
<td>0.7</td>
<td>1662</td>
<td>9.5</td>
<td>2.2</td>
</tr>
<tr>
<td>1663</td>
<td>3.3</td>
<td>1.8</td>
<td>1644</td>
<td>10.0</td>
<td>2.7</td>
</tr>
<tr>
<td>1664</td>
<td>3.7</td>
<td>1.1</td>
<td>1649</td>
<td>10.9</td>
<td>4.1</td>
</tr>
<tr>
<td>1661</td>
<td>4.1</td>
<td>2.0</td>
<td>1661</td>
<td>11.1</td>
<td>2.8</td>
</tr>
<tr>
<td>1630</td>
<td>4.3</td>
<td>1.2</td>
<td>1676</td>
<td>11.5</td>
<td>5.1</td>
</tr>
<tr>
<td>1649</td>
<td>4.6</td>
<td>1.2</td>
<td>1677</td>
<td>11.5</td>
<td>5.5</td>
</tr>
<tr>
<td>1655</td>
<td>5.1</td>
<td>2.3</td>
<td>3511</td>
<td>11.7</td>
<td>3.2</td>
</tr>
<tr>
<td>1653</td>
<td>6.8</td>
<td>2.6</td>
<td>1660</td>
<td>11.9</td>
<td>4.9</td>
</tr>
<tr>
<td>1677</td>
<td>8.8</td>
<td>2.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1654</td>
<td>10.0</td>
<td>2.9</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
possible that other factors (i.e., odors) which may cause preference under natural conditions were overridden by caging.

No significant differences existed among the seed sources in larval mortality from egg to the third larval instar or from the egg to the sixth larval instar.

This study found no significant differences in susceptibility of the 25 white spruce seed sources studied to yellowheaded spruce sawfly attack when sawflies were caged on trees. Any susceptibility differences that exist must be due to sawfly preference and not to inherent tree resistance. Of the seed sources tested, this study indicated no reason for considering the yellowheaded spruce sawfly in provenance selection.

ACKNOWLEDGMENT

Appreciation is expressed to Dr. Lynne Thompson for advice and assistance in the field; Dr. S. Weisberg for assistance in experimental design and analysis; Dr. C. A. Mohn, William Cromwell, and Charles K. Blandin Foundation for coordinating their activities and allowing the use of the provenance study for this research; Drs. R. J. Bartelt and George W. Ryan for review of the manuscript; and Barbara Clausen and Gary Glonek for laboratory technical assistance. The study was supported by the University of Minnesota Agricultural Experiment Station and Computer Center.

LITERATURE CITED


DIURNAL AND SEASONAL ACTIVITY OF FEMALE MUTILLIDS ON A MICHIGAN SAND FLAT (HYMENOPTERA: MUTILLIDAE)

David A. Evans

ABSTRACT

Diurnal activity of mutillid females of a southwestern Michigan sand area was characterized in relation to sand surface temperature conditions. Seasonal abundance patterns were determined for four Dasymutilla species.

Female mutillids are conspicuous elements of the fauna of sandy areas in southwestern Michigan, yet little information has been gathered on diurnal or seasonal activity patterns of these insects. Periodic activity in arid habitats has long been recognized as a hygrothermal stress-reducing adaptation (Cloudsley-Thompson 1975), and a number of studies have been done on temperature-related activity patterns of insects inhabiting sand areas in the northern United States (Waldbauer et al. 1977, Maier and Waldbauer 1979). Chapman et al. (1923) characterized female mutillids as the last insects to retreat from the sand as the temperature rose and the first to return when the temperature fell.

Observations were made on a single sand flat over the course of the summer season 1979 to determine the relationship of diurnal activity of female mutillids to temperature conditions, to characterize seasonal patterns of activity, and to detect differential activity patterns among the various mutillid species of the habitat.

MATERIALS AND METHODS

The site observed was a sand flat 2 km north of Alamo, Kalamazoo County, Michigan. The area measured approximately 75 by 200 m; the surface of the area varied from patchy vegetation to bare sand, and margins of the study site were sharply delimited by oak woods or old fields.

Observations were made at weekly intervals from 21 June until 6 September 1979. Temperature (air and sand surface), humidity, wind, and cloud cover data were taken hourly from 0700 through 1700 hours EST. The survey technique was similar to that used by Maier and Waldbauer (1979) in determining diurnal activity of syrphid flies. A set zig-zag path was walked over the sand flat at hourly intervals, each circuit taking roughly one-half hour. Female mutillids seen were captured, identified, and released at the point of capture.

RESULTS AND DISCUSSION

Females of eight species were collected at the site. In order of decreasing abundance, they were Dasymutilla nigripes (Fabr.), D. lepeletierii (Fox), D. canella (Blake), D. asopus hexar (Blake), Timulla v. vagans (Fabr.), D. v. vesta (Cresson), Pseudomethoca f. frigida (Smith), and P. s. sanbornii (Blake).

Overall diurnal activity patterns for all females (n = 304) are shown in Figure 1. A somewhat bimodal activity pattern is indicated from these data but is most strongly expressed when activity patterns are depicted for females (n = 98) captured on days when the
sand surface temperature exceeded 45°C (Fig. 2). Figure 3 shows little female activity below a sand surface temperature of 34°C or above 46°C with most females active at 40°C. As temperatures exceeded 45°C, females were noted walking on leaves of plants, particularly Asclepias sp., that were growing on the sand flat. Observations were also made of females apparently seeking refuge from high temperatures by crawling under protective objects on the sand surface or burying themselves under loose sand. A typical day of observation during the summer season showed commencement of female activity at 0800, a decreasing number of females on the open sand as the surface temperature rose, and an activity increase to a peak in late afternoon until about 1700, after which few females could be seen.

No species differences were detected among diurnal activity patterns of those females observed.
Fig. 3. Activity of female mutillids in relation to sand surface temperature. Summer 1979, Alamo, Michigan.

Fig. 4. Seasonal abundance of four Dasymutilla species. Summer 1979, Alamo, Michigan (weekly observations).

A seasonal progression of activity for females of the four most abundant species is shown in Figure 4. D. nigripes activity occurred throughout the summer, increasing to a peak in mid-August; peak activity for D. lepeletieri extended from mid-July to early August; D. a. bexar was prominent early in the season and again at the beginning of September; D. canella was active in late June and declined in numbers until a resurgence in early August.

Although diurnal activity patterns are probably related to sand surface conditions, seasonal activity for each species is more likely determined by presence and abundance of hymenopterous hosts of these insects. As at least one mutillid species, D. nigripes, is capable of adult overwintering in Michigan (Evans and Miller 1970), and a small number of
females were seen on the sand flat in early June, it would be desirable to begin data collection several weeks sooner than the beginning of this study. Additional information is needed on life cycles, host associations, and degrees of specificity of the Mutillidae in order to determine factors producing a characteristic seasonal progression of species.

LITERATURE CITED


NEW RECORDS FOR ECTOPARASITES OF MICHIGAN BATS

S. B. Dood and A. Kurta

During 1978, 1979, and 1981 ectoparasites of bats were collected in 16 counties of the Upper and Lower peninsulas in connection with an extensive study of Michigan bat populations (Kurta 1980, 1982). The two insect and five acarine species recovered include four new records for Michigan and two new host records for the United States. All are listed with comments on past records of Michigan bat ectoparasites.

Keys used for identifications were those of Usinger (1966), Lewis (1978), Radovsky (1967), Rudnick (1960), and McDaniel and Coffman (1970). Most ectoparasites are in the personal collections of the authors.

ECTOPARASITES AND HOSTS
(* = new state record, † = new host record)

HEMIPTERA: CIMICIDAE
Cimex adjunctus Barber: 2 females, 3 males, 1 nymph ex Eptesicus fuscus (Beauvois), Allegan, Van Buren, Eaton, St. Joseph; 1 male ex Myotis sodalis Miller and Allen, St. Joseph. Lawrence et al. (1965) listed C. pilosellus (Horvath) from Myotis sp. in Iron County. However, Usinger and Ueshima (1965) noted that this species is found in western North America while C. adjunctus is widely distributed in the east to Colorado. Also, Usinger (1966) reported C. brevis Usinger and Ueshima from Myotis lucifugus (LeConte) at Ontario, Michigan. Although the C. pilosellus specimen(s) have not been re-examined, the geographical distribution of species as presently described suggests that they may be C. adjunctus or C. brevis but probably are no longer an authentic record for C. pilosellus.

SIPHONAPTERA: ISCHNOPSYLLIDAE
Myodopsylla insignis (Rothschild): 29 females, 16 males ex M. lucifugus, Houghton, Ontonagon; 2 females, 1 male ex Myotis keenii (Merriam), Mackinac. Scharf and Stewart (1980) report this flea species from M. lucifugus in Grand Traverse and Wexford counties, and Benton (1980) added Cheboygan, Menominee, and Houghton counties without giving the host species.

ACARI: MACRONYSSIDAE
*Steatonyssus occidentalis (Ewing): 56 females, 16 males, 59 protonymphs ex E. fuscus, Cass, St. Joseph, Ingham, Oakland, Livingston, Barry, Calhoun; 2 protonymphs ex †M. sodalis, Hillsdale.

Macranyssus crosbyi (Ewing and Stover): 3 females, 1 male, 6 protonymphs ex M. lucifugus, Delta, Ontonagon, Houghton; 2 protonymphs ex M. keenii, Berrien, Eaton. The type series of another macronyssid (Cryptonyssus flexus Radovsky) was taken from M. lucifugus in Cheboygan County (Radovsky 1967).

ACARI: SPINTURNICIDAE
*Spinturnix americanus (Banks): 4 females, 7 males, 1 nymph ex M. lucifugus, Delta, Houghton, Wexford, Berrien.
*S. bakeri Rudnick: 1 female, 2 males, 1 nymph ex E. fuscus, Barry, Ingham. This family of mites has not been previously reported from Michigan.

2Department of Biological Sciences, Bowling Green State University, Bowling Green, OH 43403.
3Department of Biology, Boston University, Boston, MA 02215.
4We have been unable to locate this city.
ACARI: CHIRODISCIDAE

*Alabidocarpus calcaratus* Lawrence: 1 male ex *M. lucifugus*, Ontonagon. Dr. B. McDaniel identified this mite and retains it in his collection. This species has been recovered in California on *Myotis yumanensis* (H. Allen) (McDaniel and Coffman 1970) and may also have been taken from an unspecified bat host in Montana (McDaniel, in litt.).

ACARI: TROMBICULIDAE

No chigger mites were found in this survey; however, Wrenn (1974) reported *Leptotrombidium myotis* (Ewing) from *M. lucifugus* in Cheboygan County.

Additional species in these and other families of ectoparasites (e.g. Argasidae and Myobiidae) have been found on bats in Indiana (Whitaker 1973). Also, there are no reports of ectoparasites from several genera of bats (e.g. *Lasiusus, Lasionycteris,* and *Nycticeius*) which have been collected in Michigan. Further investigation may provide additional records of bat ectoparasites in that state.

ACKNOWLEDGMENTS

Bats and ectoparasites were collected while Al Kurta was studying at Michigan State University and Michigan Technological University. The authors would like to thank M. E. Stewart for assisting with the field work and Dr. B. McDaniel, South Dakota State University, for providing information about the chirodiscid mite.

LITERATURE CITED


DESCRIPTION OF A NEW SPECIES OF *PARADAMOETAS* (ARANEAE: SALTICIDAE), WITH A REVISED KEY TO THE GENUS

Bruce Cutler

**ABSTRACT**

*Paradamoetas changuinola* new species, is described. The range of this antlike genus of jumping spiders is extended south to Panama. A revised key to the four species currently recognized is presented.

The antlike jumping spiders of the genus *Paradamoetas* have been revised recently (Cutler 1981). This paper describes a new species from Panama, collected at about the time that the generic revision was published. I wish to thank Dr. G. B. Edwards of the Florida State Collection of Arthropods, for collecting and making these specimens available for study. All specimens are deposited in that collection.

The occurrence of the genus *Paradamoetas* in Panama has been problematical. F. O. Pickard-Cambridge (1901) recorded a female of *P. formicina* Peckham and Peckham from Bugaba. I have not seen this specimen. Banks (1929) recorded the species from Panama. I have examined Banks' specimen and it does not belong to the genus *Paradamoetas*. Chickering (1946) did not have the genus in his extensive collections from Panama. In my revision (Cutler 1981), I noted that northern Nicaragua was the southern limit of the genus. This new species extends the confirmed southern range of *Paradamoetas* to northwestern Panama.

*Paradamoetas changuinola* new species

**Diagnosis:** This species closely resembles *P. cara* in the male, and *P. formicina* in the female. The position of the promarginal cheliceral tooth readily distinguishes the male from the other species in the genus. The palpal structures are very similar to those of *P. cara*, but the embolus curves more strongly in *P. changuinola* (Fig. 4a). Details of the spermathecae separate the female of *P. changuinola* from the female of *P. formicina* (Figs. 4b&c), but these details may be difficult to see.

The white scales at the sides of the prosoma in *P. changuinola* are slightly toothed as in *P. fontana* (Levi), and have one to two pair of lateral keels in addition to the median keel (Fig. 1a). The iridescent scales of the opisthosoma (Fig. 1b) are smooth, as is typical of most iridescent scales in salticids (Hill 1979).

**Etymology:** The specific name is a noun in apposition taken from the type locality.

All measurements are in millimeters.

**Male Holotype:** Total length 3.5, carapace 1.65 long, 1.20 wide. Eyerow I width 1.05, eyerow III width 1.12, eyefield length 0.94. Eye diameters: AME 0.27, ALE 0.17, PME 0.03, PLE 0.13. Distance ALE-PME 0.23, PLE-PME 0.33. Femora length: I 0.97, II 0.73, III 0.78, IV 1.09. Leg formula 4123. Spines leg I: dorsal femoral 4, tibial 3-3, metatarsal 2-2. Carapace dark brown-black, with thin band of white scales at lateral borders. Chelicerae and palpi dark brown. Legs brown to dark yellow with brown pro- and retrolateral stripes and infuscation on patellae and tibia. Opisthosoma black and highly iridescent. Carapace length of male paratype 1.18.

**Female Allotype:** Total length 4.1, carapace 1.55 long, 1.09 wide. Eyerow I width 0.90, eyerow III width 1.09, eyefield length 0.75. Eye diameters: AME 0.27, ALE 0.15, PME 0.03.
Fig. 1. Paradamoetas changuinola immature, scanning electron micrographs, markers are 10 μm: (A) White scales at lateral border of carapace; (B) Smooth iridescent scale from opisthosoma (I) with sensory seta (S).

PLE 0.17. Distance ALE-PME 0.17, PLE-PME 0.20. Femora lengths I 0.80, II 0.65, III 0.70, IV 1.14. Leg formula 4132. Spination and coloration as in male. Carapace length of female paratype 1.50.


SYNOPSIS AND DISTRIBUTION OF PARADAMOETAS

P. cera (Peckham and Peckham). El Salvador, Guatemala, Honduras, eastern Mexico.
P. changuinola n. sp. Panama.
P. fontana (Levi). Canada, Ontario; United States, Minnesota, Wisconsin.
P. formicina Peckham and Peckham. Guatemala; Mexico, Chiapas; Nicaragua; United States, Texas. Type species of genus.

KEY TO THE SPECIES OF PARADAMOETAS

1. Males .......................................................... 2
   Females (best differentiated by details of the internal tubes of the epigynum) ........ 5
2(1). Cheliceral fang groove deeply excavated, retromarginal cheliceral tooth basal .......... 2
      Cheliceral fang groove not deeply excavated, retromarginal cheliceral tooth distal . 3
Figs. 2-4. (2) *Paradamoetas* male chelicerae; (A) *P. changinola*; (B) *P. cara*. (3) *Paradamoetas* females, internal view of left spermathecae. Markers are 0.17 mm. Arrow indicates anterior; (A) *P. changinola*; (B) *P. formicina*. (4) *Paradamoetas changinola* genitalia. Markers are 0.17 mm; (A) Ventral view of left male palpus; (B) External view of epigynum, C = clear area; (C) Internal view of epigynum. Arrows indicate openings for embolic insertion.
3(2). Promarginal cheliceral tooth opposite retromarginal tooth (Fig. 2a) ... changulinola
Promarginal cheliceral tooth proximal relative to retromarginal tooth (Fig. 2b) ... 4
4(3). Embolus a simple curve with one bend ........................................... cara
Embolus sinuous, with two bends .................................................. formicina
5(1). Epigynum elongated parallel to longitudinal axis of opisthosoma .......... cara
Epigynum elongated parallel to transverse axis of opisthosoma ............... 6
6(5). Epigynum with clear area (openings of copulatory tubes at the sides of this area) separated from spermathecae ........................................... fontana
Epigynum with spermathecae intruding into this clear area ..................... 7
7(6). Spermathecae as in Fig. 3a, note greater anteriad extension of laterad portion of spermatheca compared to Fig. 3b .......................... changulinola
Spermathecae as in Fig. 3b .................................................. formicina

LITERATURE CITED

ENTOMOLOGICAL NOTE

FIRST REPORT OF THE LEAFHOPPER GRAMINELLA FITCHII FOR MICHIGAN
(HOMOPTERA: CICADELLIDAE)

While working on a leafhopper project I came across four specimens of Graminella fitchii
(Van Duzee) in the Entomology Museum, Department of Entomology, Michigan State Uni­
versity, and five specimens in the Museum of Zoology, The University of Michigan. This is
the first report of this species in Michigan and brings the total number of species of leaf­
hoppers recorded from the state to 228 (Taboada, Great Lakes Entomol. 12:99–100, 1979).

This species is found in moist habitats and is common in the eastern states, ranging west to
Kansas and north to Ontario (Bierne, Canadian Entomol. Supp. 2:1–180, 1956, Delong,
Midland, and St. Joseph counties.

Oscar Taboada
Department of Entomology
Michigan State University
East Lansing, MI 48824
ERRATA

The following corrections should be noted in the paper

A NEW METHOD FOR EXPOSING DEPOSIT FEEDERS TO
CONTAMINATED SEDIMENTS FOR FOOD CHAIN STUDIES

by Dale Roberts and Peter G. Meier, which appeared in Volume 15:59-64.

Page 59, line 38: "< 0.05 µg/g" should be "< 0.005 µg/g"
Page 59, line 41: "0.1 mg/ml" should be "0.01 mg/ml"
Page 61, line 10: "1, 10, and 100 µg/g" should be "0.1, 1.0, and 10 µg/g"
Page 61, line 17: "1, 10, and 100 µg/g" should be "0.1, 1.0, and 10 µg/g"
Page 61, line 31: "3 µg/g" should be "0.3 µg/g"
Page 61, Figure 3: the ordinate scale for µg/g PCB should be from 0.2 to 1.0 instead of 2 to 10.
Page 62, Figure 4: the ordinate scale for µg/g PCB should be from 1.0 to 12.0 instead of 10 to 120.
Page 63, Table 1: the sediment concentrations in the boxheading should be 0.1, 1.0, and 10.0 µg/g instead of 1, 10, 100 µg/g.
BOOK REVIEW


Among the most conspicuous of the true bugs are the pentatomoid Hemiptera, stink bugs and their relatives, many of which are large, or moderately so, and brightly colored. Unwary berry pickers probably can recount an unpleasant experience with fruit tainted by the noisome odor of a stink bug, and the characteristic, barrel-shaped eggs of most Pentatomidae, often ornate and arranged in neat rows, have evoked the wonderment of naturalists and prompted numerous technical descriptions from entomologists. Contributing to the importance of this group are the crop losses inflicted by certain plant-feeding species and the destruction of insect pests by predatory stink bugs (Asopinae).

Professor McPherson now has brought together the scattered literature treating biology and distribution of the Acanthosomatidae, Corimelaenidae, Cydnidae, Pentatomidae, and Scutelleridae occurring in the northeastern United States and Canada. His thorough review of host-plant and predator-prey records, many obscured in regional faunal lists, and his updated keys to genera and species will be useful to hemipterists and nonspecialists.

The introductory sections include a brief review of the Hemiptera-Heteroptera and the superfamily Pentatomoidea. There also is a short history of work on the North American pentatomoid fauna and a list of workers who have contributed to the taxonomy and biology of the group. Instead of names presented without distinction between major workers and those of passing interest in stink bugs, a reader might have been interested in knowing which hemipterists made the greatest contributions and something about their accomplishments. Other introductory comments are devoted to the derivation of the northeastern pentatomoid fauna, generalized life history and habits, and higher classification. Preceding the keys and species write-ups is a statement of methods: geographic coverage, collections examined, and format regarding synonymy, acceptance of host records, use of scientific and common names of plants, and insect nomenclature. The major part of the book, the keys and biology (p. 9-114), is followed by eight tables (checklist of northeastern species, selected list of faunistic surveys, species collected at light, in beach drift, at high elevation, and prey of Podisus maculiventris (Say), P. modestus (Dallas), and P. serieventris Uhler), 102 morphological illustrations, and maps showing the Illinois distribution of 88 species or subspecies.

In the introductory section on biology there is almost as much information on morphology as there is on natural history. A reader might have gained a better feel for the habits of these bugs if it had been mentioned that certain members of Banasa, Euschistus, Thyanta, and other genera show a preference for developing or ripe fruits of their hosts and that nymphs of many cydnids are root feeders. Photographs of eggs showing their ornamentation and arrangement in clusters, and of predation by an asopine would have enhanced the value of the book for students and nonspecialists. A section on economic importance of stink bugs would have been useful. A reader also might like to know the rationale behind the geographic area chosen: “Labrador west to northeastern Manitoba, south through western Minnesota and western Missouri, and east to southern Virginia.” Even though the work is regional in scope with an emphasis on the fauna of Illinois, it is good to see that several extralimital species are included in the keys and review of species. I cannot resist adding that given the relatively small number of pentatomoid species occurring east of the Mississippi, a treatment of the southeastern fauna would have been welcomed.

The remainder of the book is devoted to keys to higher categories and species and to a review of distribution, host plants (or prey records for predacious taxa), habits (including overwintering stages, spring emergence, mating, oviposition), and, when appropriate, comments on nomenclatural problems and references to descriptions of immature stages and to natural enemies. Some 120 species and subspecies are covered. The only one I found...
omitted for which published records were available is the Old World cydnid *Aethus nigritus* (F.), an introduced species recorded from Delaware (Hoebeke, USDA Coop. Plant Pest Rep. 3(29): 376, 1978) and Connecticut (Hoebeke, Ibid. 5(36):691, 1980).

The literature coverage is remarkably thorough; even the most obscure local lists are included. It may be appropriate here to mention a rather inaccessible mimeograph series in which western Pennsylvania records are given. J. L. Swauger has listed the stink bugs of Powdermill Nature Reserve in the Carnegie Museum of Natural History Education Releases No. 32 (1960) and 43 (1964), and Research Reports No. 6 (1961) and 32 (1973).

The keys, adapted from various sources but with several improvements, appear workable, well illustrated (a few habitus drawings or photographs would have helped), and free of confusing terminology. Even the common species of the “difficult” corimelaenid genus *Galupha* can now be identified with some assurance! The nomenclature is sound, although some authorities are bound to dispute the validity of names used for certain taxa. McPherson clearly states that other sources are to be consulted for generic and specific synonymies, but it might have been useful to point out that the genus *Pitedia* Amyot is used in some recent works instead of *Chlorochroa* Say (see Sailer, Bull. Entomol. Soc. Amer. 26:40, 1980), or that *Elasmucha lateralis* (Say) often has been called *Meadorus lateralis*.

I found few errors in the recording of distributions; one that seems inaccurate is the Pacific Northwest record for *Neotiglossa cavifrons* Stal. Although Stoner (Canadian Entomol. 58:29, 1926) recorded this pentatomid from Victoria, British Columbia, his records pertain to *N. tumidifrons* Downes, or possibly also to *N. sulcifrons* Stal (see Downes, Canadian Entomol. 60:92, 1928). For *Nezara viridula* it might have been useful to note it is widespread in the tropics and is nearly cosmopolitan in distribution.

Host plants are thoroughly reviewed, but the listing of numerous plants for polyphagous species, in a few cases without much discussion, tends to obscure trends and to make it difficult for the user to pick out a particular host from the lists. It would be nice to know that some general feeder occurs most often on certain plants and seems to prefer, say, legumes. The addition of host plants (and prey) to the checklist of pentatomoid species (Table 1) would have been invaluable. In most cases common names are used for hosts so that the reader is apt to wonder about scientific names. An appendix giving botanical names and families (or added to an expanded checklist of pentatomoids and their hosts, possibly in place of the Illinois distribution maps) also would have been useful.

Host information that is potentially misleading occurs under *Banasa euchlora* Stal. This species is said to have been taken several times on “cedar”; then McPherson notes that he has seen a specimen with a *Juniperus* label. The cedar records undoubtedly refer to red cedar, *Juniperus virginiana* L. (or a related species), on which I have taken nymphs and adults of *B. euchlora*.

This 6 x 9 inch book is well bound and has an attractive stink bug embossed in gold on the cover; the paper quality is good. The book also is well indexed, and there are few problems with typographical errors, grammar, or syntax.

None of my comments should be construed as seriously detracting from this volume; my overall impression is favorable. McPherson’s *Pentatomoidea* should be on the bookshelf of hemipterists and really anyone with an interest in the group. Indeed, it is indispensable for its compilation of the literature and updated keys. Now who said a book devoted to stink bugs had to be repugnant?

A. G. Wheeler, Jr.,
Bureau of Plant Industry
Department of Agriculture
Harrisburg, PA 17110.
CONTINUED FROM OUTSIDE BACK COVER

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COVER ILLUSTRATION

Teneral adult cicada, Tibicen linei (Smith and Grossbeck) (Homoptera: Cicadidae).
Photograph by Nancy Wells-Gosling, School of Natural Resources, The University of Michigan.

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INFORMATION FOR AUTHORS

Papers dealing with any aspect of entomology will be considered for publication in The Great Lakes Entomologist. Appropriate subjects are those of interest to amateur and professional entomologists in the North Central States and Canada, as well as general papers and revisions directed to a larger audience while retaining an interest to readers in our geographical area.

Manuscripts must be typed, double-spaced, with wide margins on white 8½ × 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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All manuscripts for The Great Lakes Entomologist should be sent to the Editor, Dr. D. C. L. Gosling, 69063 Wallowa Road, White Pigeon, Michigan 49099, USA. Other correspondence should be directed to the Executive Secretary (see inside front cover).