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Hetoemis cinerea (Olivier) (Coleoptera: Cerambycidae) feeding on a leaf of Morus alba L. Photograph by Nancy Wells Gosling, School of Natural Resources, The University of Michigan.

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EFFECTS OF ALUMINUM FOIL MULCH ON PARASITISM AND FECUNDITY OF APTEROUS MYZUS PERSICA (HOMOPTERA: APHIDIDAE)¹

Frank G. Zalom² and Whitney S. Cranshaw

ABSTRACT

Chinese cabbage plants grown in flats containing either aluminum foil mulch or no mulch cover were uniformly infested with a single apterous adult *Myzus persicae* (Sulzer) and exposed in a greenhouse to a free-flying population of the parasite *Aphidius ervi* (Haliday). Aphid fecundity, plant growth, and temperature were greater in reflective mulch plots. Aphid parasitism was lower over mulched plots until foliage growth obscured the mulch. Later, parasitism was more frequent in mulched plots. The effects upon parasitism, fecundity, and microclimate may explain instances where aluminum mulches have not reduced aphid populations.

Reflective mulches represent a unique approach to reducing the spread of nonpersistent viruses (Kring 1964). The mulches act by reflecting the sun's ultraviolet (UV) rays, thus confusing the insect vector (Toscano et al. 1979). Reduced numbers of alate aphids alighting on plants and increased yields often result from this treatment (e.g. Wyman et al. 1979). Failure of mulches to adequately protect crops has been attributed to insufficient reflective surface (Dickson and Laird 1966, Rothman 1967), overabundance of vectors (Kring 1972), and plant growth over the mulches (e.g. Shands and Simpson 1972). Cranshaw and Radcliffe (1980) observed that a significant reduction occurred in captures of alate green peach aphid, *Myzus persicae* (Sulzer), over mulched potato plots through midseason, but that apterae on foliage were not well correlated with the alate captures. They speculated that interference with natural control over mulched plots may contribute to a higher rate of population growth by aphids colonizing mulched plots. Such secondary effects may obscure the evaluation of a mulch for plant protection particularly if primary spread by vectors early in the season is of greatest importance. and if the evaluation is made by checking apterae populations.

Here we demonstrate that aluminum foil mulching influences parasitism, aphid fecundity, and plant growth when compared to unmulched controls.

METHODS

Twenty-four wooden flats were arranged in a row two deep and 12 across on the bench in a glasshouse on the University of Minnesota campus. Each flat was filled with soil and seeded with Chinese cabbage at 13-cm intervals (12 plants/flat). Four adjacent flats constituted one replication of a treatment (48 plants total). Treatments consisted of covering the soil, excluding a 1.5 cm hole around the base of a seedling, with aluminum foil, or allowing the plants to grow over bare soil. Ultraviolet lamps were suspended 1 m above the surface of the flats to increase the intensity of UV light that was potentially reduced by the glass roof. A thermostat in the glasshouse remained set at 22°C for the experiment. A recording therm-
oograph measured the temperature immediately above the mulched and unmulched treatments. Weeds were manually removed from each flat.

When the first true leaf of each plant became fully expanded, a single aipterus adult green peach aphid was transferred to the leaf. On the same day, 24 mature cabbage plants containing numerous aphid mummies were removed from a colony cage of a braconid parasite, *Aphidius ervi* (Haliday), of the green peach aphid. The plants were evenly spaced along the length of the bench at least 25 cm from the nearest cabbage plant to allow equal dispersal of the parasites over control and treatment plots.

One week following the aphid transfer and twice weekly thereafter, 12 plants from the central area of each block were inspected for total numbers of aphids, aphid mummies, and leaves. Aphid mummies were removed from the leaves after counting. Cabbage plants from border rows in each block were not considered. Final counts were made four weeks following the initial infestation as the plants had grown to cover the mulch.

**RESULTS**

Aphid mummies were recorded on some of the Chinese cabbage plants one week after infestation by aphids and subsequent release of parasites. Initially, the number of mummies on the plants in the unmulched treatment exceeded that of the mulched treatment, but the trend was reversed beginning with the fourth sampling period (Fig. 1). The differences between the treatments were significant (*P* < 0.05) in each of the first two and final two sampling periods when compared by 2-way analysis of variance. No significant difference (*P* > 0.05) was recorded in sampling periods 3 (*F* 1 4 = 2.627) or 4 (*F* 1 4 = 2.041).

More aphids were recorded from mulched plots than unmulched plots on each sampling date (Fig. 2). Although the differences were not significant (*P* > 0.05) in sampling period 1 (*F* 1 4 = 5.077) or 2 (*F* 1 4 = 4.103), the differences were significant (*P* < 0.05) in each period thereafter when compared by 2-way analysis of variance.

The Chinese cabbage plants from blocks covered with foil mulching appeared to be noticeably larger and more robust than those from unmulched plots throughout the experiment. The mean total number leaves per 12 plants from mulched blocks was significantly (*P* < 0.05) greater than that of unmulched blocks during each sampling period when compared by 2-way analysis of variance (Fig. 3). The reflective surface was estimated to be 90% occluded due to plant growth by the fourth sampling period. Large deposits of honeydew on leaf surfaces were noted beginning with the fifth sampling period. Air temperature immediately above the mulched plots was ca. 3°C warmer than over unmulched plots prior to occlusion of the reflective surface.

**DISCUSSION**

Aluminum foil mulching seemed to significantly affect parasitism, aphid fecundity, and plant growth in our experiment. As all three factors may influence one another, the contribution of each could not be separated, but some general trends became apparent.

Significantly less parasitism was noted over mulched plots than unmulched plots before the plants grew so as to cover most of the foil, suggesting an effect on the parasites similar to that of alate aphids flying over reflective surfaces. Under these circumstances, a few initial colonizers could increase at a greater rate on mulched plots than unmulched plots. The tremendous increase in aphid mummies on the final sampling dates within blocks with a reflective surface was probably a function of increased aphid abundance on those plants and lack of interference from the foil.
Nawrocka et al. (1975) showed that although alate aphids landing on lettuce were lowest in plots treated with aluminum foil mulch, the greatest production of winged aphids also occurred on those plots. Increased fecundity could have been due to the warmer temperature (Daniels 1957, Coon 1959) noted over mulched plots. Higher reproductive rates resulting from the use of reflective mulches might require some other treatment to reduce the number of colonizers.

Figure 1. Mean \( \pm \) SD total number of green peach aphid mummies per 12 Chinese cabbage plants in flats with and without reflective mulches.
Figure 2. Mean (± SD) total number of green peach aphids per 12 Chinese cabbage plants in flats with and without reflective mulches.
Figure 3. Mean (± SD) total number of leaves per 12 Chinese cabbage plants in flats with and without reflective mulches.
LITERATURE CITED


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FIELD RELEASE OF VIRUS-SPRAYED ADULT PARASITOIDS OF THE EUROPEAN PINE SAWFLY (HYMENOPTERA: DIPRIONIDAE) IN WISCONSIN

M. A. Mohamed, H. C. Coppel, D. J. Hall and J. D. Podgwaite

ABSTRACT

Rapid field release of adult parasitoids sprayed with the nucleopolyhedrosis virus of the European pine sawfly successfully transferred the virus to feeding larval colonies.

Laboratory studies by Thompson and Steinhaus (1950) showed that the parasitoid Apanteles medicaginis (Muesebeck) could mechanically vector the virus of the alfalfa caterpillar Colias eurytheme Boisduval. Infection occurred primarily as a result of stinging with the contaminated ovipositor; however it was also suggested that body contamination of the parasitoids could spread the virus over the food plant of the pest. These same authors showed that when ants were fed on virus-filled larval cadavers and allowed to walk over uncontaminated plants, the latter became infectious when fed to healthy larvae. Stairs (1976) reported on virus dispersion and indicated that certain parasitoids play a key role in the development of epizootics because they vector the virus efficiently. He used the sarcophagid parasitoid, Sarcophaga aldrichi (Parker) to illustrate his point. These adult parasitoids are attracted to recently virus-killed larvae of the forest tent caterpillar, Malacosoma disstria (Hübner) and feed on them. Their bodies become contaminated and the virus is transferred to foliage later consumed by the host larvae. The intensity of the epizootics varied directly with the population levels of the adult parasites. Our field study is corroborative with the observations of Stairs (1976) except that we used the ichneumonid parasitoid, Lophyroplectus oblongopunctatus (Hartig), recently introduced and established in Wisconsin against the European pine sawfly, Neodiprion sertifer (Geoffroy) (Kraemer et al. 1979). We herein report the experimental manipulation of virus-sprayed parasitoids for pest suppression.

MATERIALS AND METHODS

Larvae of the European pine sawfly were collected in 1980 from the site where L. oblongopunctatus was released in 1977 (Kraemer et al. 1979). These were reared by Hall to the cocoon stage in 10# paper bags provided with foliage. Adult sawflies emerged in the fall of 1980 and those cocoons from which no sawflies emerged were stored at refrigerator temperature (4°C) during the winter months. The overwintered cocoons were placed in incubation (room temperature 21°C) during mid-April. Male and female parasitoids were observed mating in the cages. We divided the parasitoids into two groups, each consisting of ca 100 individuals in a 2:1 ratio of females to males. One group was left untreated whereas the

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2 Department of Entomology, University of Wisconsin, Madison, WI 53706.
3 Wisconsin Department of Natural Resources, Madison, WI 53706.
4 Northeastern Forest Experiment Station, Hamden, CT 06514.
second group was treated with virus while in the emergence cage. The parasitoids were sprayed with 10 ml aliquots of an aqueous suspension of the nucleopolyhedrosis virus at a concentration of $2.6 \times 10^7$ polyhedral inclusion bodies (PIB) per milliIitre. A chromist atomizer was utilized. The adults were sprayed three times with a 15 min drying period between sprays. The two groups were then transferred for release in the field.

We selected two plantations of red pine, *Pinus resinosa* Ait., where second instar *N. sertifer* larvae predominated. The densities were relatively high at 3–10 colonies per tree. Both plantations were monitored one week prior to parasitoid release. This consisted of searching for visual evidence of virus infected larvae as well as sampling apparently healthy larvae. Healthy larvae were macerated in the laboratory and examined for PIB by brightfield microscopy at 600X. After parasitoid release the plantations were monitored weekly for three weeks to detect diseased or dead larvae. Approximately 50 trees within a 90-m radius from the point of parasitoid release were examined in each plot.

Dead larvae, suspected of being virus-killed, were stored singly in sterile plastic disposable test tubes and examined in the laboratory as previously described. Two subsamples were taken at random from each larval colony which showed some mortality.

**RESULTS AND DISCUSSION**

We found no evidence of virus presence in either plantation prior to parasitoid release. Direct observations immediately following field releases showed considerable activity by the female parasitoids in and around the larval colonies. The larvae in the plantation where virus-free parasitoids were released gave no indication of nucleopolyhedrosis infection up to 21 days whereas the plantation where virus-sprayed adults were released showed 0.4% mortality from virus infection after 14 days. After 21 days the mortality rose to 2%. Dead larvae were in instars 4 to 6 and upon examination for PIB had an average of $5 \times 10^4$ PIB/larva after 14 days and $2.13 \times 10^6$ PIB/larva after 21 days.

Though the percentage mortality was low, the numbers of virus-sprayed adults released was also low. Thus the idea of introducing a virus by means of a parasitoid vector was amply demonstrated. Such a strategy does not entail large investments and ensures some measure of dispersal with the potential of reaching locations inaccessible to mist blowers or other power equipment (Franz 1964). Because the parasitoid’s presence is marked by diseased colonies one could use such data to measure its dispersal capacity as well as its microhabitat preference. Such information would be of considerable value in a classical biological control program.

**ACKNOWLEDGMENTS**

The authors gratefully acknowledge the technical assistance of Odette Mohamed.

**LITERATURE CITED**


CORRECT IDENTITY OF THE OAK TWIG PRUNER (COLEOPTERA: CERAMBYCIDAE)

D. C. L. Gosling

The oak twig pruner is a cerambycid of minor economic importance which is generally common through most of eastern North America. The adult beetles oviposit on living twigs of oak and other hardwoods, and the larvae bore within the twig, subsequently pruning it from the tree. Haldeman (1847) identified this borer as Elaphidion villosus (Fabricius), a species later placed in the genus Elaphidionoides by Linsley (1963). This identification has been accepted and followed by Baker (1972), Craighead (1923, 1950), Duffy (1960), Knull (1946), Linsley (1963), and many other authors.

A sibling species, Elaphidionoides parallelus (Newman), has frequently been confused with villosus, and was for a time regarded as the same species. The difficulty in distinguishing adults of the two species created a likely situation for error in observations of their biology, but this possibility seems to have received little consideration. The habits of parallelus have simply been described as similar to those of villosus (Knoll 1946, Linsley 1963), and parallelus has been widely ignored by authors dealing with forest insect pests.

Craighead (1923, p. 70) had a clue to the possible confusion when he observed that the beetle he considered to be villosus "is sometimes reared from branches which are dead, and in this case does not girdle them. This may be a different species, as some of the larvae show variations from the form described." He did not distinguish the habits or larva of parallelus, although what he did describe now seems to refer to that species.

My recent ecological study of Cerambycidae in southwestern Michigan (Gosling 1981) provided an opportunity to observe both species over a period of six years. I have previously described the habits of parallelus and characters useful in identifying the adults (Gosling 1978), but at that time I had not yet observed the larval activities of villosus. Subsequent success in rearing villosus from several hostplants has helped to clarify the identity of the twig pruner and relationships between the species.

The study was conducted from 1976 to 1981 in an 80-ha woodland near Tamarack Lake in St. Joseph County, Michigan. As part of a rearing program, host materials were gathered in the study area and enclosed in screened cages. Twigs infested by the twig pruner can be easily identified and 638 were collected in this manner, plus 55 twigs from another woodland nearby. All of the 280 adult beetles subsequently reared from these twigs were found to be parallelus.

Thirty-seven adults of villosus were reared from other host materials. These included branches of Tilia americana L., Acer rubrum L., and Cercis canadensis L.; a stem of Toxicodendron radicans (L.) Kuntze; and bolts of Carya glabra (Miller) Sweet. All of these hostplants were dead at the time of oviposition. The branches were 1–3 cm d and the Carya bolts were 7 cm d and larger. Adult beetles were also beaten from dead branches of Quercus velutina Lamarck and Tilia americana, and collected from a bolt of Carpinus caroliniana Walter. In all cases the adult was reared from or associated with host material which was recently dead, and generally much larger than the twigs from which parallelus adults were obtained.

These observations show that parallelus, not villosus, is the borer which regularly attacks small, living twigs of oak and other hardwoods in southwestern Michigan. E. villosus adults oviposit in branches which are recently dead and usually larger in diameter. There is no reason to believe the host selection behavior of these species in the study area is different from that elsewhere in their ranges. The identification of villosus as a twig pruner, then, is not correct.

Other differences in the behavior of these species have been noted. E. parallelus adults

1 69063 Wallowa Road, White Pigeon, MI 49099.
show an overwhelming preference for *Quercus velutina* and *Q. rubra* L. as hostplants, and only rarely attack other species of *Quercus* and *Carya*. *E. villosus* seems much more cosmopolitan in its host selection, and most of the adults were reared from *Tilia* and *Carya*. There is also a difference in their adult activity periods. Adults of *parallelus* in southwestern Michigan emerge in late May and early June, while *villosus* adults emerge later, from mid- through late June. Flight activity of *parallelus* extends from late May through early July, and that of *villosus* from mid-June through July. A similar pattern in activity periods of these species has been observed in material collected in Connecticut by M. E. Montgomery (pers. comm). 2

The published accounts of twig pruner activity cited above refer to *parallelus* and the larval behavior of *villosus* has not been described. A typical *villosus* larva feeds beneath the bark of the branch, excavating a broad, irregularly shaped chamber with an overall length of 100-150 mm and 5-20 mm wide. Its boring removes the inner bark and cuts 2-3 mm into the sapwood, leaving a paper-thin layer of outer bark covering the chamber. If the larva is boring in a small branch it will usually pupate between plugs of shredded wood in a narrow extension of the chamber. In a larger branch the larva extends a narrow, oval gallery to the center of the branch and continues down the center for as much as 120 mm. Pupation then takes place between shredded-wood plugs near the end of this gallery. In either case the emerging adult exits through a hole in the bark cut previously and used for expelling frass. The life-cycle requires two years to complete in southwestern Michigan, and adults are usually present only in odd-number years.

The larval behavior of *villosus* is similar to that of *parallelus* in several respects. *E. parallelus* larvae often excavate a smaller version of the feeding chamber before starting their principal gallery in the main stem of twig. Both species expel frass during larval feeding, and both exit as adults through pre-existing holes. If the size of the host material permits, both borers excavate a similar gallery down the center of the twig or branch and pupate at the end of it between plugs of shredded wood. The principal differences are that *parallelus* larvae begin feeding in a living twig, feed mostly by narrow galleries extended in the sapwood, and make their characteristic pruning cut which often severs the twig from the host tree. *E. villosus* larvae feed in recently dead hostplants, in a broad chamber beneath the bark, and do not make a pruning cut.

These differences in larval feeding behavior seem to be adaptations to the differences in size of host material utilized and probably in its condition as well. The mating behavior of these beetles has only been observed in cages, where adults copulate shortly after emergence. It is not known if differences in host selection serve to isolate adults while mating, but their difference in emergence period undoubtedly provides effective temporal isolation between these sympatric and presumably closely related species.

**LITERATURE CITED**


2 Northeastern Forest Experiment Station, Hamden, CT 06514.
EVALUATION OF ADULT COTTONWOOD LEAF BEETLE, 
CHRYSOMELA SCRIPTA (COLEOPTERA: CHRYSOMELIDAE), 
FEEDING PREFERENCE FOR HYBRID POPLARS

M. O. Harrell2, D. M. Benjamin3, J. G. Berbee4, and T. R. Burkot3

ABSTRACT

Foliage from the Leuce section of Populus was rejected for feeding by Chrysomela scripta adults in a choice test involving 12 hybrid poplar clones. Adults showed a feeding preference for the foliage from the Tacamahaca clones when compared to the Aigeiros clones.

The cottonwood leaf beetle, Chrysomela scripta Fabricius, is one of the most serious defoliators of hybrid poplars in the north central United States. Nursery and plantation trees often are severely stunted and deformed as the adults and larvae consume the immature foliage and kill the terminal shoots.

A number of recently developed hybrid poplar clones are currently being evaluated for use with intensively managed forest systems. One aspect of these evaluations deals with the susceptibility of these clones to insects and diseases. Recent reports by Caldbeck et al. (1978) in Iowa, and Wilson (1979) in Michigan suggested that a degree of resistance to the cottonwood leaf beetle exists in some clones. Outplantings examined following high beetle populations showed wide variations in the severity of damage.

At the University of Wisconsin, a tissue-culture process was used to develop Populus × euramericana (Dode) Guinier trees from callus tissue. Although these trees are considered to be genotypically identical, differences occur in their growth rates, branching characteristics, and leaf traits (Lester and Berbee 1977); preliminary examinations indicated some variation in their susceptibility to the cottonwood leaf beetle also existed (Burkot 1978).

Hybrid clones have been derived from each of the three major sections of the genus Populus; i.e. Leuce, the aspens and white poplars; Aigeiros, the black poplars; and Tacamahaca, the balsam poplars. These crosses have involved many native as well as exotic species. The leaf beetle is known to feed on species in the sections Aigeiros and Tacamahaca (Brown 1956), but it has not been reported in natural situations feeding on species of Leuce.

Studies by Caldbeck et al. (1978) and Wilson (1979) identified the more resistant hybrid poplar clones among those included in their studies, but their analyses did not allow extrapolation to clones not included or not yet developed. By relating the degree of resistance of a clone to the parentage of the clone this extrapolation is possible, and such information concerning cottonwood leaf beetle adult feeding preference is presented here.

1 Research supported by the School of Natural Resources, College of Agricultural and Life Sciences, University of Wisconsin, Madison, and the North Central Forest Experiment Station, USDA Forest Service Cooperative Research Grant No. 13–606.
2 Department of Forestry, Fisheries and Wildlife, University of Nebraska, Lincoln, NE 68583.
3 Department of Entomology, University of Wisconsin, Madison, WI 53706.
4 Department of Plant Pathology, University of Wisconsin, Madison, WI 53706.
MATERIALS AND METHODS

The adults used in this study were the progeny of *C. scripta* adults collected in 1979 from a planting of tissue-cultured *Populus × euramericana* at the F. G. Wilson Nursery, Boscobel, Wisconsin. The insects were reared in the laboratory on the immature foliage of tissue-cultured subclone no. 13 of *P. × euramericana* "Wisconsin no. 5."

Twelve hybrid poplar clones currently under study at the North Central Forest Experiment Station, Forestry Sciences Laboratory, Rhinelander, Wisconsin, were selected for this study based on the findings by Caldbeck et al. (1978), and on the availability of the clones from the Forest Experiment Station; an attempt was made to select clones representing a broad range of susceptibilities to the leaf beetle (Table I). In addition, eight tissue-cultured subclones (nos. 4, 6, 7, 13, 15, 4H, 7H, 17H) of *P. × euramericana* "Wisconsin no. 5" were selected to represent subclones derived from different calli produced both from heat-treated and untreated meristematic tips of the parent clone.

Leaf discs 11 mm in diameter were cut from each of the 12 clones and eight subclones, and these were soaked in water to promote saturation. Immature foliage was chosen because of the preference for this shown by *C. scripta* adults (Harrell 1980). One leaf disc from each of the 12 clones was placed randomly around the perimeter of a 9-cm-diameter Petri dish. The discs were kept in their position and slightly raised using minuten pins and a paraffin base. A moistened filter paper lining was used to prevent desiccation. One adult beetle was placed in the covered dish and allowed to feed for 24 hours. The area consumed from each leaf disc was recorded at the end of the feeding period. This design was replicated 12 times using the 12 NCFES clones and 12 times using the eight tissue-cultured subclones and their parent clone.

The leaf areas consumed were determined using a 1.5-mm-interval dot grid and the mean of three counts. The areas consumed from the leaf discs of groups of parentages were compared using Student's t-test (Sokal and Rohlf 1969). Leaf water levels were calculated for each of the clones from the fresh and dry weights of samples. Nitrogen levels were determined using a micro-Kjeldahl technique. Correlations were examined between the total leaf areas consumed and the leaf water and nitrogen levels determined in this study, and also the nitrogen and carbohydrate levels as found by Dickson and Larson (1977).

Table 1. *Populus* clones from NCFES used in the study of *C. scripta* adult feeding preference.

<table>
<thead>
<tr>
<th>NCFES clone no.</th>
<th>Defoliation Level (%)</th>
<th>Parentage</th>
<th>Sectional composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>5339</td>
<td>0</td>
<td><em>Populus alba × P. grandidentata</em></td>
<td>100% Leuce</td>
</tr>
<tr>
<td>5272</td>
<td>22</td>
<td><em>P. nigra × P. laurifolia</em></td>
<td>50% A., 50% T.</td>
</tr>
<tr>
<td>5331</td>
<td>33</td>
<td><em>P. betulifolia × P. trichocarpa</em></td>
<td>50% A., 50% T.</td>
</tr>
<tr>
<td>5322</td>
<td>41</td>
<td><em>P. × euramericana</em></td>
<td>100% Aigeiros</td>
</tr>
<tr>
<td>5260</td>
<td>47</td>
<td><em>P. tristis × P. balsamifera</em></td>
<td>100% Tacamahaca</td>
</tr>
<tr>
<td>5332</td>
<td>49</td>
<td><em>P. betulifolia × P. trichocarpa</em></td>
<td>50% A., 50% T.</td>
</tr>
<tr>
<td>5266</td>
<td>51</td>
<td><em>P. angulata × P. trichocarpa</em></td>
<td>25% A., 75% T.</td>
</tr>
<tr>
<td>5262</td>
<td>52</td>
<td><em>P. candicans × P. berolinensis</em></td>
<td>25% A., 75% T.</td>
</tr>
<tr>
<td>5377</td>
<td>65</td>
<td><em>P. × euramericana</em> &quot;Wisconsin no. 5&quot;</td>
<td>100% Aigeiros</td>
</tr>
<tr>
<td>5334</td>
<td>66</td>
<td><em>P. angulata × P. trichocarpa</em></td>
<td>50% A., 50% T.</td>
</tr>
<tr>
<td>5263</td>
<td>68</td>
<td><em>P. candicans × P. berolinensis</em></td>
<td>25% A., 75% T.</td>
</tr>
<tr>
<td>5264</td>
<td>78</td>
<td><em>P. angulata × P. plantierensis</em></td>
<td>100% Aigeiros</td>
</tr>
</tbody>
</table>

a Level of defoliation reported by Caldbeck et al. (1978).
b A. = Aigeiros; T. = Tacamahaca
c *P. berolinensis* = *P. nigra × P. laurifolia
RESULTS AND DISCUSSION

Adult beetles showed a significant (P < 0.01) non-preference for the Leuce foliage when compared to the Aigeiros and Tacamahaca foliage (Table 2). Adults also showed preferences for pure Tacamahaca foliage when compared to pure Aigeiros (P < 0.05), and for clones of 75% Tacamahaca when compared to 50% Tacamahaca (P < 0.06). No differences were found within any other comparisons, including those made among the tissue-cultured sub-clones and their parent clone. In no replicate did an adult consume an entire leaf disc, and in each replicate the wandering of the adult was more than sufficient to allow repeated encounters with each type of foliage.

The non-preference shown by the leaf beetle for the Leuce foliage was expected since the aspens and white poplars that comprise this section are not reported hosts of the beetle. Caldebeck et al. (1978) and Wilson (1979), however, showed a small amount of attack for Leuce clones such as 5339. The difference in the relative feeding preferences found between the Aigeiros and Tacamahaca foliage suggests that variations in susceptibility to the leaf beetle exist also among the clones derived from the beetle's natural hosts.

The foliar components responsible for the differences in feeding intensity on the Aigeiros and Tacamahaca clones have not been determined. No correlations were found between the total leaf areas consumed and either the moisture, nitrogen, or carbohydrate levels of the clones, and there were no apparent differences in leaf thickness, toughness, or surface characteristics. It also is not clear why a significant difference was apparent between leaf beetle activity on the Aigeiros and Tacamahaca clones in this study, but not in the reports by Caldebeck et al. (1978) and Wilson (1979). Differences among the studies that could account for this include the conditions under which the studies were carried out, the ways in which feeding was measured, and the methods of analysis.

The data presented here and in the reports by Caldebeck et al. (1978) and Wilson (1979) suggest that hybrid poplar clones with Leuce parentages have a high degree of resistance to the cottonwood leaf beetle. The differences in beetle activity on the Aigeiros and Tacamahaca clones found in this study suggest that greater resistance to C. scripta might be achieved by increasing the Aigeiros component of the hybrid clones.

Table II. Comparisons of C. scripta adult feeding intensity on leaf samples in a 12-clone test.

<table>
<thead>
<tr>
<th>Parentage of Clones</th>
<th>Mean leaf area consumed (mm ± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leuce(^a)</td>
<td>0.7 ± 0.45</td>
</tr>
<tr>
<td>Aigeiros &amp; Tacamahaca(^b)</td>
<td>41.1 ± 4.22(^g)</td>
</tr>
<tr>
<td>100% Aigeiros(^c)</td>
<td>36.8 ± 8.72</td>
</tr>
<tr>
<td>100% Tacamahaca(^d)</td>
<td>76.3 ± 14.63(^h)</td>
</tr>
<tr>
<td>50% Tacamahaca(^e)</td>
<td>32.7 ± 5.20</td>
</tr>
<tr>
<td>75% Tacamahaca(^f)</td>
<td>54.0 ± 11.22(^i)</td>
</tr>
</tbody>
</table>

\(^a\) NCFES clone 5339.  
\(^b\) NCFES clones 5260, 5262, 5263, 5264, 5266, 5272, 5322, 5331, 5332, 5334, and 5377.  
\(^c\) NCFES clones 5264, 5322, and 5377.  
\(^d\) NCFES clone 5260.  
\(^e\) NCFES clones 5266, 5272, 5331, 5332 and 5334.  
\(^f\) NCFES clones 5262 and 5263.  
\(^g\) level of significance (P < 0.01)  
\(^h\) level of significance (P < 0.05)  
\(^i\) level of significance (P < 0.06)
LITERATURE CITED


REDESCRIPTION OF *MICROPSECTRA POLITA* (DIPTERA: CHIRONOMIDAE) WITH THE FEMALE AND IMMATURE STAGES

Donald W. Webb 1

Malloch (1915) described *Micropsectra polita* (as *Tanytarsus politus*) from males collected along the banks of Central Dredge Ditch at Easton, Mason County, Illinois. Females of this species were not collected at that time. On 12 February 1974, males, females, and larvae were collected from a small spring-fed seep (Fig. 1) running into Muncie Pond, in Vermilion County, Illinois. Males were easily collected as they swarmed over vegetation along the edge of the seep. Females were collected by sweeping nearby vegetation. Larvae were collected from fine sand covered by 5–10 cm of water; several specimens were reared through to the adult stage.

Fig. 1. Spring-fed seep running into Muncie Pond, 0.5 miles SSE of Muncie, Vermilion County, Illinois.

The terminology in this paper follows Saether (1980).

**Male.** Length 3.51–4.01, 3.74 ± 0.09 mm (N = 5). Head pale brown, pedicel, flagellomeres, clypeus, maxillary palps dark brown. Eyes black, dichoptic, facets of equal size, glabrous. Coronal triangle broad, 1.0–1.1 times longer than wide; coronal setae absent. Scape flattened, ring-shaped, 1.6 times longer than wide; pedicel globose, as long as wide, macrosetae absent; flagellomere lengths 0.054–0.072, 0.064; 0.030–0.042, 0.032; 0.030; 0.030–0.036, 0.034; 0.030–0.036, 0.035; 0.036–0.042, 0.038; 0.036–0.048, 0.041; 0.042–0.048, 0.044; 0.042–0.048, 0.044; 0.042–0.048, 0.046; 0.045–0.054, 0.048; 0.048–0.054, 0.050; 0.414–0.588, 0.528 mm. Clypeus broad, 1.4–2.2, 1.7 times wider than long; clypeal setae 16–23, 19.

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1 Section of Faunistic Surveys and Insect Identification, Illinois Natural History Survey, Champaign, IL 61820
Maxillary palps membranous, cylindrical; length of palpomeres 0.064–0.092, 0.075; 0.058–0.069, 0.064; 0.129–0.161, 0.142; 0.202–0.267, 0.224 mm; setae fuscus, elongate, scattered. Inner vertical setae 3–9, 6; outer vertical setae 1–3, 2; frontal and postorbital setae absent. Cibarial pump triangular, 3.93–4.80, 4.21 mm long, 4.2 times longer than wide. Tentorium 4.41–5.27, 5.03 mm long.


Wing length 2.14–2.72, 2.58 ± 0.11 mm, 4.16 times longer than wide. Membrane hyaline to pale yellow; microtrichia absent; macrosetae elongate, covering entire wing; veins pale brown. Costa ending anterior to apex of wing, not extending beyond apex of $R_{4+5}$. Sc ending slightly beyond middle of wing, not reaching costa. $R_{3+3}$, indistinct, lying along $R_{4+5}$. $R_5$ ending at costa anterior to apex of wing. $M_1+2$ ending slightly posterior to apex of wing. Fork of Cu originates distal to r-m, VR 0.96–1.08, 1.02. Anal vein extends to fork of Cu. Alula reduced, indistinct. Squama small, without marginal fringe of setae.

Legs pale brown, concolor. Fore femur clavate, apex 3.2 times width at base, remaining segments linear. Spur on fore tibia 0.030 mm. Combs on middle and hind tibiae contiguous, spurs absent. Apical claws on tarsomere 5 simple, paired, dark brown. Pulvilli reduced, 0.5 times length of apical claws.

Lengths (in mm) and proportions of legs:

<table>
<thead>
<tr>
<th></th>
<th>$P_1$</th>
<th>$P_2$</th>
<th>$P_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_1$</td>
<td>0.979–1.239, 1.141</td>
<td>0.719–0.887, 0.832</td>
<td>1.025–1.239, 1.178</td>
</tr>
<tr>
<td>$P_2$</td>
<td>0.918–1.209, 1.120</td>
<td>0.826–1.040, 0.982</td>
<td>0.444–0.536, 0.521</td>
</tr>
<tr>
<td>$P_3$</td>
<td>1.148–1.392, 1.312</td>
<td>1.056–1.346, 1.243</td>
<td>0.689–0.872, 0.780</td>
</tr>
<tr>
<td></td>
<td>$ta_1$</td>
<td>$ta_2$</td>
<td>$ta_3$</td>
</tr>
<tr>
<td></td>
<td>0.428–0.505, 0.484</td>
<td>0.291–0.337, 0.328</td>
<td>0.153–0.184, 0.175</td>
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<tr>
<td></td>
<td>0.230–0.291, 0.269</td>
<td>0.153–0.199, 0.181</td>
<td>0.077–0.122, 0.107</td>
</tr>
<tr>
<td></td>
<td>0.337–0.413, 0.390</td>
<td>0.214–0.260, 0.245</td>
<td>0.122–0.138, 0.130</td>
</tr>
<tr>
<td></td>
<td>$ta_4$</td>
<td>$ta_5$</td>
<td>LR</td>
</tr>
<tr>
<td></td>
<td>1.934–1.998</td>
<td>1.657–1.716</td>
<td>1.426–1.397, 1.416</td>
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<tr>
<td></td>
<td>2.977–2.889</td>
<td>3.928–4.196</td>
<td>0.538–0.515, 0.531</td>
</tr>
<tr>
<td></td>
<td>2.664–2.680</td>
<td>3.199–3.140</td>
<td>0.652–0.648, 0.628</td>
</tr>
</tbody>
</table>

Abdomen and terminalia (Fig. 2) pale brown; setae dark brown, scattered. Anal point short, acute. Superior volsella bulbous, rounded apically with ventral projection narrow, extending slightly beyond apex of bulbous portion. Inferior volsella capitate, apex truncate. Medium volsella narrow, elongate, extending beyond apex of inferior volsella; setae on basal half elongate, linear. setae on apical half sigmoidal.

The males of Micropsectra polita are very similar to M. dives in the leg ratio of the foreleg, but the short, bulbous shape of the superior volsella and the extension of the median volsella distal to the apex of the inferior volsella readily separate this species from M. dives.

**Female.** Characters similar to male except for following variation. Length 1.99–3.15, 2.49 ± 0.19 mm (N = 5). Head pale yellowish brown; vertex, pedicel, and dorsal half of labrum dark brown; flagellomeres pale brown. Coronal triangle broad, 1.2 times longer than wide. Pedicel globose (Fig. 3); flagellomere lengths 0.096–0.120, 0.109; 0.084–0.090, 0.085; 0.078–
0.090, 0.085; 0.084–0.090, 0.085; 0.114–0.144, 0.127 mm, flagellomeres 1–4 with subapical pair of hyaline, sclerotized blades, each 0.056 mm in length, apical flagellomere without macrosetae. Clypeus broad, 1.4 times wider than long, clypeal setae 20–24. Maxillary palps pale yellowish brown; length of palpomeres 0.024–0.042, 0.032; 0.036–0.054, 0.043; 0.120–0.144, 0.134; 0.108–0.144, 0.122; 0.150–0.174, 0.162 mm; setae fuscus, elongate, scattered. Inner vertical setae 6–7; outer vertical setae 2–3. Cibarial pump 0.138 mm long, 0.078 mm wide, 1.7 times longer than wide.


Wing (Fig. 4) length 2.34–2.71, 2.50 ± 0.06 mm (N = 5), 3.2 times longer than wide. VR 1.16.

Figs. 2–5. *Micrapseclra palila*, Male: (2) genitalia, (SV) superior volsella, (IV) inferior volsella, (MV) median volsella; Female: (3) antenna, (4) wing, (5) genitalia, (GcIX) gonacoxite IX, (Ce) cercus, (GpVIII) gonapophysis VIII, (R) rami of gonapophysis IX.
Spur on fore tibia 0.012 mm long. Lengths (in mm) and proportions of legs:

<table>
<thead>
<tr>
<th></th>
<th>P</th>
<th>L</th>
<th>LR</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>0.949-0.995, 0.972</td>
<td>0.719-0.765, 0.742</td>
<td>1.010-1.025, 1.017</td>
</tr>
<tr>
<td>P2</td>
<td>0.918-1.040, 0.991</td>
<td>0.857-0.918, 0.887</td>
<td>0.428-0.490, 0.455</td>
</tr>
<tr>
<td>P3</td>
<td>1.071-1.239, 1.152</td>
<td>1.086-1.224, 1.163</td>
<td>0.643-0.750, 0.694</td>
</tr>
<tr>
<td>P1</td>
<td>0.398-0.413, 0.405</td>
<td>0.291-0.306, 0.298</td>
<td>0.153-0.153, 0.153</td>
</tr>
<tr>
<td>P2</td>
<td>0.214-0.245, 0.233</td>
<td>0.138-0.168, 0.153</td>
<td>0.107-0.108, 0.107</td>
</tr>
<tr>
<td>P3</td>
<td>0.321-0.367, 0.347</td>
<td>0.184-0.214, 0.194</td>
<td>0.122-0.122, 0.122</td>
</tr>
<tr>
<td>P1</td>
<td>1.922-1.957</td>
<td>1.651-1.717</td>
<td></td>
</tr>
<tr>
<td>P2</td>
<td>2.960-3.001</td>
<td>3.996-4.147</td>
<td></td>
</tr>
<tr>
<td>P3</td>
<td>2.692-2.765</td>
<td>3.284-3.355</td>
<td></td>
</tr>
</tbody>
</table>

Abdomen pale yellowish brown. Genitalia (Fig. 5). Gonocoxite IX with 1 seta. Spermatheca oval to spherical, length 0.072-0.096, 0.078 mm, width 0.048-0.066, 0.056 mm, 1.39 times longer than wide. Cercus length 0.060-0.114, 0.092 mm. Ventrolateral lobe of gonapophysis VIII broad, setae fine, short. Rami of gonapophysis IX elongate, length 0.198-0.210, 0.204 mm, posterior fourth clavate.

**Pupa.** Length 4.73-4.90, 4.81 mm (N = 3). Exuvium pale yellow. Thoracic horn (Fig. 6) plumose, with filaments arising dorsally from broad basal shaft, length over 25 times width at base. Precostral setae 1-2 (Fig. 6) paired. Pc3 positioned laterally, near base of thoracic horn. Cephalic tubercles short, rounded, with single apical macroseta over 7 times length of cephalic tubercle. Frontal warts absent. Dorsoventral setae 1-2 paired, close together. Dorsoventral setae 3-4, metanotal, prealar, supraalar, postorbital and ventral setae on ocular field absent. Nose of wing sheath short, rounded, pearl row absent. Tergite II (Fig. 7) with posterior row of hooks continuous; fine shagreen covering entire tergite. Tergites III-VI with pattern of medial spines or spinules (Fig. 7). Segment IV with two filamentous L-setae, segment V with three filamentous L-setae, segments VI-VII with four filamentous L-setae, segment VIII with five filamentous L-setae. Segments III-IV with one pair of dorsal setae, segments II, V-VI with two pairs of dorsal setae, segment VII with five pairs of dorsal setae, dorsal setae absent on segment VIII. Fringe of anal lobe with 35-40, 37 setae. Anal macrosetae absent. Posterolateral tubercle on tergite VIII, short, rounded (Fig. 8).

The pupa of *Micropschra polita* is distinctive in having a paired medial patch of fine spinules on abdominal tergite VI, and is readily separated from *M. dives* in having the paired medial patch of spines or spinules on abdominal tergites IV-VI with a narrow posterior lateral extension.

**Larva.** Head capsule length 0.383-0.413, 0.407 mm (N = 5), width 0.306-0.337, 0.321 mm, 1.27 times longer than wide; postoccipital margin invaginated ventrally, V-shaped, extending anteriorly 0.41 of way from posterior margin of head. Antenna (Fig. 9), length of segments in mm: 0.200-0.242, 0.226; 0.062-0.076, 0.069; 0.009; 0.009; 0.007; AR = 2.41. Width of basal antennal segment 0.021-0.041, 0.029 mm. 7.8 times longer than wide, 3.3 times length of second segment; distance from base to annular organ 0.154-0.173, 0.162 mm, blade at apex 0.012-0.018, 0.015 mm. Lauterborn organs small, on elongate petiole 0.61 times length of basal antennal segment, 2.0 times length of second antennal segment. Basal tubercle of antenna broad, subrectangular, 1.2 times longer than wide, with short mediolateral spur, 0.014 mm. Mentum (Fig. 10), length 0.051-0.060, 0.057, width 0.094-0.115, 0.102, 1.8 times wider than long, convex anteriorly; median tooth trilobed, five pairs of lateral teeth descending in height from median tooth. Ventromental plate narrow (Fig. 10), elongate,
Figs. 6-8. *Micropsectra polita*, pupa: (6) thoracic horn, (Pc1-3) precorneal setae, (7) abdominal tergites, (8) posterolateral tubercle, tergite VIII.

separated medially by distance less than width of median tooth; length 0.023–0.025, 0.025 mm, width 0.117–0.131, 0.125 mm, 5.0 times wider than long; anterior margin smooth, striations fine. Mandible (Fig. 11), length 0.115–0.147, 0.134 mm; lateral margin broadly rounded, not crenulate; mediolateral margin straight, not serrated; apical tooth short, blunt, 0.6 times width of three lateral teeth; seta subdentalis (SSd) narrow, elongate, extending to apex of apical tooth; setae interna plumose, with three basal branches; two lateral setae elongate. Premandible (Fig. 12) elongate; length 0.074–0.087, 0.081 mm; inner blade broad, rounded apically; lateral blade narrow, acute, ending before apex of inner blade; premandibular brush broad, with numerous fine setae. Setulae I large (Fig. 13), pectinate, with 15–19 teeth. Labral lamella broad (Fig. 13), with 20–22 acute teeth. Pecten epipharyngis (Fig. 13) separated into three distinct plates, lateral plates with 6–7 rounded, apical teeth; median plate with 4 rounded apical teeth.

Procercus reduced (Fig. 14), broad, 1.3 times wider than long, slightly raised above dorsum of abdomen, lightly sclerotized, with seven apical setae, apical claws on posterior prolegs simple, falcate.

The larva of *M. polita* is similar to *M. dives* in having the basal segment of the antenna 3.3 times longer than the second antennal segment, but differs from *M. dives* in lacking a dorsal tubercle on abdominal segment VIII, and in having the mentum with a trilobed median tooth.
Figs. 9–14. *Micropsectra palila*, larva: (9) antenna, (10) mentum and ventromental plates, (11) mandible (SSd) seta subdentalis, (12) premandible, (13) pecten epipharyngis (Pe), labral lamella (L.L.), and setulae 1 (S1), (14) procercus.

**LITERATURE CITED**

Entomophily is commonly associated with flowering plants and their pollen vectors, but also occurs in other groups of plants. Among fungi, several genera of Phallaceae offer food rewards to calliphorid and muscid flies, which inadvertently disperse the fungal spores (Ingold 1964). Bryhn (1897) first noted a relationship between various species of Diptera and members of the moss family Splachnaceae. The nature of this interaction has been the subject of much speculation (Bequaert 1921, Erlanson 1935, Crum et al. 1972, Koponen and Koponen 1977), but no experimental evidence has been collected.

In an earlier study, *Pyrellia cyanicolor* Zetterstedt was observed visiting the sporophytes and transporting the spores of the moss *Splachnum ampullaceum* Hedw. in northern Michigan (Cameron and Troilo, in press). *P. cyanicolor* is distributed throughout North America, but few details of its biology are known. Adult females are reported to prefer carrion for oviposition sites but will utilize dung when carrion is not available. The larvae are general scavengers (Cole 1969). *Splachnum ampullaceum* occurs throughout the cold, temperate regions of North America (Crum and Anderson 1981) and is restricted to organic or organically enriched substrates (dung). Rarely, it has been collected from soil (Crum et al. 1972).

The sporophytes of the moss possess many presumed adaptations for entomophily. These include the production of a distinct, dung-like odor, and an expanded, brightly pigmented capsule base (the apophysis), both of which are believed to be adaptations for attracting dispersal agents. The occurrence of completely recurved peristome teeth and the capsule walls which shrink upon drying are thought to be important in spore presentation. Adhesive spores are believed to be an adaptation for attachment to the dispersal vector.

The purpose of this study was to determine (1) if *S. ampullaceum* is attractive to *P. cyanicolor*, and (2) if a food reward is obtained by the flies visiting the sporophytes. To this end, behavior exhibited by the flies on substrates of nutritional value was examined and quantitatively compared to behavior displayed by the flies while on the *S. ampullaceum* sporophytes.

**METHODS**

The study site was located in a black spruce (*Picea mariana* A. Dietr) swamp on the northwest shore of the Stutsmansville Lake Bog, Emmet County, Michigan (T35N, R6W, Sec. 24). A total of 19 hours was spent observing flies from 12 July to 3 August 1980. Observation periods began at 1000 hrs and ended at 1500 hrs EDT.

The behavior of *P. cyanicolor* was observed on four substrates presented in the field: (1) sporophytes of *S. ampullaceum*; (2) carbohydrate food reward (~5 ml 0.5 M sucrose solution containing apple bits) provided on red, yellow, and blue petri dishes, one dish/color, spaced ~1 m apart; (3) red squirrel (*Tamiasciurus hudsonicus* Erxleben) carrion, a protein food source and substrate for oviposition; (4) commercial fly medium (Ralston-Purina), an alternate food source and possible oviposition site. Substrates were presented and observed individually without competition from other substrates.

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1 Supported in part by The University of Michigan Biological Station and the Palfrey Fund, Botany Department, The University of Georgia, Athens, GA 30602.
2 Biology Department, The City College of The City University of New York, New York, NY 10031.
3 Botany Department, The University of Georgia, Athens, GA 30602.
Stopwatches and hand tally event recorders were used for data collection. Behaviors measured for the four substrates were (1) visit frequency and duration, (2) proboscis behaviors, and (3) grooming. Proboscis behaviors were divided into two categories, feeding and sampling. Feeding was noted when the proboscis was extended and left in continual contact with the substrate for longer than 3 sec. or when the proboscis, while remaining fully extended, was tapped on the substrate surface continuously for at least 3 sec. Sampling was seen as the rapid extension and withdrawal of the proboscis from the substrate surface. The criterion for these categories is based largely on the work of Dethier (1976). Grooming behavior was recorded when the front tarsi were rubbed together, with or without drawing the tarsi over the head region, and when the rear tarsi were rubbed together.

RESULTS

Flies were most active on sunny and warm (24-32°C) days. This was also the period when sporophytes of *S. ampullaceum* produced the strongest odor.

Typically, flies approaching the moss patch flew directly to the sporophytes. Occasionally they landed on a neighboring plant or other substrate, oriented toward the moss, and then walked or flew directly to the sporophytes (Fig. 1). When an individual on the moss was chased away, it often returned after a short flight to a neighboring plant or fallen log.

The total number of visits observed, hours of observation time, mean length of visits, and average visits per observational hour are presented for each substrate in Table 1. On the average, *S. ampullaceum* is visited nearly as frequently as the carrion and more so than the carbohydrate nutrient source or the fly medium.

A one-way ANOVA for visit duration on the four substrates indicates that the means were not equal (P < 0.0001). Duncan's multiple range test (Table 1) indicates that the mean visit duration on *S. ampullaceum* was significantly shorter (P < 0.01) than the carrion and commercial fly medium but not significantly different from the carbohydrate substrate. This test also demonstrates that the mean visit duration for the carrion and fly medium (both protein sources) were not significantly different.

In the color preference experiment, *P. cyanicolor* preferred the yellow petri dishes containing carbohydrate food reward. For a sample size of 22, red was never visited, blue was visited twice, and yellow 19 times (χ² test, P < 0.01).

Proboscis behaviors were categorized as either feeding or sampling. The number of individuals falling into each of these categories for each of the substrates is summarized in Table 1. Proboscis behaviors associated with feeding do not take place on *S. ampullaceum*; only sampling behavior was observed.

The carbohydrate, carrion, and fly medium were grouped as a category representing food rewards (n = 46). This group was then compared to *S. ampullaceum* in terms of the frequencies of proboscis behaviors by χ² analysis. Proboscis behavior on *S. ampullaceum* was determined to be significantly different from that shown on substrates with nutritional value (P < 0.01).

Table 1 also shows the number of individuals grooming on each of the substrates. A χ² 2 × 2 contingency analysis showed that the number of flies grooming on *S. ampullaceum* was significantly lower than the carbohydrate and the carrion (P < 0.01 for both tests). The fly medium was excluded in the χ² analysis, because the expected frequency generated was too low. Comparison of the carrion with the carbohydrate showed no significant difference in terms of the number of flies grooming on each (P > 0.05).

DISCUSSION

*Splachnum ampullaceum* is indeed attractive to adult *Pyrellia cyanicolor*. In terms of the number of visits per observational hour, *S. ampullaceum* is at least as attractive as carrion. Furthermore, *S. ampullaceum* is more attractive than either carbohydrate or fly-medium substrates. Observations concerning orientation of individual flies to the moss sporophytes and the immediate return of chased individuals adds further evidence to the attractiveness of *S. ampullaceum*.
Fig. 1. Pyrellia cyanicolor on Splachnum ampullaceum sporophytes (~10x). Note the left mesotarsus resting on the capsule mouth.

The significance of a yellow color preference in carbohydrate feeding suggests the yellow color of the sporophytes is important to the relationship, possibly as a short distance attraction cue (Kugler 1956). The odor emitted by the sporophytes, presumably a long distance cue, undoubtedly plays an important role in attraction.

Apparently, flies do not obtain a food reward from the moss sporophytes. Two observations point to this conclusion. First, visit duration on \textit{S. ampullaceum} is significantly shorter than on protein-supplying substrates. Also, the analysis of proboscis behavior indicates that feeding was probably not taking place on the \textit{S. ampullaceum} sporophytes. However, we could not rule out the possibility that spores were being ingested. Proctor and Yeo (1972) have pointed out that many flies which normally feed on exposed liquids are capable of ingesting small solid particles, including pollen grains and spores. A moisture reward cannot be ruled out either.

Nevertheless, the short visit duration and the lack of continuous proboscis extension by \textit{P. cyanicolor} on \textit{S. ampullaceum} makes the occurrence of a significant food reward improbable. Furthermore, the number of flies grooming on \textit{S. ampullaceum} was significantly lower than for substrates of known nutritional value. The reduced frequency of grooming on \textit{S. ampullaceum} suggests an absence of feeding, although the exact relationship between feeding and grooming incidence is not known. It most likely functions as a means for cleaning contact chemoreceptor hairs located on the tarsi and labellum.

From the results of this study and that of Cameron and Troilo (in press), we suggest the following relationship between \textit{S. ampullaceum} and \textit{P. cyanicolor}. \textit{Splachnum ampullaceum} sporophytes are attractive to \textit{P. cyanicolor} apparently through mimicry of visual and olfactory cues normally provided by nutrient resources. When a fly visits \textit{S. ampullaceum} sporophytes, it senses the substrate with its tarsal chemoreceptor hairs and, less frequently, with its labellar sensory hairs. Upon determining that no food is present, it quickly leaves. While there, however, it may inadvertently pick up spores from the capsules (Cameron and Troilo, in press). These spores may then be deposited on nutrient sources for the fly, where
Table 1. Visit duration, proboscis behavior, and grooming behavior of *Pyrellia cyanicolor* on *Splachnum ampullaceum* and substrates of nutritional value.

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Observations</th>
<th>Duration (sec.) $\overline{X} \pm S^2$</th>
<th>Mean visits/observ. hour</th>
<th>Proboscis behavior</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours</td>
<td>Numbers</td>
<td></td>
<td></td>
<td>Feeding</td>
</tr>
<tr>
<td><em>S. ampullaceum</em></td>
<td>7</td>
<td>59</td>
<td>$25.8 \pm 35.8^a$</td>
<td>8.4</td>
<td>0</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>8</td>
<td>19</td>
<td>$36.4 \pm 37.0^a$</td>
<td>2.7</td>
<td>22+</td>
</tr>
<tr>
<td>Carrion</td>
<td>2</td>
<td>17</td>
<td>$99.5 \pm 64.8^b$</td>
<td>8.5</td>
<td>17</td>
</tr>
<tr>
<td>Fly medium</td>
<td>2</td>
<td>7</td>
<td>$94.8 \pm 77.4^b$</td>
<td>3.5</td>
<td>0</td>
</tr>
</tbody>
</table>

$^a, ^b$ Means with the same letter not significantly different.

$^c n = 22.$
the spores are able to develop. This relationship may be termed commensal. The moss benefits from the fly-mediated spore dispersal, while the fly seems to derive neither harm nor benefit from the interaction.

ACKNOWLEDGMENTS

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LITERATURE CITED

SURVIVAL AND FOOD DETECTION BY FIRST-INSTAR
MELANOPUS FEMURRUBRUM (ORTHOPTERA: ACRIDIDAE)

R. G. Bland

ABSTRACT

Newly hatched *Melanoplus femurrubrum* (DeGeer) were evaluated for survival without food under various moisture, temperature, and light conditions. Although nymphs survived up to 113 h without food, they required food 48–60 h after hatching to ensure continued survival and growth. Olfactory food detection was very limited and feeding tended to occur on the first suitable food encountered. Food covered with a film of water and held within several millimetres of the palpi evoked palpal vibrations followed by antennal movements. The evidence suggests that hygroreceptors occur on the palpi and palpal stimulation is necessary before antennal olfaction occurs.

Grasshopper host selection and feeding behavior have been studied by numerous investigators and much of the research has been reviewed by Dadd (1963), Mulkern (1967), Gangwere (1972), and Chapman (1977). Nearly all work has been with adults or late instars because the major crop damage occurs at these stages, the insects display the greatest behavioral diversity, and their relatively large size makes them easy to manipulate and observe.

Investigations into feeding habits of 1st instars are uncommon even though this stage is relatively vulnerable to adverse environmental conditions and subject to high mortality (Pickford 1960, 1962). Williams (1954) included 1st instars of locusts and various grasshoppers in his research on physical and biological factors affecting feeding behavior and host preferences. Bernays and Chapman (1970) used 1st instars and other stages of *Chorthippus parallelus* (Zetterstedt) to determine the role that physical characteristics of leaves have in food selection. The duration of survival of starved 1st instar *Camnula pellucida* (Scudder) and *Melanoplus sanguinipes* (Fabricius) was recorded by Smith (1960). Mulkern (1969) observed responses of nymphs (including 1st instars in some cases) and adults of eight acridid species to variations of light, visual patterns, food quality, and feeding extracts.

This study deals with the survival and food detecting ability of grasshopper hatchlings when confronted with suboptimum habitat conditions. The species chosen was *Melanoplus femurrubrum* (DeGeer), the redlegged grasshopper, a common mixed feeder found throughout most of North America (Vickery et al. 1974). The objectives were to (1) determine survival ability under varying food and moisture conditions, (2) evaluate the ability to detect food and moisture, and (3) observe the use of the antennae, mouthparts, and front legs for food and moisture detection.

METHODS AND MATERIALS

Egg cases were obtained from caged, field-collected adults in central Michigan and incubated in moist sand at 24°C for 30 days. After refrigeration for 6 months the eggs were incubated at 27°C on moist filter paper in a petri dish. Young leaves of dandelions (*Taraxacum officinale* Weber) and alfalfa (*Medicago sativa* L.) were used as food for hatchlings. Most experiments used five hatchlings and each test was replicated three times. Specific test conditions are described in the Results section.

1 Biology Department, Central Michigan University, Mount Pleasant, MI 48859.
RESULTS

Egg Hatch. Hatching occurred 6-18 days after incubation, with 60% of the eggs hatching between days 15-18. Two percent of the eggs did not hatch and 11% of the hatchlings did not survive eclosion. The early hatching was probably due to eggs which were not in diapause within ca 2 weeks after oviposition and continued to develop until refrigerated.

Survival without Food. Hatchlings were maintained in a petri dish at 27°C and a 15 h photophase which approximate the average daytime temperature and photoperiod during the middle of June in Mount Pleasant when egg hatch occurs. Three moisture conditions were used: high (water droplets occupying ca 25% of the dish bottom surface), ambient (70-75% RH) without free water, and low (CaCl₂ covering the bottom surface beneath a false floor in the dish). A fourth condition consisted of keeping the hatchlings at 27°C during 15 h of light and 13°C for 9 h of darkness. The night temperature is the average that occurs during the middle of June. Moist filter paper lined the bottom of the dish in this test.

Survival results are shown in Table 1. There was no significant difference (Student's t-test, P > 0.05) in survival between high and ambient moisture conditions. Survival in low humidity and different day-night temperatures was significantly different (P < 0.05) from the high and ambient moisture conditions. Low night temperature extends longevity, low moisture reduces longevity, and moderate to high moisture levels appear to have little effect on survival in the absence of food. The minimum overnight (8 h) temperature at which 100% of 12-h-old instars will survive is -3 to -4°C.

Survival with Variable Food Conditions. Intact discs of soil with undisturbed plants were removed from the grasshoppers' habitat during the week of hatching. Discs were trimmed to fit into extra high petri dishes. The control consisted of intact soil, debris, and trimmed plants enclosed in a petri dish. The substrates were modified as follows: (1) all visible vegetation and debris removed, and (2) all visible vegetation removed except dry debris (primarily fine roots and bits of leaves). The substrates were oven dried until no further weight loss occurred and then separated into two groups; one group would remain dry and the other would have one-third of the soil surface moist. Hatchlings were placed in the containers and held at 27°C and a 15L:9D photoperiod.

Table 1. Survival duration with variable food and moisture conditions at 27°C or at a 27°C day and 13°C night regime. A 15L:9D photoperiod was used.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean Hours Survived ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter paper substrate</td>
<td></td>
</tr>
<tr>
<td>Low moisture</td>
<td>60 ± 2</td>
</tr>
<tr>
<td>High moisture</td>
<td>86 ± 5(^a)</td>
</tr>
<tr>
<td>Ambient moisture</td>
<td>94 ± 5(^a)</td>
</tr>
<tr>
<td>27°C/13°C, ambient moisture</td>
<td>108 ± 12(^b)</td>
</tr>
<tr>
<td>Soil substrate</td>
<td></td>
</tr>
<tr>
<td>Control (with vegetation)</td>
<td>2nd instar</td>
</tr>
<tr>
<td>Dry debris only</td>
<td></td>
</tr>
<tr>
<td>Moist</td>
<td>115 ± 7(^b)</td>
</tr>
<tr>
<td>Dry</td>
<td>93 ± 5(^a)</td>
</tr>
<tr>
<td>No debris or vegetation</td>
<td></td>
</tr>
<tr>
<td>Moist</td>
<td>96 ± 4(^a)</td>
</tr>
<tr>
<td>Dry</td>
<td>84 ± 3(^a)</td>
</tr>
<tr>
<td>No debris or vegetation</td>
<td></td>
</tr>
<tr>
<td>27°C/13°C, ambient moisture</td>
<td>113 ± 5(^b)</td>
</tr>
</tbody>
</table>

\(^a,b\) Means with the same letter are not significantly different (P > 0.05).
Grasshoppers in the control dishes all survived and developed into the 2nd instar (Table 1). When all vegetation and debris were removed, grasshoppers lived an average of 84 h (no moisture) and 96 h (moisture). The difference between these means was not significant (P > 0.05) nor were the means significantly different (P > 0.05) from the high and ambient moisture conditions on filter paper substrate. If dry debris was present the duration of survival increased slightly to 93 h (no moisture) and 115 h (moisture). The presence of moisture with dry debris caused a significant (P < 0.05) increase in longevity when compared to the absence of debris but grasshoppers were unable to survive to the 2nd instar. Reducing the night temperature also increased survival significantly (P < 0.05) even though debris was absent.

**Survival and Moisture.** Each hatchling was placed in a 1-oz clear plastic container within 30 min of eclosion. The small container allowed close contact with a leaf of alfalfa or dandelion under the following conditions: fresh leaf ± water, dry leaf ± water. Fresh leaves were replaced with new leaves every 12 h. Dry leaves were produced by air drying at 27°C for 2 days. Wet cotton was the water source. Containers were held at 24, 27, 30, 33 and 36°C.

Hatchlings did not begin feeding until nearly 3 h after eclosion. Those held at 24°C fed little or not at all and died after 3 days. Grasshoppers with fresh leaves ± water and those with dry leaves + water survived and molted to the 2nd instar, taking 5 days at 27°C and 4 days at the higher temperatures. Individuals with dry leaves as food but without water did not survive past 3 days at all temperatures. These results show that 1st instars can survive and develop on fresh leaves without water or dry leaves with water if the temperature is high enough for feeding activity to occur.

**Starvation Recovery.** Hatchlings were starved 24, 36, 48, 60, and 72 h in 1-oz plastic containers held at 27°C and a 15 h photophase. A water droplet was present in each cup. Fresh alfalfa was placed in each cup at the end of a starvation period. All hatchlings fed and molted to the 2nd instar when given food after a 24-48 h starvation period. After 60 h without food they were alive but some were too weak to feed and others that fed nevertheless died by 72 h. Thus a 1st instar may survive 86-108 h under certain conditions (Table 1) but it must feed within 48-60 h to ensure continued survival and growth.

**Food and Moisture Detection.** Hatchlings were held in petri dishes either without food and water or with only water available for 8, 16, and 24 h in constant light. The tests were conducted at 30°C because the minimum temperature for good feeding activity was 25-27°C. Below this temperature range the grasshoppers were relatively inactive and preferred to climb the sides of the container and/or move toward any light source where they remained with little additional activity. Fresh and air-dried (24 h at 27°C) dandelion and alfalfa and filter paper were used as food. Slivers of leaves and paper were cautiously presented to the side of a grasshopper through a hole in the side of the dish.

No measurable behavioral differences occurred between nymphs held with or without water and thus they are evaluated as one. Grasshoppers starved 8 and 16 h turned toward the fresh food or made slow semicircular movements that brought them to the leaves from a distance of ca 7 mm. Only 35% of the nymphs responded to dried leaves at that distance. Individuals starved for 24 h responded to fresh and dry leaves as well as filter paper up to a distance of ca 7 mm.

Both vision and olfaction may apparently cause the individual to turn toward the potential food since the filter paper presumably has no attractive odor. The grasshopper slowly waves its antennae as it approaches, not usually touching the food with the antennae, until the front tarsi contact the food enabling the insect to climb onto the surface. The antennae or mouthparts do not have to touch the food before the tarsi make contact. Biting occurs on both leaves and filter paper but feeding proceeds only on the leaves. Feeding occurs immediately after biting on fresh leaves but the grasshopper takes longer to begin eating dry leaves because it moves about on the leaf biting various areas before feeding. One antenna (usually the same one) is lowered briefly every 8-12 sec to touch the leaf surface as the grasshopper initiates feeding and after 30-60 sec the frequency of antenna lowering decreases to once every 18-25 sec. When the grasshopper bites filter paper, the antennae are jerked upward rather than slowly lifted as if mechanoreceptors are strongly stimulated.

A second experiment exposed starved grasshoppers to fresh and dry alfalfa at 27°C and allowed them to select one for feeding. Two groups of hatchlings were starved for 24 h; one
group had water available and the other lacked water. They were then introduced through a
dark tube into one side of a petri dish. A light bulb was placed at dish level on the opposite
side of the entrance at a sufficient distance so as not to act as a heat source. Fresh and/or dry
alfalfa leaves were placed in the dish on the side opposite to the release hole so the insects
would walk past the food as they moved toward the light.

The grasshoppers exhibited an extreme attraction to the light and would walk past the
food without stopping unless they were within ca 5–7 mm of the alfalfa as they passed by it.
At this distance nearly 75% of the nymphs would touch it with their antennae or front tarsi
and then climb on the leaf to bite and feed. They exhibited a slight but not significant ($P >$
0.05) preference for fresh over dry alfalfa when the leaves were adjacent. The leaf that was
touched first was the one fed upon. The presence or lack of water for 24 h did not cause a
preference for fresh or dry leaves.

A third experiment exposed the grasshoppers to a 1-cm strip of wet filter paper under the
same conditions as the second experiment. To move toward the light the insects had to cross
the wet strip. Hatchlings without food and water for 24 h walked directly to the strip,
stopped to drink, and then continued over the strip. Nearly two-thirds of those without food
but with water for 24 h stopped 10–25 mm from the strip and slowly weaved side-to-side.
Seventy-seven percent jumped over the strip without contacting it first and the remainder
walked over the paper without stopping to drink.

**Food Detection and Feeding in Darkness.** Hatchlings were placed in darkness immediate­
ly after eclosion and starved without water for 0, 4, 16, and 24 h at 21, 24, and 27°C. Grasshop­
pers which would not have to search for food were each placed in petri dishes, after the
appropriate starvation time, with pieces of alfalfa leaves scattered over ca half the bottom
surface. Those needing to search for food were anesthetized with $\text{CO}_2$ and each placed in
half of a petri dish which was separated from the other half by a vertical wall with two
evenly spaced openings 10 mm wide and 15 mm high. Pieces of alfalfa leaves were scattered
over ca half of the bottom surface on the side opposite the grasshopper.

After 8 h in darkness all individuals at 24 and 27°C had fed on the alfalfa and continued to
feed over the next 3 days they were monitored. Grasshoppers at 21°C did not feed and most
rested on the sides of the vertical walls. These results indicate that 1st instars will move and
feed in darkness if the temperature is sufficiently high for general activity. Based on their
limited ability to locate food in light as shown earlier in this study, it’s likely that they
encountered the alfalfa by chance in their general movements rather than orienting to it by
olfactory means.

**Sensitivity of Antennae, Palpi and Tarsi to Food and Water.** Hatchlings were mounted on
tape so their ventral side was up and held without food or water for 24 h. Strips of fresh
alfalfa and dandelion leaves and dry or wet filter paper were cut 1 mm wide and presented to
the insects while observing them through a dissecting microscope.

Alfalfa and dandelion strips provoked similar responses. When the strips were moved
close to but not touching the antennae, maxillary and labial palpi, or front tarsi, these append­
geages (including the mandibles) moved 0–11% of the time. When one antenna was touched
briefly, it (and frequently the other antenna) was immediately raised and the mouthparts and
front legs began moving which indicated an attempt to locate or sample potential food. If a
food strip was moved toward the mouthparts after contacting the antennae, they were
lowered as if to touch the strip but contacted it less than half the time even when held within
reach of the antennae. When leaf contact ceased, antennal movements declined and generally
stopped after ca 30 sec but could be restimulated by again touching one or both antennae.

When the maxillary and labial palpi were contacted they began palpating the leaf strip and
the front legs were raised in an attempt to grasp the strip. Biting and a slight amount of
feeding occurred regardless of whether or not the front tarsi grasped the leaf. Contacting
only the front tarsi with a strip caused the palpi and labrum to move and the head to bend
forward as the grasshopper attempted to touch the food with its mouthparts. The antennae
were lowered and raised slowly during the head movement.

Dry filter paper strips evoked no response when held near the antennae, palpi, or front
tarsi. When an appendage was touched, the grasshopper’s response was essentially the same
as the response to leaf strips except that only biting occurred and not feeding on the paper.

Wet filter paper strips held near the antennae and front tarsi did not stimulate movement
of these appendages. When the appendages were touched the response was the same as to
dry filter paper and leaf strips. However, when the wet paper strip was brought to within ca
0.5 mm of the maxillary and labial palpi, both vibrated rapidly, the mandibles and labrum
moved, and one antenna was lowered although it did not touch the wet strip. Utilizing this
information, alfalfa and dandelion strips were dipped in distilled water and held ca 0.5 mm
from the antennae, palpi, and front tarsi. Again, only the palpi responded to wet paper
strips. These results indicate that the maxillary and labial palpi contain olfactory hygrorecep­tors whereas the antennae, palpi, and front tarsi, which responded only to contact, bear
mechanoreceptors and/or contact chemoreceptors and any hygroreceptors present are not
functioning.

The above tests were repeated with an ink-white glue-water mixture covering the com­pound eyes of the grasshoppers to determine the importance of vision in antennae, mouth­parts, and front tarsi responses. The reactions to dry and wet leaf and filter paper strips
were generally the same as when the eyes were uncovered although the reaction speeds
were more subdued.

DISCUSSION

A multitude of environmental components such as weather, food quality and quantity,
habitat and natural enemies confront a population of grasshopper hatchlings. Newly hatched
*M. femurrubrum* did not initiate feeding until three or more hours after eclosion. The
minimum temperature for feeding activity under laboratory conditions was 24°C. Smith
(1960) noted that feeding did not start for 8 h at 30°C for *M. sanguinipes* and *C. pellucida*.
During the prefeeding time, the strong negative geotaxis and even more vigorous positive
phototactic response of *M. femurrubrum* (Mulkern 1969) often causes them to climb nearby
vegetation. By being above ground level for lengthy periods the risk of predation from
depthilous arthropods (e.g., ants, carabid beetles, and certain spiders) is reduced. In addi­tion, the drowning of hatchlings from excess rainfall or dew is less likely and the typically
lower humidity above ground level may reduce the chance for fungal infections.

Cleanly tilled soil, continuous rain, or abnormally cool temperatures at the time of egg
hatch require the hatchlings to survive until seedlings emerge, or dispersal takes them to
nearby food, or the weather improves to allow for food-searching activity. In the laboratory
*M. femurrubrum* survived an average of 60 h (2.5 days) at low humidity and constant
temperature to 113 h (4.7 days) with moderate humidity and low night temperature (Table 1).
Moisture lengthened survival duration on soil with debris but had no effect on bare soil.
Under constant temperature conditions 1st instars must locate food within 2.5 days or
become too weak to feed and utilize available food. Smith (1960) showed that *M.
sanguinipes* and *C. pellucida* would survive 4 days at 30°C and 5 days at 25°C constant
temperature which averages about 0.5 days longer than *M. femurrubrum* under similar
conditions. He did not check for their ability to resume feeding and survive during this time.

If negative geotactic and positive phototactic responses have not caused the hatchling to
climb onto a suitable host then the grasshopper must search for food. Hunger stimulates
random movements until the nymph perceives a vertical object for orientation (Williams
1954, Kaufmann 1968, Mulkern 1969). Color appears to have no effect on food selection
(Williams 1954, Mulkern 1969). In this study *M. femurrubrum* was found to move toward
and contact food only when within ca 7 mm of the food. The nymphs showed no long
distance olfactory ability to recognize food and fed on whichever suitable source they first
encountered. Mulkern (1969) reported that adult and last instar *M. femurrubrum* had to be
within 3–4 cm of fresh or dried vegetation to locate it and Dadd (1963) has also referred to the
limited olfactory guidance of grasshoppers. Riegert et al. (1954) found that 2nd instars of *C.
pellucida* and *M. sanguinipes* released in a bare field were unable to orient themselves and
move toward a food supply several hundred metres distant. Second-instar *C. pellucida*
moved up to 82 m in 8 days and the direction was primarily downward. However they would
have been feeding during this time or otherwise the nymphs would not have survived so
long.

Pruess (1969) and Bernays and Chapman (1970) cited evidence that a grasshopper's diet is
generally determined by its acceptance or rejection of the plant it is perched on when ready to feed. In this study, *M. femurrubrum* 1st instars had a slight but statistically insignificant (P > 0.05) preference for fresh alfalfa over dry alfalfa. Nymphs required free water in order to survive on dry alfalfa indicating that if the habitat contains food that is palatable and nutritious but in a dry condition, the grasshopper will feed on the dry food and develop at least to the 2nd instar as long as a moisture source is available and the temperature is sufficiently high for feeding activity. Williams (1954) found that food with a higher moisture content was preferred by grasshoppers he studied, but Bernays and Chapman (1970) observed that moisture was not important in the differential selection of fresh leaves in *C. parallelus*. They noted that the leaves used by Williams (1954) were probably much drier than the more controlled moisture levels they tested. Kaufmann (1968) and Lewis (1979) observed that *M. differentialis* (Thomas) preferred dried or wilted tissue in the presence of fresh plants. Lewis (1979) related this preference to nutrient or chemical defense changes or that the leaf is easier to chew. Other studies on the role of water content were reviewed by Gangwere (1972).

If environmental conditions such as rainfall, low temperatures, or wind prevent *M. femurrubrum* hatchlings from feeding during the day, night feeding can occur as long as the temperature is high enough (> 24°C) for general locomotor activity that results in encountering food. Williams (1954) observed that the adults of *Locusta migratoria* (L.) fed at a reduced level when their eyes were blackened and Blaney et al. (1973) reported that 5th instars of this species fed in darkness with the only change being a longer interfeed period than in the light. Mulkerin and Mongolkiti (1977) noted that grasshoppers probably feed at night if hungry and the temperature is high enough to stimulate activity. Nymphs of *M. femurrubrum* that have had water but not food available will generally jump over a wet paper strip as they move toward a light. They do not need to contact the paper and may weave side-to-side before exhibiting avoidance behavior, indicating a reception of olfactory and/or visual signals. Kendall and Seddon (1975) showed that hydrated *L. migratoria* avoid a wet paper strip but they point out that humidity differences also occur as the insect approaches the strip. Early instars of grasshoppers and locusts select low humidity (Kennedy 1937, Riegert 1959) unless they are close to the time of molting (Riegert 1958) or have been deprived of food (Aziz 1957).

A wet paper strip held at various distances from the antennae and front tarsi of mounted *M. femurrubrum* maintained without food and water elicited only an occasional antennal or mouthpart response. However when moved to ca 0.5 mm of the maxillary or labial palpi, both pairs of appendages vibrated which indicated that hygroreceptors were present, and the antennae, labrum, and mandibles began to move. This study does not explain why nymphs were able to detect and avoid a wet paper strip from greater distances as previously described. Slifer (1955), Riegert (1960) and Waldow (1970) had evidence that grasshopper and locust antennae contain hygroreceptors and Kendall and Seddon (1975) also implicated the tarsi as possible contact hygroreceptors. Neither these workers nor those dealing specifically with locust mouthpart function have reported the response of palpi to moisture, but the palpi have been proven without doubt to be contact chemoreceptors (Haskell and Mordue 1969, Haskell and Schoonhoven 1969, Blaney and Chapman 1970, Blaney 1975).

Fresh alfalfa and dandelion leaves and dry filter paper did not elicit a response from 1st instars when these items were held up to but not touching the antennae, mouthparts, and front tarsi. The lack of response to the leaves was unexpected since nymphs in a petri dish are attracted toward a leaf when it is brought to within ca 7 mm of the grasshopper. However, vision may play a major role in attracting the grasshopper especially if the potential food contrasts greatly with the background as it does in a petri dish. In addition, individuals were unrestrained in petri dishes rather than mounted dorsally, and the more natural position and environment may allow greater sensory activation and coordination. When the leaves and paper were dipped in distilled water and again offered to the mounted grasshopper, the palpi responded by vibrating followed by attempts to feed. These results indicate the presence of palpi olfactory receptors more responsive to water vapor (hygroreceptors) than phagostimulatory odors that are presumed to emanate from the cut leaves.

Touching the antennae, mouthparts, or front tarsi with leaves and filter paper caused all of
these appendages to move in a predictable fashion indicating that contact chemoreceptors and/or mechanoreceptors are present. The likely mode of food selection is through chance contact with plant material followed by exploratory biting. The antennae generally did not contact the preferred food once it had touched the palpi, and instead usually one antenna was intermittently waved up and down. This movement suggests that important olfactory reception occurs while the palpi palpate the food and during exploratory biting, and that chemotactic sensilla on the palpi must be stimulated before olfactory sensilla on the antennae are receptive. The antennae may then respond to food odors and/or moisture. The front tarsi also produce the same antennal response and may serve the same initiation function as the palpi or act simultaneously with the palpi to activate the antennal olfactory system. As mentioned earlier, antennal movement does not occur in the presence of water vapor until the palpi begin to vibrate, presumably stimulated by their hygroreceptors. Perhaps antennal olfaction and palpal chemotactic or hygroreceptive activity are needed simultaneously for exploratory biting to proceed to actual feeding.

The antennae of grasshoppers are assumed to be the major olfactory site by virtue of the abundance of thin walled, multiporous basiconic sensilla (Slifer et al. 1959). Numerous studies have demonstrated olfaction in foodfinding with detection ability ranging from a few centimetres to over 1 m (Williams 1954, Slifer 1955, Dadd 1963, Mulkern 1967). However, adult or late instar grasshoppers have been used in these sense organ studies and perhaps the weak olfactory response of 1st instar *M. femurrubrum* occurs because they have not developed full innervation of the basiconic or coeloconic sensilla on the antennae or have not learned to recognize the appropriate olfactory stimuli that signal food.

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ENTOMOLOGICAL NOTES

THE FIRST RECORDS IN ILLINOIS OF *HELICONIUS CHARITONIUS* (LEPIDOPTERA: HELICONIIDAE) AND *PHOEBIS AGARITHE* (LEPIDOPTERA: PIERIDAE)

Our key to Illinois butterflies, exclusive of the skippers (Hesperiidae), was published in 1980. It includes those butterflies listed by Irwin and Downey in their 1973 Illinois checklist plus two species, *Anaea aidea* (Guerin-Meneville) (Nymphalidae) and *Celastrina ebenina* Clench (Lycaenidae), added to the state list after 1973. Presented here are two additions to the Illinois list, the zebra butterfly, *Heliconius charitonius* (Linnaeus) (Heliconiidae), and the large orange sulphur, *Phoebis agarithe* (Boisduval) (Pieridae).

*H. charitonius*, in the United States, is presently known from South Carolina, Georgia (Comstock and Brown 1950), Florida, the Gulf Coast, and Texas, and to stray northward to Kansas (Ehrlich and Ehrlich 1961) and Colorado (Howe 1975).

We have recently examined a male specimen of *H. charitonius* that is housed in the Illinois State Museum, Springfield. The label information is as follows: Monroe Co., Illinois; 1 mile north of Waterloo (T2S R10W S13); 13 Aug. 1970; on petunia; Tim Vogt, Collector.

This species can be separated from *Agraulis vanillae nigrior* Michener, the only other Illinois heliconiid, by the dorsal color pattern of the wings. *H. charitonius* has black ground color and yellow stripes, whereas *A. vanillae nigrior* has orange-brown ground color and lacks yellow stripes.

*Klots* (1951) reported that *P. agarithe* occurs from Florida along the Gulf Coast to Texas, and south into Mexico, and strays north to Kansas, Arkansas, and Illinois; Howe (1975) added Arizona. Irwin and Downey (1973) listed *P. agarithe* as a species of possible occurrence in Illinois and referred to Klots (1951). However, Klots did not cite specific records to support his inclusion of Illinois in the range of this sulphur.

We have recently seen two Illinois male specimens of *P. agarithe*. One of these was observed in flight at Fountain Bluff, Jackson Co., on 7 June 1981, but was not captured. The other was captured by another collector who donated it to the SIU Entomology Collection, Zoology Research Museum. The label information is as follows: Sparta, Illinois; Randolph Co.; 2 May 1981, T. L. Wiley, Collector.

*P. agarithe* can be separated from *P. philea* (Johansson) and *P. sennae eubule* (Linnaeus), the other Illinois representatives of *Phoebis*, by the dorsal color pattern of the wings. Males of *P. agarithe* have orange ground color, whereas those of *P. philea* and *P. sennae eubule* have yellow ground color. Females of *P. agarithe* have wings with pinkish orange ground color and fore wings with a row of discontinuous brown marginal spots; females of *P. philea* have wings with dull orange to brownish yellow ground color and fore wings with a brown marginal border, and those of *P. sennae eubule* have wings with yellow ground color and fore wings with a row of brown marginal spots which may be continuous. The wings of female *P. philea* and *P. sennae eubule* are illustrated in Figs. 23 and 24, respectively, of our 1980 Illinois butterfly key.

ACKNOWLEDGMENTS

We wish to thank Dr. E. D. Cashatt, Illinois State Museum, for allowing us to examine the specimen of *H. charitonius*; and Mr. T. L. Wiley, R. R. #1, Sparta, Illinois, for donating his specimen of *P. agarithe* to the SIU Entomology Collection.
NEW RECORDS OF *PASIMACHUS ELONGATUS* IN MICHIGAN
(COLEOPTERA: CARABIDAE: SCARITINI)

*Pasimachus elongatus* LeConte is a large (21-28 mm), flightless ground beetle which occurs from Michigan westward to Montana and south to Louisiana and Arizona. A search of major entomological collections and the literature revealed that only a few specimens have actually been collected in Michigan. Banninger (Rev. de Entomologia 21:481-511, 1950) did not specify where his Michigan specimens were taken. The United States National Museum has two specimens labelled "Mich.", one collected by C. V. Riley and one by W. Robinson, and seven specimens from St. Joseph (Berrien Co.), Michigan collected by H. G. Butler between 14 July and 19 August 1938.

In 1979 five barrier-type pitfall traps were installed in the Barry County State Game Area (T3N, R10W, Sec. 22, Barry Co.), Michigan to sample the carabid fauna. The soil in the area is sandy and covered with lichens, moss, and herbaceous vegetation. The overstory is scattered, mature black oak with an understory of "scrub" oak and black cherry.

A single *Pasimachus elongatus* was captured on 10 June 1979; three additional specimens were taken on 17 June 1979. Another specimen was taken from the same area on 28 June 1980. These captures represent new county records, and are significant because the site is 60 miles northeast of the St. Joseph locality. Also, *P. elongatus* has apparently not been taken in Michigan since 1938. However, it is possible that this species occurs in scattered localities throughout southwestern Michigan in areas of open woodland with sandy soil.
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