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Rearing Hepialid Moths (Lepidoptera)

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Abstract.—Techniques for rearing hepialid moths from egg to adult are described. The polyphagous larvae will accept a variety of diets, but do well on carrots. Six species in three genera were carried through to late instars. Adults of *Hepialus humuli* Fabricius, "*Hepialus*" *behrensii* (Stretch) and *Korscheltellus gracilis* (Grote) issued after 1 yr, although all may have 2-yr life cycles in nature.

The immature stages of hepialids are poorly represented in collections. For example, larvae are known for only 7 of the 20 North American species, and only 4 of these have been figured in any detail. Still less has been published on the egg and pupal stages. This situation could be ameliorated if greater efforts were placed on rearing Hepialidae. Here I describe methods to rear *Hepialus humuli*; *Phassus triangularis* Hy. Edwards; *Korscheltellus gracilis*; and three species of an undescribed genus, henceforth to be referred to as the "*Hepialus*" *californicus* group: "*Hepialus*" *behrensii*, "*H.*" *californicus* Bdv., and "*H.*" *hectoides* Bdv. The taxonomy and biology of the "*H.*" *californicus* group are treated in Wagner (1985).

Egg Collection and Incubation

Hepialids are arguably the most fecund Lepidoptera. Even small species such as *Korscheltellus gracilis,* with wing spans under 45 mm, can lay up to 590 eggs (Wagner and Rosovsky, in prep.). Females of "*Hepialus*" *behrensii* lay as many as 6400+ eggs (Wagner, 1985). The large Australian hepialid, *Trictena argentata* (H.-S.) may be the most fecund lepidopteran—one female released 29,100 eggs and died with an additional 15,000 fully developed eggs in her abdomen (Tindale, 1932).

Females of most hepialids presumably release ova aerially (for example, Edwards, 1964; Grehan, 1987; Wagner and Rosovsky, in prep.), although a few genera oviposit as they crawl or flutter over the surface of the ground (Madge, 1956; Hardy, 1973, 1974). Confined females readily release ova during evening and predawn flights. Where female hepialids come to light, ova can be collected from light traps if a killing agent is not employed (Wood, 1970).

Gravid females will oviposit in virtually any type of container, vials or plastic bags with lightly moistened paper toweling work well. Relatively sterile egg collection environments will diminish subsequent losses due to fungal contamination during the incubation period.

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The newly laid, cream colored eggs become glossy black within a few hours, even if unfertilized. During development the egg shell partially collapses. The eggs of *Hepialus,* "*H.*" *californicus* group, *Korscheltellus* Borner, and *Phassus* Walker hatch after 10–30 days at room temperature. However, several egg collections of the late summer- or early fall-flying *Gazoryctra* Hubner (*roseicaput* Neum. & Dyar, $n = 2$; and two undescribed species, the first from Arizona, $n = 3$; and the second from Washington, $n = 2$), failed to hatch after 60 days, perhaps because the eggs diapause through the first winter.

Hepialid eggs may desiccate in dry environments (Madge, 1956; Edwards, 1964; Martyn, 1960), and hence, survivorship can be enhanced by incubating the eggs under high humidities. Three methods proved satisfactory for incubation: leaving the eggs in the plastic bag in which they were laid, periodically moistening the toweling to keep the internal humidity high; placing sublots of eggs in Petri dishes over moistened filter paper; and placing them over recently set plaster. Set plaster has the advantage of being nearly sterile and it also helps to maintain high humidity. Fungal contaminants are frequently a problem in saturated atmospheres; dividing the eggs into several sublots and providing modest spacing in each container will minimize losses. The eggs should be checked daily because the minute first instars are susceptible to desiccation and starvation, as well as excessive moisture.

First Instars

Most, if not all, hepialids are polyphagous, accepting a wide range of larval diets including fungi, ferns, and a variety of gymnosperms and angiosperms. For example, larvae of "*Hepialus*" *californicus* accept a wide range of diets, including natural field hosts such as the root crown tissues of *Eriophyllum staechadifolium* Lag., *Helenium puberulum* DC., *Lupinus arboreus* Sims, and *Rubus* L. (Williams, 1905a, 1905b; Essig, 1926; Wagner, 1985), as well as synthetic diets, e.g., such as those used for rearing the codling moth (*Cydia pomonella* (L.)) and spruce budworms (*Choristoneura* Led. spp.) (Wagner, 1985). Larval growth in *Korscheltellus gracilis* was monitored by measuring weight gain of 20 larvae per host over a period of 8 wk. Greatest weight increases occurred on carrots and two mosses (*Sphagnum* L. and *Polytrichum* Hedw.), but excised roots of *Abies balsamea* (L.) Mill., *Acer saccharum* Marsh., *Betula papyrifera* Marsh, and *Picea rubens* Sarg. were also accepted. Poorest growth was noted in cultures fed on *Dryopteris campyloptera* (Kunze) Clarkson and *Sorbus decora* (Sarg.) Hyland (Wagner, unpubl. data).

Carrots offer several advantages: (1) they are inexpensive and always available; (2) the tissue lasts for weeks or even months; and (3) they are not especially sensitive to mold or bacterial infections.

At eclosion the first instars (and remaining unhatched eggs) can be scattered over a bed of chopped carrots—the pieces ranging from 3 to 15 mm on a side. Sandwich boxes lined with paper toweling and a 2-cm layer of carrots work well for rearing the early instars.

There is some evidence that early instar hepialids are mycophagous (Grehan, 1983, in press). Thus, it may be advantageous to prepare the carrot bed a few days in advance of the anticipated larval emergence so that the carrots have a light flush of fungal hyphae over their surface. Larvae do well if saprophytic fungi

are present in the rearing environment, but bacterial fluxes are detrimental. Replace fully soiled sections. Often greater than 90% first-instar mortality occurs during the first week.

Handling Established Larvae

Leave the immatures in the initial carrot bed for the first two or three instars. To enhance survival, transfer the entire carrot piece(s) with the intact larval shelter from the carrot bed to either a small vial or jar with three or four carrot pieces. Conceal the negatively phototaxic larva by adding fresh carrot pieces. Transfer smaller individuals with camel hair brushes.

Third to Final Instars

The larvae of cannibalistic species need to be transferred to individual containers. In *Hepialus humuli* and "*Hepialus*" *californicus* the incidence of cannibalism increased beginning with the third and fourth instars. Wielgus (pers. comm.) noted significant cannibalism in his colony of *Phassus triangularis.* In contrast, little cannibalism occurred in *Korscheltellus gracilis.*

Larvae of *Hepialus humuli,* "*Hepialus,*" and *Korscheltellus* appeared fully grown after a few months on carrots, but only exceptionally did such larvae go on to pupate. Significant numbers of adults were obtained only after the larvae were subjected to winter-like conditions. To approximate natural conditions, the larvae were wintered outdoors. In late fall, each larva was placed in a cup and covered with a 6–8-cm layer of vermiculite, to which a large carrot section had been added. A folded paper towel was placed between the cup and cover to serve as a wick to draw away excessive moisture. Plastic specimen cups (120 cc) for large species or vials (15–50 cc) for smaller larvae worked suitably.

After the larvae established tunnels in the vermiculite, the cups were moved outdoors, away from direct sunlight and exposure to rain. Although hepialid larvae may be active at temperatures as low as 2–3°C (Edwards, 1964), under natural conditions, larvae presumably avoid freezing temperatures by tunneling deeper into the soil (e.g., Chen et al., 1973). Hence, do not expose the immatures to prolonged subfreezing temperatures. Expect little winter feeding by any of the species. Once every 6–8 wk check for and replace soiled carrots, while leaving the larval tunnel intact. A loose moss, such as sphagnum, can be used as a substitute for vermiculite.

Pupation

As warmer temperatures return, feeding may resume, silk production within the tunnel increases, and the larval tunnel is extended to or above the surface of the vermiculite. The prepupal larva may even gnaw an emergence hole through a thick plastic or wooden lid, and extend the cocoon to this hole. Prior to pupation, the distal end of the cocoon is closed with a thin sheeting of silk.

Once the larval tunnel is closed, the lid can be removed. Prior to emergence, place the cups into an enclosure. A loose layer of crumpled toweling over the vermiculite provides a secure purchase for the eclosing adults from which to hang while pumping up their wings.

Length of Life Cycle

Cultures of *Hepialus humuli,* "*Hepialus*" *behrensii,* and *Korscheltellus gracilis* yielded adults after 1 yr; larvae of both "*H.*" *hectoides* and "*H.*" *californicus* also appeared fully grown after a single season of growth. However, under natural conditions, these species probably have 2-yr life cycles. For example, Edwards (1964) noted that lab colonies of *Hepialus humuli* matured after 1 yr, while field-grown larvae took 2 or even 3 yr to mature. A study of head capsule sizes of "*Hepialus*" *californicus* taken by F. X. Williams at Point Reyes, Marin County, California, supported a 2-yr life cycle (N. B. Tindale, pers. comm.). Label data of adult captures and larval collections of *Korscheltellus gracilis* suggest that it too has a 2-yr life cycle under natural conditions (Wagner, 1988; Tobi et al., 1988; Wagner et al., in press).

General Comments

Early instars of six species belonging to three genera were reared on carrot. With slight modification the methods should work for other hepialids. This is not to say that it will work for all species. For example, late instar larvae of *Sthenopis auratus* (Grote) refused to transfer from ostrich fern (*Matteuccia struthiopteris* (L.) Todaro) to carrot. And it is unlikely that carrots would be consumed by any of the foliage-grazing Hepialidae, which can be reared using the methods of Elder (1970).

Potato sections also were accepted by young instars of *Phassus triangularis.* Other subterranean root or stem tissues, e.g., jicama and beet, might be tried as alternatives. The simplicity of this technique will be advantageous to many. For those with access to insect culturing materials, the semi-synthetic diets suggested by Viedma et al. (1986) for lignicolous Lepidoptera offer the advantages of standardized media. Particular success might be obtained by substituting grated carrots for the "specific component" in their second recipe. A similar semi-synthetic diet was used by Dodgshun (1970) to rear melolonthiine scarabaeids and hepialids in New Zealand.

A major improvement in this method would be to determine those conditions which minimize first-instar mortality. As the eggs are usually broadcast over the ground, it seems likely that components of the litter or humus layer must be critical for first-instar survival. Early instar litter-feeding has been reported in a diversity of hepialids (see review in Grehan, in press). And, in the related Mnesarchaeidae, the larva appears to feed entirely upon forest floor litter (Gibbs, 1979). Hence, greater success might be achieved by provisioning newly hatched larvae with partially decomposed leaf litter, and or other common elements of the forest floor such as bryophytes or fungal hyphae.

Another technique was employed by Edwards (1955, 1964) to rear larvae of *Hepialus humuli.* He placed larvae in individual wells drilled into blocks of set plaster of Paris. Sheets of glass were used to cover adjacent cells. Wells for young larvae measured ¼ in. (6.3 mm) in depth and diameter; these dimensions were increased to an inch (25.4 mm) for older larvae. Periodically the soiled food in each cell was removed and fresh carrot was added. The bottoms of the plaster blocks were then placed in water to maintain high (98%) relative humidities within the larval cells.

A method also needs to be developed for incubating species with an egg diapause. One possibility would be to place the eggs in cavities drilled into wooden blocks, which are then placed outside for the winter—a technique which has been employed for overwintering nymphalid larvae (Mattoon et al., 1971). Scattering the eggs over clumps of moss might also provide a suitable overwintering substrate.

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Literature Cited

Chen, T. L., C. C. Tang, and C. L. Hao. 1973. [A preliminary study on the biology of the "Insect Herb," *Hepialus armoricanus* Oberthur.] Acta Entomol. Sinica, 16:198–202.

Dodgshun, T. J. 1970. A semi-synthetic maintenance diet suitable for hepialid [Lep.] and melolonthid [Col.] larvae. N.Z. Entomol., 4:78–79.

Edwards, C. A. 1955. Simple techniques for rearing Collembola, Symphyla, and other small soil-inhabiting arthropods. Pp. 412–416 *in* D. K. McE. Kevin (ed.), Soil zoology. Butterworth, London.

———. 1964. The bionomics of swift moths. I. The ghost swift moth, *Hepialus humuli* (L.). Bull. Entomol. Res., 55:147–160.

Elder, R. J. 1970. A rearing technique for *Oncopera brachyphylla* Turner and *Oncopera mitocera* (Turner). Queensland J. Agric. & Anim. Sci. 27:401–404.

Essig, E. O. 1926. Insects of western North America. MacMillan Co., New York, p. 755.

Gibbs, G. W. 1979. Some notes on the biology and status of the Mnesarchaeidae (Lepidoptera). N.Z. J. Zool., 3:327–331.

Grehan, J. R. 1983. Larval establishment behavior of the borer *Aenetus virescens* (Lepidoptera: Hepialidae) in live trees. N.Z. Entomol., 7:413–416.

———. 1987. Life cycle of the wood-borer *Aenetus virescens* (Lepidoptera: Hepialidae). N.Z. J. Zool., 14:209–217.

———. In press. Larval feeding habits of the Hepialidae (Lepidoptera). J. Natural History.

Hardy, R. J. 1973. The biology of *Fraus simulans* Walker (Lepidoptera: Hepialidae). J. Australian Entomol. Soc., 12:113–120.

———. 1974. The biology and pest status of *Oxycanus fuscomaculatus* Walker (Lepidoptera: Hepialidae) in Tasmania. J. Australian Entomol. Soc., 13:317–328.

Madge, P. E. 1956. The ecology of *Oncopera fasiculata* (Walker) (Lepidoptera, Hepialidae) in South Australia. III. The influence of temperature and moisture on survival rate of the larvae. Australian J. Zool., 4:346–357.

Martyn, E. J. 1960. The ecology of *Oncopera intricata* Walker and *Oncopera rufobrunnea* Tindale (Lepidoptera: Hepialidae). Res. Bull. Dept. Agric. Tasmania, No. 3.

Mattoon, S. O., R. D. Davis, and O. D. Spencer. 1971. Rearing techniques for species of *Speyeria* (Nymphalidae). J. Lepid. Soc., 25:247–256.

Tindale, N. B. 1932. Revision of the Australian ghost moths (Lepidoptera Homoneura, Family Hepialidae). Part 1. Rec. S. Aust. Mus., 4:497–536.

Tobi, D. R., W. E. Wallner, and B. L. Parker. 1989. The conifer swift moth, *Hepialus gracilis,* and spruce-fir decline. Pp. 361–363 *in* Proceedings of the US–FGR Symposium, Effects of atmospheric pollutants on the spruce-fir forests of the eastern United States and Federal Republic of Germany. General Technical Report, USDA Forest Service Northeastern Forest Experiment Station, Broomall, Pennsylvania.

Viedma, M. G. De, J. R. Baragano, A. Notario, M. Rodero, and C. Iglesias. 1986 (1985). Artificial raising of lignicolous Lepidoptera. J. Res. Lepid., 24:372–374.

Wagner, D. L. 1985. The biosystematics of the Holarctic Hepialidae, with special emphasis on the *Hepialus californicus* species group. Ph.D. dissertation, Univ. California, Berkeley.

———. 1988. Taxonomic status of *Korscheltellus* Börner in North America (Lepidoptera: Hepialidae). J. New York Entomol. Soc., 96:345–354.

——— and J. Rosovsky. In prep. Mating behavior of *Korscheltellus gracilis* (Hepialidae), with a review of the mating systems of primitive Lepidoptera.

———, D. R. Tobi, B. L. Parker, W. E. Wallner, and J. G. Leonard. In press. Immature stages and natural enemies of *Korscheltellus gracilis.* Ann. Entomol. Soc. Amer.

Williams, F. X. 1905a. The larvae of *Hepialus sequoiolus* Behrens. Entomol. News, 16:19–20.

———. 1905b. Notes on the life history of *Hepialus sequoiolus* Behrens. Entomol. News, 16:283–287.

Wood, J. 1970. Rearing *Wiseana* species in the laboratory. N.Z. Entomol., 4:3–7.