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Effect of Photoperiod on Molting of Chortophaga viridifasciata (De Geer) (Orthoptera: Acrididae)

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Most species of Acrididae in temperate regions overwinter in the egg stage—in diapause—but a few species pass through the winter in a late juvenile stage. These overwintering nymphs, usually in the third or fourth instar, are dormant during cold weather. They become active whenever there is a warm period during the winter, but they rarely molt during the winter, even during prolonged periods of mild weather. Is this period of suspended molt comparable to what we usually call diapause? If it is a form of diapause, is it facultative or obligatory—to use terms adopted by several previous investigators (Andrewartha 1952, Lees 1955)—and what environmental factors are associated with it?

The most abundant acridians overwintering as nymphs in northern Colorado are *Arphia conspersa* Scudder, *Eritettix simplex tricarinatus* (Thomas), and *Xanthippus corallipes leprosus* Saussure. Less frequent but present in the same region is *Chortophaga viridifasciata* (DeGeer). Juveniles of all these species are active in midwinter during periods of mild temperature, but only one, *Arphia conspersa,* occasionally molts into the adult condition during prolonged periods of warm winter weather. (On one occasion in late January, and a few times in February, the second author has collected adults of this species near Boulder, Colorado.) Molting in the other species is delayed until April or May (March or April for most individuals of *Arphia conspersa*). The nymphs appear to be in

[1] Present address, Rt. 1, Clarksville, Tenn. The experiments on *Chortophaga viridifasciata* here reported were conducted by the first author in partial fulfillment of the requirements for the Master's degree. This study was under the direction of the second author, who has contributed the general material and has prepared the whole for publication.

diapause as far as development is concerned, and this diapause is not broken by increased temperature. The most likely variable other than temperature that might release them from diapause is the increasing photoperiod (Lees 1955, 1959).

Several observations by the second author suggest that increasing photoperiod is indeed the probable factor that induces molting in overwintering nymphs. On several occasions overwintering nymphs were brought into the laboratory at Boulder, Colorado, after periods of cold weather. Mere exposure to the higher temperature of the laboratory failed to induce molting; in these observations, there was no modification of the natural photoperiod. In specimens that survived long enough, molting began at the end of winter, in March or April, after weeks of exposure to room temperature. The only environmental variable at the time of molting was, apparently, the increasing length of day.

With the possibility in mind that the longer photoperiod is a stimulus for molting in juvenile grasshoppers, the first author undertook a series of experiments at his home near Clarksville, Tennessee. These were based on the assumption that if a long photoperiod releases nymphs from diapause one might expect to find more molts in a group of nymphs exposed to a long day than in a group exposed to a short day. Such a correlation would suggest the stimulus under which a grasshopper might have two broods during a long summer season and still overwinter as a nymph.

The experiments were carried out on *Chortophaga viridifasciata* (DeGeer), a widespread species that overwinters as a juvenile in much of its range— including northern Tennessee, where the experiments were conducted. In the area of study *Chortophaga* is abundant in suitable habitats, particularly south-facing, grass-covered slopes. It persists through the winter in the juvenile condition, though two generations may occur during the long summer. This variation in its life cycle suggests that it might be particularly susceptible to the effect of change in photoperiod.

In the locality of study large numbers could be collected in a short time. The nymphs were collected with care not to injure them; they were not netted but were caught individually in glass jars placed over them. The method of study involved placing third and fourth instar nymphs in cages of uniform size. These cages were eight inches square, nine inches high, with wood tops and bottoms, wood frames, fine wire screen on three sides, and a sliding glass door on the front. Canopies to exclude light from these cages were constructed of plywood; they were three to four inches larger in each dimension than the cages to be covered.

The experiments were conducted in a basement laboratory in which the temperature was maintained constant at 72° F. The relative humidity was not regulated but remained fairly constant at about 55%. Light for each cage was provided by two 100-watt white-light lamps, one about five inches from each side of the cage. In each experiment, each cage was under separate photoperiodic control. All lights were turned on every morning at 6 o'clock. An opaque canopy was placed over each cage as it came to the end of its assigned photoperiod. All lights were turned off at the end of the longest photoperiod of each experiment, at which time all canopies were removed.

At the beginning of each experiment twenty nymphs were placed in each cage. These were provided with fresh food and water daily. The food in early winter was Japanese clover, bluegrass, or Johnson grass, the variety being dependent upon what was available but the same food being used each day in each cage. Later in the winter, cultivated winter rye was supplied. Water was supplied in small vials with cotton wicks. The cages were cleaned daily, and in this process the exuvia were recovered and counted. Thus a daily record on molts was maintained.

The first experiment was begun September 17, 1961, and was carried on 82 days. Three cages were involved, each with 20 nymphs. One was exposed to a 6-hour photoperiod, one to a 10-hour photoperiod, and the third to a 14-hour photoperiod. Twenty-four molts occurred in the cages subjected to a 6-hour day, 30 under the 10-hour day, and 46 under the 14-hour day. Thus, the number of molts was directly correlated with length of photoperiod.

The second experiment was carried on for ten days only, from December 18, to December 27, 1961. Two cages were used, one under a 6-hour photoperiod, the other under 14 hours of light daily. Six molts occurred among the twenty specimens in the 6-hour photoperiod, sixteen under the 14-hour photoperiod.

The third experiment was modified to provide extreme contrast. Two cages were used, one exposed to a 1-hour photoperiod, the other to a 12-hour photoperiod. (It should be noted that although there is a big difference in day length, a 12-hour day is actually not a long photoperiod.) During the 30-day period of this experiment, which lasted from December 28, 1961, to January 26, 1962, twelve molts occurred among the 20 nymphs subjected to the 1-hour photoperiod while 25 occurred under conditions of a 12-hour day.

All these experiments were carried on with temperature controlled at 72° F. Only one experiment testing temperature was conducted. Twenty nymphs under a 12-hour photoperiod at 60° F. molted approximately 20% less frequently than did those in a similar cage maintained at 72° F. In other words, a 12-degree (F.) difference in temperature had much less effect than a difference of a few hours of daylight.

One final experiment was carried on outdoors, during the summer of 1962 (June 14 to July 14). Two cages were used, and they were exposed to natural fluctuations of temperature and relative humidity. One cage was exposed to the natural photoperiod (average 15 hours); the other was covered every day after approximately six hours of daylight. Twenty-nine molts occurred among the nymphs exposed to the 15-hour photoperiod; only nineteen molts occurred under the 6-hour day (even with a temperature range from 75° to 102° F.)

It seems reasonable to assume, on the basis of our observations and experiments, that increasing photoperiod rather than increasing temperature is the major factor in releasing overwintering juvenile grasshoppers from diapause, a diapause that we should probably call facultative. The observations here summarized are, however, merely strong suggestions in that direction. More extensive experiments, involving various species, will be required before this statement may be made a valid generalization for all overwintering juvenile grasshoppers.

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