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A Simple Method for Measuring the Mandibular Movements of the Cabbage Armyworm (*Mamestra brassicae* L.)[1]

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A measurement of the mandibular movements of phytophagous insect larvae is often useful in various biological, pharmacological, or toxicological studies. A device, capable of continuously recording mandibular activity following treatment with drugs, repellents, or feeding stimulants, would be particularly useful in feeding studies. Although several studies on sucking insects (GETTING, 1971; GETTING and STEINHARDT, 1972; FREDMAN and STEINHARDT, 1973; FREDMAN, 1975) and on phytophagous insects (WAGO and YAMAMOTO, 1978) have reported electrophysiological measurements of motor output during feeding, a direct measurement of mandibular movement would also be desirable.

Therefore, the present paper will describe and present representative data from a recording apparatus, consisting of a kymograph and an electronic counter, which is capable of directly monitoring mandibular activity.

Animals: Last instar larvae and post-wandering-stage prepupae of the cabbage armyworm (*Mamestra brassicae*), reared on an artificial diet at 25°C under a long-day photoperiod, were used in the present study. The subjects were ligated with three threads located between the head and thorax, between the mesothorax and metathorax, and just anterior to the anal proleg. The free ends of the ligatures were used to secure the animals, venter-side up, to a small wooden block.

Apparatus: The basic apparatus is illustrated in Fig. 1. A clip was attached to the subject's mandible so that lateral movements of the mandible would activate the arm of the kymograph, thus recording the movement on the smoked drum. An electronic counter (DC-UB4-A, Hokuyo Automatic Co., Ltd.) was attached to the apparatus to count the individual movements. The kymograph was modified so that slight displacements of the arm would activate the counter by making or breaking an electrical connection through the dipping of a contact into a solution of NaCl. The use of a liquid contact instead of a mechanical switch minimized the interference of the counter with the animals' movements. The mandibular movements were simultaneously recorded through change of blood pressure with the outward and inward movements (unpublished data).

Sample Data: Fig. 2 gives a representative recording of the spontaneous mandibular movements (SMM) of a prepupa and a last-instar larva. The last-instar larva was considerably more active than was the prepupa. The kymograph tracings for the last-instar larva were similar to those

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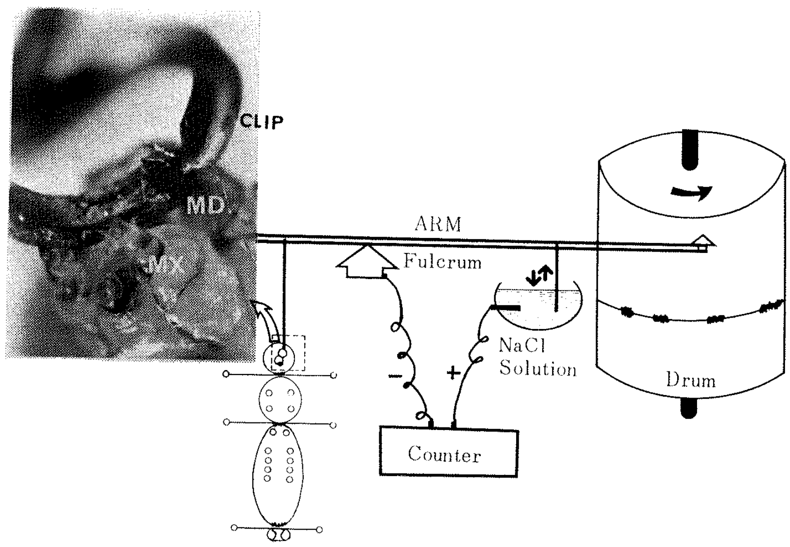

Fig. 1. A schematic illustration of the apparatus used to monitor the mandibular activity of a restrained insect larva or prepupa. Movement of the subject's mandible results in movement of the arm of the kymograph which records the activity upon the smoked drum. The electrical connection made by dipping the contact into the NaCl solution permits an electronic counter to be used in the circuit. MD=mandible; MX=maxilla.

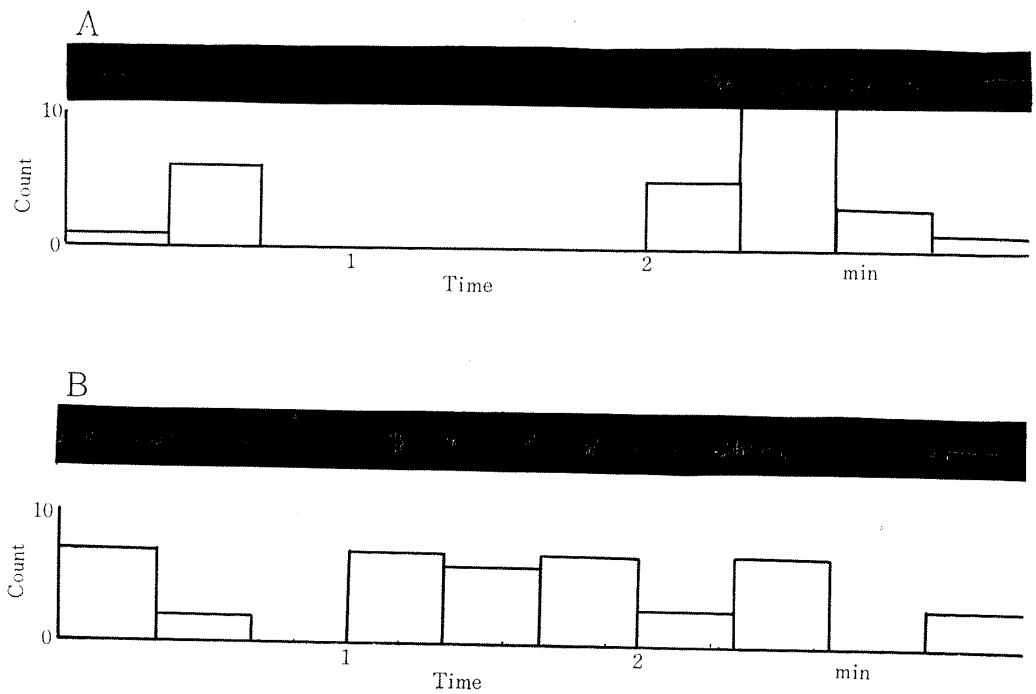

Fig. 2. A sample recording of the spontaneous mandibular movements (SMM) of a prepupa (A) and of a last-instar larva (B). The upper portion of each figure gives the tracing produced by the kymograph, while the histogram gives the counts of the mandibular movements (per 20-sec interval) as accumulated by the electronic counter.

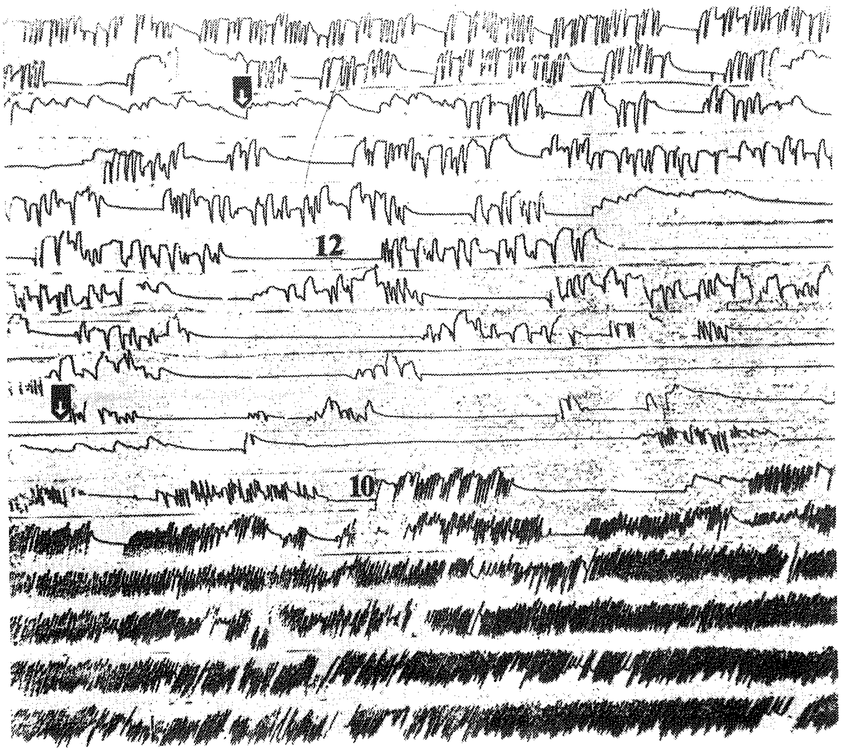

Fig. 3. A recording of mandibular activity before and after treatment with a solution of chlordimeform hydrochloride. Spontaneous mandibular movements (SMM) are illustrated before the first arrow, which indicates the time of the application of a 10 ppm solution to the animal's mouthparts. Note that this treatment did not produce an appreciable increase in the rate of mandibular activity. The "12" indicates the point on the tracing 12 min after the application of chlordimeform. The second arrow indicates the application of a 1000 ppm solution of chlordimeform hydrochloride. The tracing indicates that at approximately 14 min after the application, continuous, repetitive busrt mandibular movements (CBMM) were induced. The "10" indicates 10 min after application.

obtained with electrophysiological measurement of muscle activity during feeding by Wago and Yamamoto (1978). In general, it has been found that both larvae and prepupae tend to show more rapid mandibular movements at the beginning of a test session.

To demonstrate the apparatus' ability to measure rapid movement, some animals were treated with chlordimeform, since this is known to induce continuous, repetitive burst mandibular movements (CBMM) in these animals (Shimizu et al., 1980). Therefore, 10 and 1000 ppm solutions of chlodimeform hydrochloride were prepared (using distilled water) and each 2 μl was placed upon the mouthparts of the subjects. Fig. 3 shows the results of these treatments. The 10 ppm solution had no appreciable effect upon the rate of mandibular movement, with the animal showing approximately the same rate of SMM both before and after treatment. However, 14 min after the application of the 1000 ppm solution, rapid (approximately 110 per min) and regular CBMM were detected. Recently we screened the effect of chlordimeform analogues on mandibular movements by using this system, and it was found that two compounds with 2-methyl substitution caused CBMM (Shimizu et al., 1980).

Applications: As indicated by the results in Fig. 3, this device can be used to provide a sensitive measure of the effects of various toxicants upon mandibular activity. The system could also be used to measure changes in mandibular activity following treatment with feeding stimulants such as organic acids (cf. Matsuda and Matsumoto, 1975).

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Functional Responses of a Predacious Phytoseiid Mite in Different Sizes of Experimental Universe[1]

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Sigmoid functional response has been generally thought to be associated with vertebrate predators (see eg. HOLLING, 1965). However, recent studies (HASSELL et al., 1977; HASSELL, 1978) show that sigmoid response is also widespread among invertebrate predators. They pointed out that sigmoid functional response would be expected for almost all species of predator in cases where there is a threshold density below which searching efficiency of predator declines. Furthermore, HASSELL et al. suggested that if the size of experimental universe is greatly increased, a sigmoid response would be generated. This will be because if the size of experimental universe for functional response experiments is too small, it is often the case that changes in prey density may not affect significantly any change in the searching efficiency of predators. This present study is intended to test the above hypothesis by HASSELL et al., by changing the size of experimental universe, thereby exposing predators to a wide range of prey density, including extremely low densities.

The predator species used in this study was the predacious phytoseiid mite *Phytoseiulus persimilis* ATHIAS-HENRIOT and the prey was the tea red spider mite *Tetranychus kanzawai* KISHIDA. Experimental universe was a white, thick drawing paper with bent edges (1.5 cm wide) around which a wet strip of gause was streched (see TAKAFUJI and CHANT, 1976). Experiments were run on the universes of five different sizes from 4^2 to 22.6^2 cm^2, in each of which each of seven different numbers of *T. kanzawai* eggs from 1 to 64 was evenly distributed, together with a single adult female *P. persimilis* from 1 to 6 days post-maturation. Prey density per 4^2 cm^2 thus ranged from 0.03 to 64. The number of eggs eaten by predators was recorded after 24 hr. Experiments were run in a chamber that was controlled at 25 ± 1°C, 70 ± 10 RH, with continuous illumination.

Figs. 1A-C show the functional responses in the universes of various sizes. In smaller and medium universes, the proportions of prey eaten remained relatively constant initially, decreasing gradually with increasing numbers of prey. Thus, the responses showed almost linear rises initially, then gradually approaching maxima at continually decreasing rates. This type of response is typical for various species of phytoseiid mites (see eg., CHANT, 1961; TAKAFUJI and CHANT, 1976; EVERSON, 1979). The functional response in each of the two larger universes, however, showed a sigmoid increase: the proportion of prey eaten showed a sharp rise up to the density of eight. The results thus showed that if the predator was

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