LOCOMOTOR BEHAVIOR OF DIAPAUSING AND NONDIAPAUSING LARVAE OF CADRA CAUTELLA (WALKER) (LEPIDOPTERA, PYRALIDAE)

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Burges and Haskins [1] reported a slight increase in the last-larvae stadium for *Cadra cautella* (Walker) but not a diapause such as that described for closely related species, i.e., *Plodia interpunctella* (Hübner) and *Ephestia elutella* (Hübner) [2] or *Cadra figulilella* (Gregson) [3]. Subsequently, we discovered in a citrus pulp warehouse a strain of *C. cautella* that diapaused as last-instar larvae. Diapause is an important consideration in any control program because of its significant influence on population trends or its contribution to the ability of a species to survive unfavorable conditions. In the case of *C. cautella*, a high incidence of diapause could result in increased damage to the commodity, because larvae remain capable of locomotor activity, feeding, and silk production while in diapause [4]. In the warehouse, we found that larvae entered diapause throughout the storage period, that the percentage of larvae collected that were in diapause increased, and that diapausing larvae remained active after nondiapausing larvae of the same generation had pupated. Because the probability of a larvae entering an artificial pupation site (actually only a resting site in the case of diapausing larvae) should be proportional to the amount of locomotion (provided all of the larvae reaching a pupation site enter), the extended period of locomotor activity for diapausing larvae would result in a disproportionately large number of diapausing larvae being collected. Thus, estimates for incidence of diapause would tend to be high. Estimates for the incidence of diapause might be made more precise through comparative studies on the behavior of diapausing and nondiapausing larvae or through release and recapture of diapausing and nondiapausing larvae in the warehouse. The results of such studies are reported here.

The tendency for larvae to enter artificial pupation sites in the laboratory was studied in 10 cm high X 18 cm long X 13 cm wide cages containing 200 ml of either standard laboratory medium [5] or citrus pulp. Citrus pulp, a by-product from the production of orange juice concentrate, is sold as animal feed. It is coarser than laboratory medium and is assumed to provide a greater number of resting sites. Artificial pupation sites were rolls made from 76 cm long X 2 cm wide strips of single-faced corrugated cardboard; each provided approximately 250 cells. In most of the experiments reported here, the artificial pupation sites were placed in the center of each cage and were removed after twenty-four hours

exposure. Usually sufficient populations were set up so each cage could be discarded after the pupation site was removed; however, this was not so for studies of the spontaneity of locomotion among diapausing larvae. For these studies, two pupation sites, one empty and one with 100 diapausing larvae, were placed in each cage equidistant from each other and the edges of the cage. The initially empty pupation site was removed and replaced after a week, and both were removed at the end of a 2nd week. All laboratory tests were made at 27°C and 60% RH with 14 hr photophase.

The locomotion of nondiapausing and diapausing larvae was at first evaluated separately. The influence of larval age was evaluated for nondiapausing larvae because of its importance when larval activity is to be terminated by pupation. Other factors such as abundance of pupation sites or frequency of encounters with other larvae are more important in the case of diapausing larvae that remain active or at least retain potential for renewed locomotor activity. Increased activity resulting from handling was evaluated for both, because of its potential importance when larvae are released in the warehouse.

The influence of handling and larval age on the tendency of nondiapausing larvae to enter pupation sites was evaluated by stocking cages containing laboratory medium with 50 larvae taken from 13-, 15-, 17-, and 19-day-old cultures and, when possible, introducing pupation sites at 0 to 9 days subsequent to handling when these insects were 17, 18, 19, 20, 21, or 22 days old. The entire test was replicated twice with both a warehouse strain and a laboratory strain possessing the bl gene [6]. This same laboratory strain was also used for release in the warehouse, because larvae have black rather than brown head capsules and are thus distinguishable from the strain native to the warehouse. Handling of young larvae was apparently inconsequential since there was no significant different between results for larvae from 13-, 15-, and 17-day-old cultures of either strain (these data have been combined in Fig. 1). However, effects of handling on larvae from 19-day-old cultures was apparently significant since they were much more active than larvae handled at a younger age. Also, while the warehouse strain was much more active than the laboratory strain, the locomotor activity of both strains peaked at 19 days.

The influence of larval density, availability of pupation sites, and handling on the tendency of diapausing larvae to enter pupation sites was evaluated by placing 10, 50, or 100 larvae on either citrus pulp or laboratory medium and introducing artificial pupation sites after 1, 2, 3, and 7 days (Fig. 2). Throughout the test period, the locomotor activity or at least the tendency for larvae to enter the artificial pupation sites decreased. Locomotor activity was thus inversely related to the time elapsed since insects were handled. The decline in activity with time was sharper when they were on citrus pulp than when they were on laboratory medium regardless of density and also at the lowest larval density on either media than at higher densities. This suggests that locomotor activity of diapausing larvae is significantly influenced by

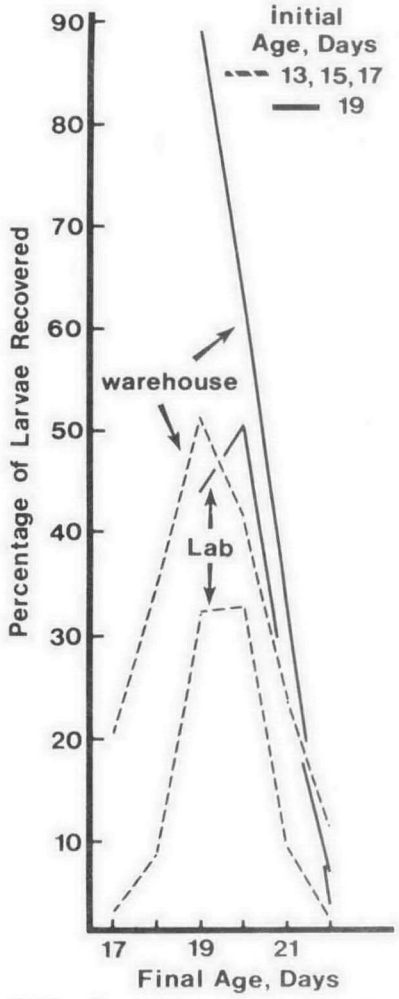

FIG. 1. Percentage of nondiapausing larvae of laboratory or warehouse strain entering artificial pupation sites as a function of age of larvae when introduced into test cage (initial age) and age of larvae when artificial pupation site is introduced (final age).

both larval density and the number of suitable pupation sites, i.e.; citrus pulp provides a greater number of alternatives to artificial pupation sites than does laboratory diet. The significance of the effects of handling is apparent when the results of this test are compared with those from studies of spontaneity of locomotor activity among diapausing larvae. Laboratory and warehouse strains of diapausing larvae placed in artificial pupation sites, left these sites at a rate of 18 and 9% per week, respectively, the 1st week and 0 and 9% per week, respectively, the 2nd week. The test was replicated 3 times for each strain.

The possibility of another larva displacing a diapausing larva from a pupation site was evaluated by placing 10, 50, or 100 diapausing larvae on citrus pulp, allowing 4 days for the larvae to find pupation sites, adding 0, 10, 50, or 100 nondiapausing larvae with the bl gene from 19-day-old cultures, and introducing artificial pupation sites either immediately or after 24 hr. In 2 separate trials, the locomotor activity of the diapausing larvae was increased 2- and 4-fold the 1st 24 hr and 3- and 8-fold the 2nd 24 hr by the addition of active larvae; the influence of density of either the resident population or of the introduced population was not significant. The induced increases in the activity of diapausing larvae persisted even though the activity of nondiapausing larvae was lower the 2nd day, i.e., 38 and 17% recovered on the 1st and 2nd days, respectively.

The influence of larval density and possible competition for pupation sites in the warehouse upon locomotor activity was evaluated by releasing each of 3 densities of 19-day-old larvae (10, 50 and 100) with bl gene in each of 3 areas of the warehouse where densities of the native population were different, i.e., pupation sites recovered a mean 16, 58, or 108 wild-type larvae. In 24 hr, the pupation sites collected approximately 30 and 45% of the released larvae at densities of 10 or 50 and 100, respectively,

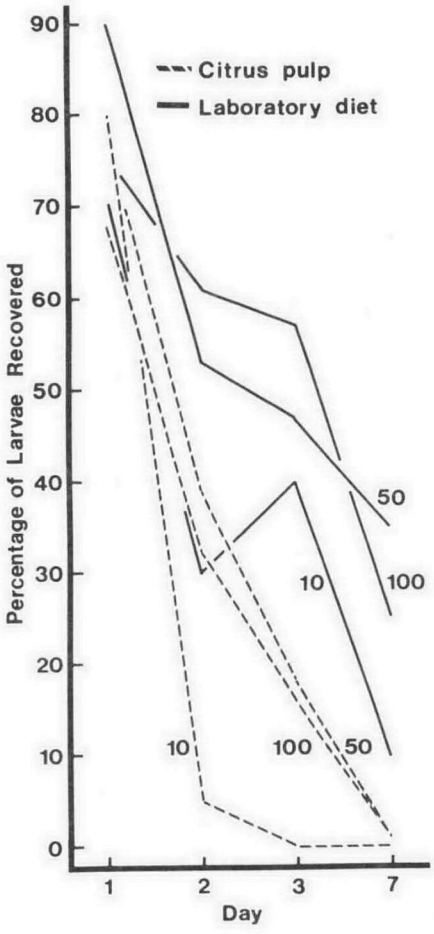

FIG. 2. Percentage of field collected, diapausing larvae entering artificial pupation sites on 1st, 2nd, 3rd, and 7th day of test as a function of larval density (10, 50, or 100) and type of medium used.

and the number recovered was not significantly influenced by the density of wild-type larvae in the release area. The overall results would suggest that pupation sites are so abundant in the warehouse that larvae do not compete for them.

When pupation sites are so abundant that larvae need not compete for them, laboratory studies suggest that diapausing larvae might remain active for only a brief time after nondiapausing larvae of the same generation have pupated, and errors in estimation of the incidence of diapause could be quite small. However, other laboratory studies show that these diapausing larvae can resume activity when displaced from pupation sites by encounters with other larvae.

Because of basic differences in the behavior of diapausing and nondiapausing larvae in laboratory cages, a direct, quantitative comparison of their catchability is not feasible. At first, simultaneous releases of diapausing and nondiapausing larvae to estimate differences in catchability in the warehouses would seem reasonable. However, laboratory studies suggest that field collected larvae should be used because their behavior differs considerably from that of laboratory strains. Further, larvae must be released before reaching maturity to avoid increased activity such as that observed with handling in laboratory studies. Technical difficulties encountered are considerable for both. Thus, it may be more reasonable and productive to examine seasonal variation in the frequency of gene(s) for diapause as a means of interpreting seasonal trends in incidence of diapause rather than pursuing an absolute measure of incidence of diapause.

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