THE EFFECT OF PHOTOPERIOD ON DIAPAUSE INDUCTION AND INHIBITION IN *HIPPODAMIA TREDECIMPUNCTATA* (COLEOPTERA: COCCINELLIDAE)[1]

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Abstract

Diapause in *Hippodamia tredecimpunctata* (Linnaeus) can be inhibited by exposing adult females to photoperiod regimens of LD 16:8 or 14:10 hours. Exposing adult females to a photoperiod of LD 12:12 hours initiates diapause. The photoperiod to which the egg, larval, and pupal stages are exposed has no effect on the developmental rate and has little effect on adult diapause status.

Introduction

The 13-spotted lady beetle, *Hippodamia tredecimpunctata* (Linnaeus), is one of the most common lady beetles feeding on potato infesting aphids in Maine. There are usually two generations per year, depending upon the spring and fall weather conditions. The beetles overwinter as adults. Adults of the first generation are usually found in July, and the second generation adults in September.

Hagen (1962) described three main types of dormancy in predaceous coccinellids based upon the seasons the adults are reproductively inactive. Lees (1955) defined diapause as arrested development, and this may occur in any of the three types of dormancy. Hodek and Cerkasov (1961) and McMullen (1967) determined that varying photoperiod, temperature, and food would induce or inhibit diapause in *Coccinella septempunctata* (Linnaeus) and *C. novemnotata* Herbst, respectively.

The purpose of this investigation was to observe the effects of four different photoperiod regimens on larval development, diapause induction or inhibition, and egg deposition in *H. tredecimpunctata*.

Materials and Methods

Green peach aphids, *Myzus persicae* (Sulzer), were used as prey for larvae and adult beetles. The aphids were reared on radish and Chinese cabbage plants in a greenhouse under a photoperiod regimen of 16 light : 8 dark (LD 16:8) hours.

Adult beetles were collected in potato fields at Presque Isle, Maine. Stock cultures of one female and one male were placed in ½ pt ice cream cartons and fed an excess of aphids daily. The cultures were maintained in an incubator at a temperature of 21±2°C and with an LD 16:8 photoperiod.

Experiments were performed during 1967 and 1968 in incubators set for a constant temperature of 21±2°C and photoperiod regimens of LD 12:12, 14:10, 16:8, and 24:0. In each experimental series the immature stages (eggs, larvae, and pupae) were maintained at one photoperiod, while the emerged females were exposed to each of the four photoperiod regimens. Experimental series were tested for each photoperiod regimen and were replicated three times.

Eggs were collected each morning from the stock cultures and placed under experimental conditions. When the eggs hatched, the larvae were reared individually in 10-dr vials and fed daily an excess of aphids. The time in days from egg hatch to pupation was recorded for each larva. The student's *t*-test was used

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to determine significant differences in the rate of larval development between the different treatments. The time between pupation and emergence was also recorded. Adults emerged 5 or 6 days after pupation.

Newly emerged females were placed in ½ pt ice cream cartons, up to five beetles per container, and fed an excess of aphids daily until the experiment was terminated. The females were placed in one of the four photoperiod regimens. Males were always placed in an LD 16:8 photoperiod. After 10 days, one female and one male were placed in a new ½ pt ice cream container. The number of eggs laid each day for 20 days was recorded for 10 females in each photoperiod regimen. The eggs deposited daily by the female were kept under the same conditions as the female until one mass hatched. If a female died during the 20-day period, it was replaced by an unmated female exposed to the same conditions as the female which died. Dead males were also replaced.

The criterion used to diagnose diapause was oviposition. The hatching of eggs laid by a particular female was not used as a criterion for diapause because the viability of the sperm was not known. The chi-square test was used to determine significant differences between the number of females ovipositing in each treatment. The female beetles from one replicate were fixed in alcoholic Bouin's solution and the ovaries later removed for observation.

The mean number of eggs per female per day for each treatment was calculated for the 20-day test period. Duncan's Multiple Range Test was used to compare the mean number of eggs per day to determine significant differences between treatments.

Results and Discussion

There are no significant differences in larval development in the four photoperiod regimens (Table I). This agrees with the results of Hodek (1958) on *C. septempunctata* and McMullen (1967) on *C. novemnotata.* Records of larval mortality showed no significant differences between treatments. Most larval mortality occurred in the first larval stage.

Photoperiod, temperature, and food were factors which regulated diapause in *C. septempunctata* (Hodek and Cerkasov 1961) and *C. novemnotata* (McMullen 1967). Photoperiod was the most important factor for the induction or inhibition of diapause in these two species. The temperature or amount of food, however, could partially modify the effects of the photoperiod. McMullen determined that the newly emerged adult was most sensitive to photoperiod. The photoperiod to which the adult is exposed is responsible for diapause induction or inhibition in *H. tredecimpunctata* (Table II). A significantly greater number of females oviposit

Table I. Larval duration (in days)

Larval photoperiod (light:dark)	Totals	Larval photoperiod (light:dark)	Totals
12:12	$\bar{x}$ = 10.50 n = 402 r = 7–20	16:8	$\bar{x}$ = 10.58 n = 450 r = 7–15
14:10	$\bar{x}$ = 9.61 n = 450 r = 7–15	24:0	$\bar{x}$ = 10.65 n = 412 r = 7–14

Table II. Effects of diapause on number of females ovipositing

Photoperiod treat. (larval/adult) (light:dark/light:dark)	No. of females tested	No. of females ovipositing	Test of significance at 0.05 level*
16:8 /16:8	30	30	a
12:12/16:8	30	30	a
24:0 /16:8	30	29	ab
14:10/16:8	30	28	abc
16:8 /24:0	30	26	abcd
12:12/14:10	30	25	bcd
14:10/14:10	30	23	cde
16:8 /14:10	30	21	de
24:0 /14:10	30	18	ef
24:0 /24:0	30	17	efg
14:10/24:0	30	16	efg
12:12/24:0	30	13	fgh
16:8 /12:12	30	10	ghi
14:10/12:12	30	10	ghi
12:12/12:12	30	8	hi
24:0 /12:12	30	4	i

*Differences between treatments were tested with the chi-square test. Two or more treatments sharing a common letter are not significantly different.

in adult photoperiods of LD 16:8 and 14:10 than in adult photoperiod of LD 12:12. Examination of the females from one replicate showed that ovaries of females that did not oviposit contained no mature ova. Mortality seldom exceeded one or two females within any treatment.

Females exposed to an LD 16:8 photoperiod as adults laid at least two times as many eggs as females exposed to an adult photoperiod of LD 14:10, and at least four times as many eggs as those exposed to a photoperiod of LD 12:12 as adults (Table III). The same relationship is observed for the number of days upon which oviposition occurred. Duncan's Multiple Range Test showed that there was no significant difference in the daily rate of eggs deposited per female per day at the 5% level. This indicates that photoperiod has little influence on the number of eggs laid per day.

Table III. Rate of oviposition at different photoperiods

Photoperiod treat. (larval/adult) (light:dark/light:dark)	Total no. of eggs deposited	Total no. of days of oviposition	Daily rate of eggs deposited
12:12/16:8	5457 (30)	287	19.01
14:10/16:8	5770 (28)	307	18.79
16:8 /16:8	7943 (30)	400	19.86
24:0 /16:8	6747 (29)	335	20.14
12:12/14:10	2745 (25)	153	17.94
14:10/14:10	2615 (23)	164	15.95
16:8 /14:10	2197 (21)	144	15.26
24:0 /14:10	1736 (18)	103	16.85
12:12/12:12	105 (8)	14	7.50
14:10/12:12	617 (10)	47	13.13
16:8 /12:12	1185 (10)	69	17.17
24:0 /12:12	189 (4)	15	12.60
12:12/24:0	909 (13)	59	15.41
14:10/24:0	1229 (16)	81	15.17
16:8 /24:0	2700 (26)	173	15.61
24:0 /24:0	2976 (17)	153	19.45

NOTE: Numbers in parentheses indicate the number of females which oviposited.

The critical photoperiod for diapause induction in *H. tredecimpunctata* is between 12 and 14 hours of light per day. In northern Maine this photoperiod range occurs from late August to mid-September. Newly emerged, wild females, collected in early September, oviposited when placed in incubators at 21±2°C with an LD 16:8 photoperiod.

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ERRATUM

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p. 1678 and 1680: The illustrations should be reversed.

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