Reports

Photoperiodic Induction and Termination of Diapause in an Insect: Response to Changing Day Lengths

Abstract. Chrysopa carnea *diapaused after experiencing a decrease in day length above the critical photoperiod. Animals experiencing increasing day lengths less than the critical photoperiod did not diapause, and those in diapause began to reproduce. These experiments are the first to demonstrate that insects respond to the direction of change in photoperiods (both increasing and decreasing) which do not encroach on the critical photoperiod.*

In the study of insect photoperiodism it has been an open question whether insects respond to the direction of the change in day length as opposed to the absolute duration of daily periods of light and darkness (*1*, *2*). For example, in some insect species the significant factor of photoperiod is whether the days are "long" or "short" (*3*), whereas some insects appear to respond to the direction in the change of day length (*4*). In addition, some species react to a "long day, short day" sequence in which the two lighting regimens are on opposite sides of the critical photoperiod (*5*, *6*). However, it has not been shown conclusively that insects respond to the direction of changing day length—that is, to a sequence of day lengths which fall on the same side of the critical photoperiod.

Studies with *Chrysopa carnea* Stephens indicated that, under constant temperature conditions, a light-dark period of 16 to 8 hours (LD 16 : 8) promotes continuous development and reproduction (*7*, *8*), whereas LD 12 : 12 produces a relatively short imaginal diapause ($\bar{x} = 34$ days) (*9*). A reproductive diapause of longer duration ($\bar{x} = 95$ days) occurs when the animals experience a long day cycle (LD 16 : 8) before their transfer to LD 12 : 12 (*9*). This more enduring diapause could result either from a long day, short day effect (*5*, *10*) or because the insects perceive the direction of changing day length. To differentiate between these two effects it would be necessary to show that insects subjected to a sequence of decreasing photoperiods longer than the critical photoperiod enter diapause, although singly these photoperiods promote continuous breeding. Conversely it would be necessary to show that insects subjected to a sequence of increasing photoperiods do not undergo diapause, although singly these regimens are diapause inducing.

Table 1. Incidence of diapause in *Chrysopa carnea*. The temperature was maintained at 24° ± 1°C. In all groups of insects the sex ratio was 1:1.

Photoperiod	Animals (No.)	Diapause (%)
LD 8:16	50	100
LD 10:14	96	100 (7)
LD 12:12	52	100
LD 14:10	22	0
LD 16:8	66	0
LD 18:6	20	0
LD 18:6, then LD 14:10*	48	29
LD 8:16, then LD 12:12*	36	0

* The first photoperiod was continued until larval-pupal ecdysis; then the second photoperiod was commenced.

Table 1 gives the temperature and photoperiodic conditions; all other physical factors and the methods for rearing are similar to those reported (*8*, *9*). The criteria for reproductive diapause were lack of oviposition for females and waxy appearance of the cuticle, fat body deposition, and associated color change for both sexes.

Within each constant photoperiodic regime, all *C. carnea* responded to the absolute duration of the photoperiod in the same way (Table 1). The critical photoperiod for our population is greater than LD 12 : 12 and less than LD 14 : 10 (Table 1). The periods LD 18 : 6 and LD 14 : 10 are longer than the critical photoperiod, and each one separately promotes uninterrupted reproduction in all animals; however, when the insects were transferred from LD 18 : 6 to LD 14 : 10, diapause ensued in more than one-quarter of the animals of both sexes. When LD 8 : 16 and LD 12 : 12 are used singly, diapause is induced in all experimental animals; however, transfer from LD 8 : 16 to LD 12 : 12 allows reproduction in all animals (Table 1).

We also studied the perception of direction of changing day lengths in terms of diapause termination, with the use of photoperiods shorter than the critical time. For example, when the photoperiodic cycle of diapausing adults was changed from LD 8 : 16 to LD 12 : 12, oviposition occurred within 16.5 ± 3.3 days (S.D.) ($N = 12$). However, when the cycle was LD 8 : 16 diapause continued for 75 ± 8 days ($N = 18$), and at LD 12:12 diapause continued for 34 ± 11 days ($N = 52$). Thus, LD 12 : 12 can function either as a diapause-inducing, diapause-preventing, or diapause-terminating day length, depending on the photoperiodic history of the insects.

Our data show that *C. carnea* can perceive and respond to both decreasing and increasing day lengths which do not encroach on the critical photoperiod.

MAURICE J. TAUBER
CATHERINE A. TAUBER
Department of Entomology and Limnology, Cornell University, Ithaca, New York 14850

References and Notes

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6. Critical photoperiod is defined as the point at which the response curve of a population changes from a high incidence to a low incidence of diapause (*1*).
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