# Initiation and Termination of Pupal Diapause in the Fall Webworm, *Hyphantria cunea* Drury[1]

MANN-YEON CHOI AND KYUNG-SAENG BOO

최만연 • 부경생 : 흰불나방(*Hyphantria cunea* D.) 용의 휴면 유기와 종료

*Korean J. Plant Prot.* 26(3) : 139~144 (1987)

**ABSTRACT** This study was carried out to investigate the incidence and termination of pupal diapause in the fall webworm, *Hyphantria cunea* Drury. Larvae obtained from overwintered pupae were reared on *Morus alba* leaves at 25±1°C with the relative humidity of 60% or higher in a laboratory. The critical photoperiod for pupal diapause initiation is between 14hrs and 14hrs & 30 minutes at 25±10°C. The developmental period of larvae was shorter under longer photoperiod at 25±1°C. In nature, diapause termination seems to begin in late December. The diapausing pupae did not emerge at all when they were transferred to a favorable environment before the time.

## INTRODUCTION

Diapause is an important adaptive mechanism for survival during periods of unfavorable environmental conditions. Many reports suggested that the induction of diapause depends on both photoperiod and temperature (2, 4, 5, 7, 9, 14, 16)

In field, the incidence of diapause in the fall webworm, *Hyphantria cunea*, is determined by interactions among environmental factors such as short daylength, relatively low temperature, food quality and humidity in developmental periods of larvae and genetic variations resulting from local conditions (11, 19). The critical photoperiod for the induction of the winter diapause at 25°C was reported to be between 14hrs & 30min and 14hrs & 45min in Tokyo(Japan) in the fall webworm(11), although it may become shorter with high temperature.

Diapause termination is influnced by photoperiod and temperature(3, 13, 15) and long daylength and/or chilling are often used to terminate dipause in the laboratory(10). In most species with an 'overwintering diapause', diapause ends in midwinter rather than in spring(17).

The fall webworm has four generations a year in Lousiana (USA), three in Arkansas (USA), two in Tokyo(Japan) and Suweon(Korea)(11, 12, 18, 20) and shows facultative type of diapause in the above localities.

This study was carried out to investigate the incidence and termination of diapause in the fall webworm, *Hyphantria cunea*

## MATERIALS AND METHODS

### Critical photoperiod

Larvae obtained from overwintered pupae were reared on *Morus alba* leaves at 25±1°C with relative humidity higher than 60% in a laboratory. In the first brood, larvae were exposed to 13hrs, 14hrs, 14hrs & 30min 15 hrs, and 16hrs of the light period per day. The photophase of 14hrs & 30min was also tried at 30±1°C, besides 25±1°C. In the second brood, photophases of 13hrs & 40 min, 14 hrs, 14hrs & 15min, 14hrs & 30min, and 16hrs were applied. Here again the photoperiod of 14hrs had another combination with 30±1°C. These photoperiods were mai-

Dept. of Agricultural Biology, College of Agriculture, Seoul National University (서울대학교 농과대학 농생물학과)

① This research was financially supported by the Korea Science and Engineering Foundation(1985~1986).

ntained even after pupation. The pupae were placed at 25±1°C and 60% relative humidity for 1 month and the emergence of adults were recorded daily.

**Diapause termination**

The diapausing pupae were collected from field in Suweon area from late September to mid October. In addition, some second generation larvae were reared to pupal stage in the laboratory under natural temperature and photoperiod, and daipausing pupae were obtained from them. The diapausing pupae obtained from above conditions were buried outdoors in late October. To examine the termination of diapause in field, the pupae from outdoor storage site were periodically transferred to the laboratory with LD 16 : 8 at 25±1°C and 60% relative humidity, and the number of days for emergence was counted.

## RESULTS AND DISCUSSION

*Hyphantria cunea* is a typical long-day species. This is evident from Figs. 1 and 2 in which the percentage of pupae going into diapause is plotted against photoperiod. In an experiment with the larvae obtained from overwintered pupae, all resulting pupae entered diapause when reared in photoperiods of 13hrs or shorter, but those from photoperiods of 14hrs & 30min or longer emerged to adults within 4 weeks showing no sign of diapause. In larvae grown in the photoperiod of 14hrs, about three quarters of the resulting pupae entered diapause(Fig. 1).

To clarify this point further, second generation larvae were again grown in various photoperiods of around 14hrs, with intervals of 15 minutes (Fig. 2). As with first generation pupae, those from the larvae grown in the photoperiod of 14hrs & 30min did not go into diapause at all. However, all those from

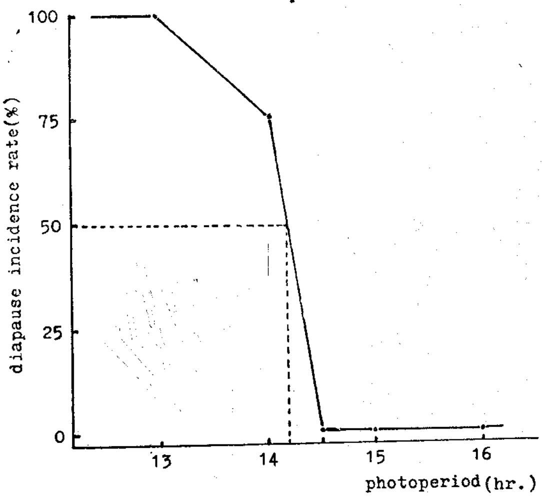


**Fig. 1.** Relation between diapause incidence rate and photoperiod for larval growth of *Hyphantria cunea* at 25±1°C. Carried out in May-July with larvae obtained from overwintered pupae.

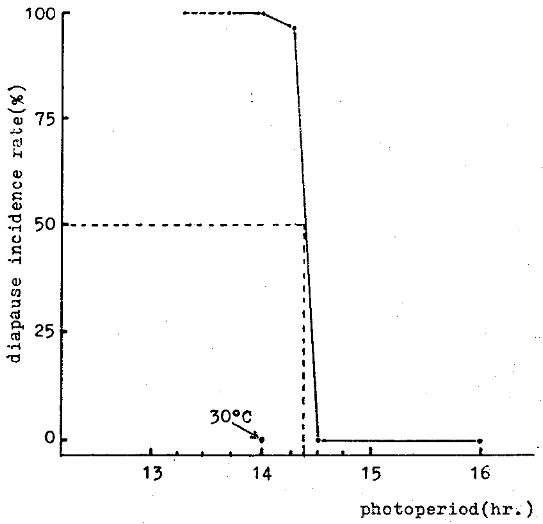


**Fig. 2.** Relation between diapause incidence rate and photoperiod for larval growth of *Hyphantria cunea* at 25±1°C. Carried out in July-August with larvae obtained from 1st generation pupae.

the photoperiod of 14hrs entered diapause, in contrast to the case in the first generation. And among pupae obtained from the photoperiod of 14hrs & 15min, about 95% of them showed diapause. From these results the critical photoperiod for the incidence of diapause in *H. cunea* pupae appears to be between 14hrs and 14hrs & 30min depending on generations.

The critical photoperiod for this species was reported to be 14hrs & 30min at 72°F (about 22°C) in New Brunswick and Nova Scotia(around 46°N) of Canada(12), and between 14hrs & 30min and 14hrs & 45min at 25°C in Tokyo area(35°41′N) of Japan(11). In terms of the latitude, Suweon area (37°6′N) is between the other two, but the critical photoperiod is the shortest, even though the difference is not great. The diapause was not induced under 14hrs of photoperiod at 30 ±1°C(Fig 2). The incidence of diapause was apparently suppressed due to high temperature.

The critical photoperiod for the incidence of diapause in a laboratory was similar to that of field(17) In the fall webworm, the incidence of diapause was determined during early larval instar, not late ones(11) The egg, larval and pupal stage spend about 8, 30, and 11 days, respectively, at 25°C, and if 10°C is used as the threshold temperaure for development in the fall webworm(12, 18), the number of degree-days of each stage is 120, 450 and 165, respectively. Then the total heat requirement would be in the range of between 700 and 800 degree-days. In Suweon area, the first generation starts during late May or June. The first generation has the degree-days of 700~800 in mid and late July. In most cases, the larval development of second generation begins in early August and they enter overwintering pupal diapause in late August and early September. During this period the number of degree-days for larvae is about 400~500 because of high temperature(about 26.3°C) in field. The early larval instars of second brood grow under shorter daylength of 13hr & 40min in mid August than the critical photoperiod for the incidence of diapause (Figs. 1, 2) in Suweon area and they may determine the incidence of diapause during this time. In a few cases in which the larval development of the 2nd brood begins in mid July, the early instars grow under relatively longer daylength(14hrs & 24min) of late July(25.2C) in field than the critical photoperiod(Figs.1, 2), therefore, the 6th instars do not enter diapause. Since the number of the degree-days is about 700 ~800 from mid July to early September, it may be possible that the third generation may appear. In nature, 3rd generation larvae have been seen in some years (unpublished observation). This interpretation is also supported by their shorter developmental period at longer photoperiods than shorter periods (Table 1).

**Table 1.** Developmental period of *Hyphantria cunea* larvae reared on *Morus alba* leaves under different photoperiod and two temperatures.

| Temp. (°C) | Photoperiod (L/D) | No. of larvae | Larval periods (Days) |
|---|---|---|---|
| 25±1 | 13 : 00/11 : 00 | 33 | 33±4 |
| 25±1 | 13 : 45/10 : 15 | 31 | 31±2 |
| 25±1 | 14 : 00/10 : 00 | 27 | 31±2 |
| 25±1 | 14 : 15/09 : 45 | 21 | 32±2 |
| 25±1 | 14 : 30/09 : 30 | 25 | 30±3 |
| 25±1 | 16 : 00/08 : 00 | 150 | 26±1 |
| 30±1 | 14 : 00/10 : 00 | 95 | 23±1 |
| 30±1 | 14 : 30/09 : 30 | 25 | 23±1 |

When the diapausing pupae were transferred from the outdoor storage sites into the laboratory, they were able to emerge only when they were sampled on Dec. 21 or thereafter. This suggests that essential features of diapause development for this species are completed by this time. However, it took 50 ~70 days for the pupae to emerge when they were transferred during late Dec.-early Jan. From these facts it can be said that they were still in a state of partial 'diapause' in the population. This speculation is also substantiated by the rate of adult emergence (Figs. 3, 4). The rate gradually increased

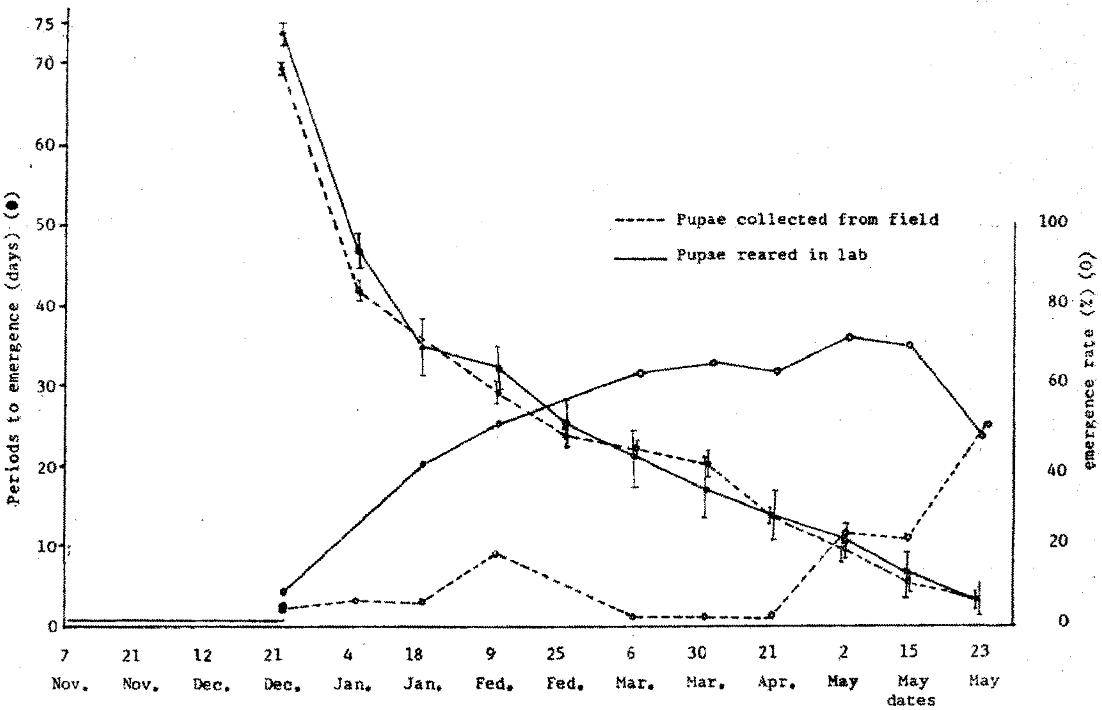


**Fig. 3.** Number of days at 25±1°C needed for adult emergence and its rate from diapausing pupae taken in from the outdoor storage site on dates indicated(1983~1984).

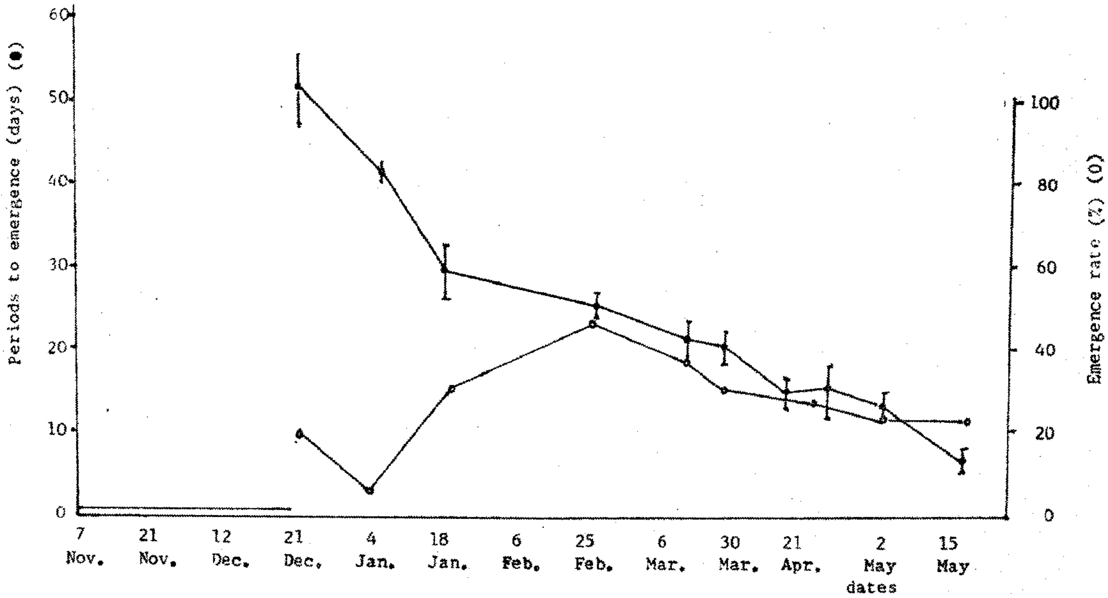


**Fig. 4.** Number of days at 25±1°C needed for adult emergence and its rate from diapausing pupae taken in from the outdoor storage site on dates indicated (1984~1985).

with sampling dates. The number of days needed for the adult emergence gradually decreased with time until mid May, when it is less than 12days, which is the period necessary for non-diapause development. at the temperature (25°C). This shows that pupal development for the adult already begins in May outdoors(Figs.3, 4).

For diapause maintenance, low temperature and short daylength are required(6, 10, 17). Furthermore, low temperature, especially towards the of diapause, may help prevent the exhaustion of metabolic reserves before diapause ends(1). Diapausing pupae from outdoors, when tranferred into the laboratory, did not emerge until 21 December, probably because there was an insufficient period of certain low temperature required for diapause development. The truth must be found with more experiments.


## 적 요

흰불나방의 蛹 休眠 誘起와 월동휴면 終了시기를 조사한 실험에서 다음의 결과를 얻었다.

1. 25±1°C온도 조건에서 휴면유기의 임계일장은 14시간과 14시간 30분 사이에 존재하였다.

2. 유충 발육기간은 25±1°C조건에서 일장이 길어질 수록 약간씩 단축되었다.

3. 야외에서 월동휴면 종료는 12월하순 이후에 부분적으로 시작되었으며 그 이전에 꺼낸 용은 성충으로 전혀 우화되지 않았다.


## LITERATURES CITED


1. Beck, S.D. 1967. Water intake and termination of diapause in the European corn borer, *Ostrinia nubilalis*. J. Insect Physiol. 13 : 739~750. (indirectly cited from Ann. Rev. Ent. 1976. 21 : 90)
2. Beck, S. D. 1983. Thermal and thermoperiodic effects on larval development and diapause in the European corn borer, *Ostrinia nubilalis*. J. Insect Physiol. 29 : 107~112.
3. Bell, C.H. 1983. The regulation of development during diapause in *Ephestia elutella*(Hubner) by temperature and photoperiod. J. Insect Physiol. 29 : 485~490.
4. Cullen, J.M. and T.O. Browing. 1978. The influence of photoperiod and temperature on the induction of diapause in pupae of *Heliothis punctigera*. J. Insect Physiol. 24 : 595~601.
5. Dean, J.M. 1982. Control of diapause induction by a change in photoperiod in *Melanoplus sanguinipes*. J. Insect Physiol. 28 : 1035~1040.
6. De Wilde, J. 1962. Photoperiodism in insects and mites. Ann. Rev. Ent. 7 : 1~26.
7. Gangavalli, R.R. and M.T. Aliniazee. 1985. Diapause induction in the obliquebanded leafroller *Choristoneura rosaceana* (Lepidoptera: Tortricidae): role of photoperiod and temperature. J. Insect Physiol. 31 : 831~835.
8. Ito. Y., K. Miyashida and H. Yamada. 1968. Biology of *Hyphantria cunea* Drury (Lipidoptera: Arctiidae) in Japan. IV. Effect of temperature on development of immature stages. Appl. Ent. Zool.3 : 163~175.
9. Kikukawa, S. and S. Masaki. 1984. Interacting effects of photophase and scotophase on the diapause response in the Indian meal moth, *Plodia interpunctella*. J. Insect Physiol. 30 : 919~925.
10. Lees, A.D. 1956. The physiology and biochemistry of diapause. Ann. Rev.Ent. 1 : 1~16.
11. Masaki, S., K. Umeya, Y.Sekiguchi and R. Kawasaki. 1968. Biology of *Hyphantria cunea* Drury(Lepidoptera: Arctiidae) in Japan. III. Photoperiodic induction of diapause in relation to the seasonal life

cycle. Appl. Ent. Zool- 3 : 55~66.

12. Morris, R.F. 1967. Factors inducing diapause in *Hyphantria cunea*. Can. Ent. 99 : 522~529.
13. Orshan, L. and M.P. Pencer. 1979. Termination and reinduction of reproductive diapause by photoperiod and temperature in males of the grasshopper, *Oedipoda miniata*. Physiol. Entomol. 4: 55~61.
14. Saunders, D.S. 1982. Photoperiodic induction of pupal diapause in *Sarcophaga argyrostoma:* temperature effects on circadian resonance. J. Insect Physiol. 28 : 305 ~310.
15. Saunders, D.S. 1983. A diapause induction-termination asymmetry in the photoperiodic response of the linden bug, *Pyrrhocoris apterus* and an effect of near-critical phtoperiods on development. J. Insect Physiol. 29 : 399~405.
16. Shimada, K. 1983. Photoperiodic induction of diapause in normal and allatectomized precocious pupae of *Papilio machaon*. J. Insect Physiol. 29 : 801~806.
17. Tauber, M.J. and C.A. Tauber. 1976. Insect seasonality: Diapause maintenance, termination, and postdiapause development. Ann. Rev. Ent. 21 : 81~107.
18. Warren, L.O. and M. Tadic. 1970. The fall webworm, *Hyphantria cunea* (Drury). Arkansas Exp. Sta. Bull. 759. 105pp.
19. Watanabe, N., K. Umeya and S. Masaki. 1970. Biology of *Hyphantria cunea*(Lepidoptera: Arctiidae) in Japan. X. Development of larvae in relation to the induction of the pupal diapause. Res. Bull. Pl. Proc. Japan 8 : 30~80.
20. Woo, K.S. 1961. Studies on *Hyphantria cunea* Drury, a newly introduced insect pest. Seoul Nat'l Univ., Dept. of Agric. Biol. Res. 5 : 11~23. (Korean)