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Suppression of Indian Meal Moth (Lepidoptera : Pyralidae) by Iterative Mass Release of *Bracon hebetor* (Hymenoptera : Braconidae) in Wheat Elevators

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대형 엘리베이터에서 *Bracon hebetor* (벌목 : 좀벌과)의 반복 방사에 의한 화랑곡나방 (나비목 : 명나방과)의 방제 효과

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ABSTRACT : Biological control of Indian meal moth (*Plodia interpunctella* (Hübner)) by iterative mass release of its larval parasitoid, *Bracon hebetor* Say, was tested in a large wheat elevator (diameter 8 m, height 41 m) containing 6,000 t of wheat. Adult parasitoids were released seven times from July 23 to September 3, 2002. The number of parasitoid adults per release time varied from 3,000 to 10,000 so that the total number released was 50,000. The moth population density in the parasitoid-released elevator was maintained at a level of ≈30% compared to the moth population in untreated elevators.

KEY WORDS : *Plodia interpunctella*, *Bracon hebetor*, Biological control, Wheat elevator

초 록 : 대용량 밀 저장 엘리베이터(직경 8 m, 높이 41 m)에서 화랑곡나방(*Plodia interpunctella* (Hübner))의 유충기생봉, *Bracon hebetor* Say, 방사를 통한 화랑곡나방 개체군의 억제 실험을 수행하였다. 2002 년 7월 23일부터 일주 간격으로 총 50,000 마리의 기생봉을 방사하였던 바 화랑곡나방 성충의 밀도 수준이 방사하지 않은 엘리베이터에 비해서 30% 수준으로 유지되었다.

검색어 : *Plodia interpunctella*, *Bracon hebetor*, 생물적 방제, 밀 저장 엘리베이터

Biological control of Indian meal moth (*Plodia interpunctella* Hübner) by its larval parasitoid, *Bracon hebetor* Say, has been reported to be successful or partially successful (Brower and Press, 1990; Brower et al., 1995; Cline and Press, 1990; Cline et al., 1984; Duott, 1958). However, most studies were conducted in small storage facilities or laboratories (see Brower et al., 1995) and could not provide reliable evidences for the biological control of the moth by release of *B .hebetor* in large storage warehouses or processing facilities. The present study was to test suppression of Indian meal moth population by iterative mass release of *B. hebetor* in great wheat elevators. Although this study applied single replication to evaluate the suppression effect of Indian meal moth population by the parasitoid release, a time series analysis of the moth population in the wheat elevators with and without release of *B. hebetor* and a big experimental size gave some information on the

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biological control in large storage warehouses or processing facilities.

Materials and Methods

Insects

Indian meal moth was collected at a warehouse for dried vegetables located in Taegu in 1995, and its stock culture have been maintained on dried onion (*Alium fistulosum*L.) at 28±0.5°C and 70-80% RH with photoperiod of 16:8 (L:D) in the laboratory of population ecology, Korea university.

B. hebetor were collected from the stock culture of Indian meal moth in 1996 and maintained on the fourth and fifth larval instars of Indian meal moth. We introduced 10 adult parasitoids (< 24 h old) together with 200 4th and 5th larval instars of the moth into a glass jar (ϕ 8.5 cm, height 13.5 cm) and allowed to lay eggs on the larvae. Thereby, we could yield more than 200 adult parasitoids from a single rearing jar and manipulated the number of rearing jars as required.

Parasitoid release

The release site was a wheat -elevator (8 m, height 41 m) which contains continuously more than 6,000 t of imported wheat before processing, which is located in Asan-Si, Chungnam-Do

We conducted this study in the three elevators in the wheat storage; (1) Elevator with *B. hebetor* (E with B.h.), (2) Elevator without B. hebetor 1 (E w/o B.h.1), and Elevator without B. hebetor 2 (E w/o B.h.2). Three thousand adults of *B. hebetor* (<24 h old) were released into the E with B.h. and then 5,000-10,000 adults were released weekly until September 3, 2002 (Table 1). The total number of adults *B. hebetor* released was 50,000. Two other elevators of the same size without parasitoids release provided untreated control (E w/o B.h. 1 and E w/o B.h. 2).

Table 1. Release date and number of adult *B. hebetor* released in the wheat elevator

Release date	Number of *B. hebetor* released
July 23	3,000
July 30	5,000
August 6	5,000
August 13	10,000
August 20	7,000
August 27	10,000
September 3	10,000
Total	50,000

Evaluation of suppression of the moth population

Temperature and relative humidity in the elevators during the study period were recorded by automatic temperature and relative humidity recorder (Hobo, Onset Computer Co., U.S.A.)

The number of Indian meal moth in the elevators were caught by the pheromone-baited sticky trap (Pherocon II). The trap manufactured by Trécé (Salinas, U.S.A.) has a single pheromone component, Z-9, E-12-tetradecadienyl acetate (Doud and Phillips, 2000). The traps were hung $\approx$ 1 m above the wheat surface in the elevators using a cotton thread fixed at the elevator cover. From July 2 to November 9, we collected the traps and counted the number of the moth in the trap and replaced the trap with a new one by every week.

To estimate the suppression efficiency of the parasitoid, we analyzed sequential trend of the moth caught by autoregressive-integrated moving average process (Box and Jenkins, 1976) using PROC ARIMA (SAS Institute, 1992).

Results and Discussion

The wheat stored in the elevators provided suboptimal or optimal environment for both the Indian meal moth and the parasitoid populations. Fig. 1 shows the trend of temperature and relative humidity recorded every 25 minutes in the elevators during the study period from July 9 to September 7, 2002. The mean temperature (s.d.) was 27.7±2.46°C and varied from 23.63°C to 36.13°C. The relative humidity (s.d.) was 62.7±5.43% and varied

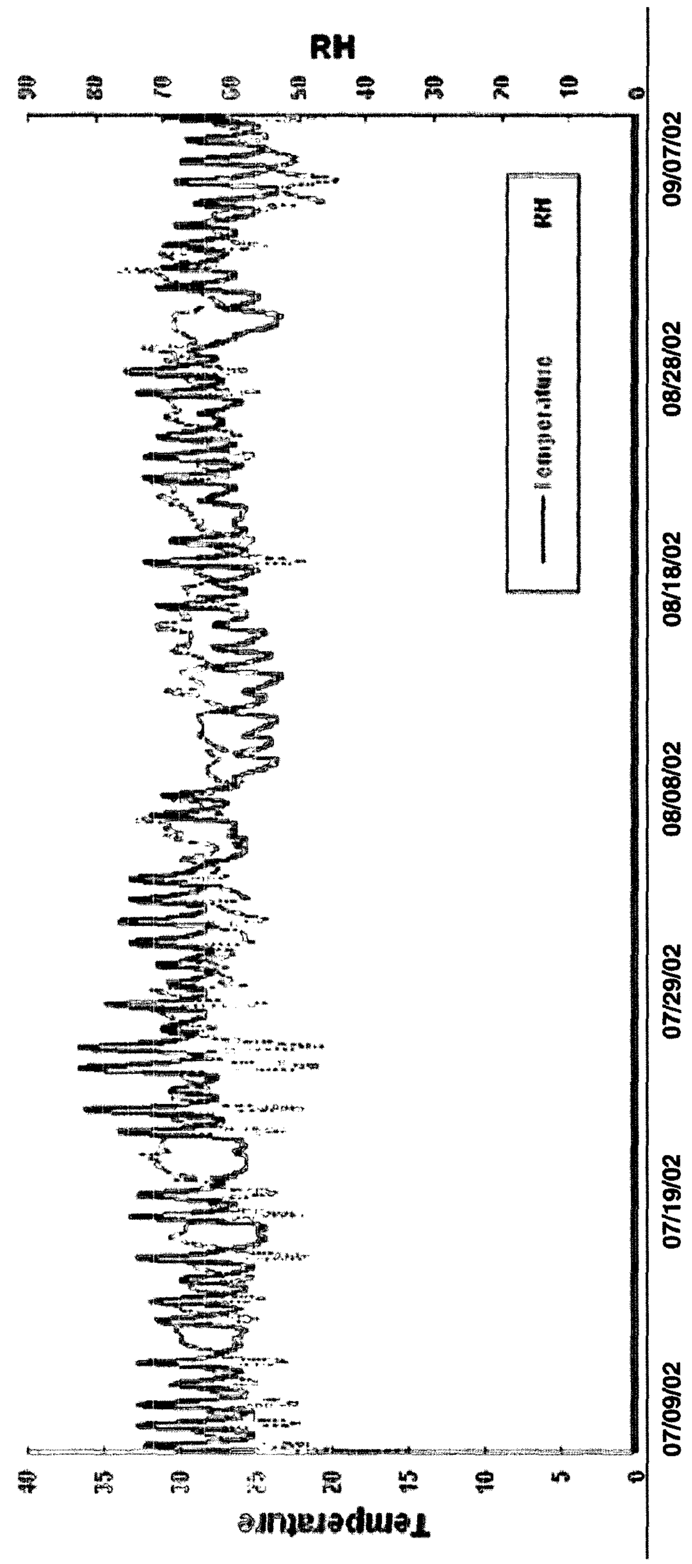

Fig. 1. Sequential changes in the temperature and relative humidity in a wheat elevator.

from 46.1% to 76.5%. Indian meal moth is active at the temperature range of 15.2 - 35°C with an optimum at around 30°C (Johnson et al., 1992; Na and Ryoo, 2000). The threshold of relative humidity for the moth development was about 40% (Howe, 1965). *B. hebetor* requires a similar physical condition with the moth (Kim et al., 2000).

The number of moth caught by the pheromone-baited traps were similar in the period of July 2 to July 23 when parasitoids were not released ($F=1.79$ and 1.70; $df=2,8$; $P>0.28$, for the elevators and period, respectively) (Fig. 2). However, the numbers of moth in the parasitoid-released elevator (E with B.h.) was reduced from an average level (s.d.) of 73.0±6.58 to 23.4±3.80,

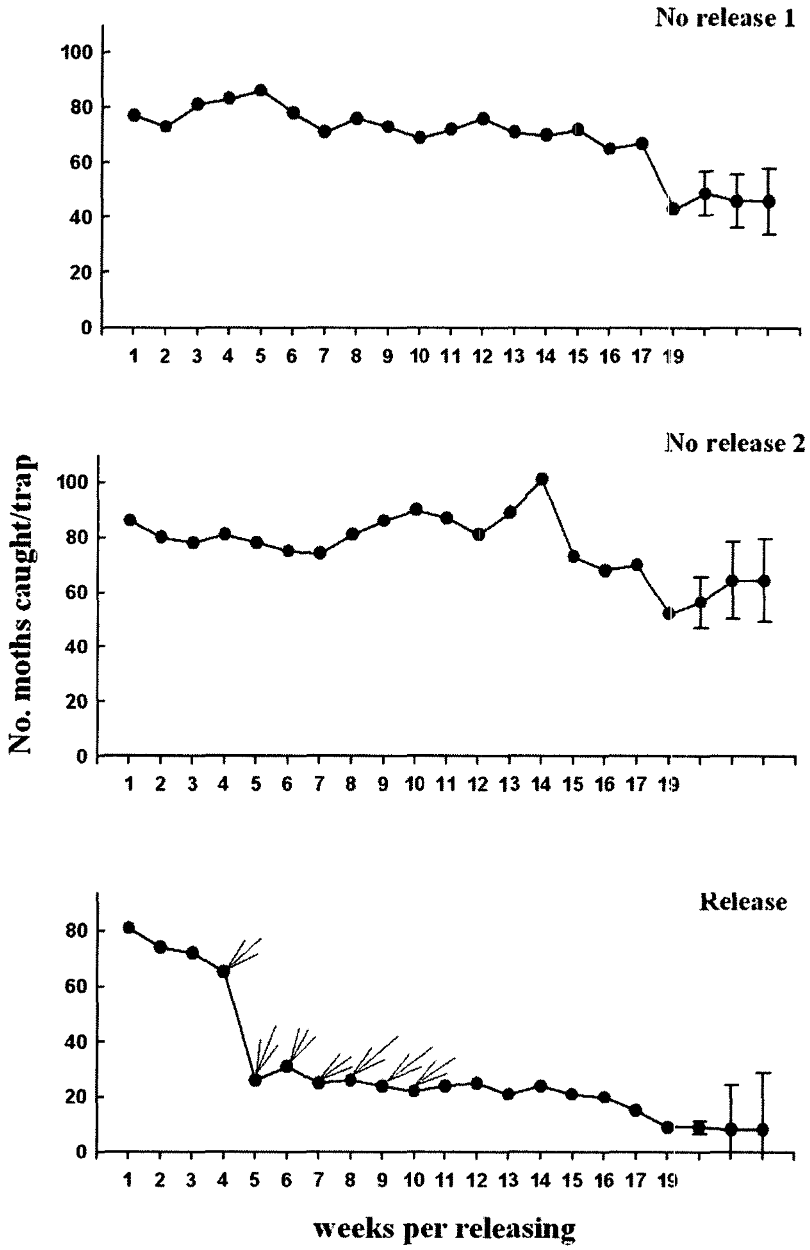

Fig. 2. Sequential changes of number of moth caught in the elevators with and without *B. hebetor* released. The values with standard error (vertical bar) indicate the theoretical values by weighted moving average estimation. The equations for the estimation are $Z_t = Z_{t-1} + a_t - 0.2493a_{t-1} + 0.1225a_{t-2}$, $Z_t = Z_{t-1} + a_t - 0.1112\ a_{t-1} + 0.1486\ a_{t-2}$, $Z_t = Z_{t-1} + a_t - 0.11195a_{t-1} + 0.14857a_{t-2}$, for E w/o B.h.1, E w/o B.h.2 and E with B.h., respectively. a_t is white noise at time t.

whereas the numbers of the moth in the other two elevators without the parasitoids release were kept continuously at an average level of 77.6±7.79. The number of moth trapped decreased in all the three elevators in November. Population of Indian meal moth showed 47.5±6.36 per trap in the elevators without parasitoids, but only 9 per trap in the parasitoid-released elevator (E. with B.h.) on November 7. The sequential trends of moth caught per trap were well fitted to a weighted moving average model (χ^2 =2.56-7.38 and P>0.68) (Fig. 2). The predicted number of three further sequential periods were estimated as 48.81±7.78, 45.97 ±9.72 and 45.97±11.86, and 56.34±9.43, 64.29± 14.05, and 64.29±15.10 for E w/o B.h. 1 and E w/o B.h. 2., respectively. Whereas the estimates were 9.00± 12.17, 8.12±16.28, and 8.22±20.62 in B with B.h. Though the variation of the estimated values were so great to evaluate the suppression efficiency of the parasitoid on the Indian meal moth, the sequential trend of the number of moth caught showed that the level of the moth abundance in E with B.h. was about 30 % of that in E w/o B.h. 1 and E w/o B.h 2.

In a laboratory study, the releasing ratio of one female parasitoid to 7.2 larvae of Indian meal moth could induce 97% larval mortality (Reinert and King, 1971). The present study suggested that suppression of the moth population in a large elevator by the parasitoid could not be so efficient as in the laboratory, suggesting more parasitoids should be released to reduce the Indian meal moth population sufficiently. To do this, we should develop more efficient mass rearing system than simply using moth larvae as media. In addition, an evaluating method for the moth density in the elevator is required, which can adjust optimum release of the parasitoid and maximize the suppression efficiency.

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