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Biology and Control of *Crocidolomia binotalis* in Indonesia

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Abstract

The diamondback moth, *Plutella xylostella* (L.), is the most important pest of crucifers in Indonesia. In most highland vegetable areas, this pest has been effectively controlled by the ichneumonid parasitoid, *Diadegma semiclausum* Hellen. However, the cabbagehead caterpillar (*Crocidolomia binotalis* Zeller) which is the secondary pest of cabbage, may become a serious problem, particularly during the dry season. Results of laboratory and field studies of *C. binotalis* during the last 10 years are reviewed and discussed in this paper. Under laboratory conditions (26-33°C and 54-87% RH), the life cycle lasted about 28 days (26-32 days). This period increased from 30 to 41 days at lower temperatures (16-22°C). The egg incubation period lasted for 4 days (3-6 days). There are five larval instars with the mean duration of 14 days (11-17 days). The pupation period took about 10 days (9-13 days). A female moth may lay on an average 300 eggs (68-590 eggs) in its lifetime; 92% (69-100%) of the eggs will hatch. Two larval parasitoids were tentatively identified as *Inareolata argenteopilosa* Cam. (Ichneumonidae) and *Sturmia inconspicuoides* Bar. (Tachinidae). Rates of parasitization were low throughout the sampling period. Larval population increased starting from 2 weeks after planting, peaked at 8-10 weeks after planting and declined thereafter up to harvest time. Abundance of *C. binotalis* larvae was negatively correlated with rainfall. Counts of the immature stages of *C. binotalis* showed that the distribution of larval populations followed a negative binomial pattern. Studies have also been conducted to evaluate efficacy of insecticides on *C. binotalis* larvae and their effect on the fecundity of female moths. In line with the development and implementation of integrated control of *C. binotalis*, control threshold level needs to be determined. Research along this line is still underway.

Introduction

Since 1973, it has been known that the diamondback moth (DBM), *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae), and cabbagehead caterpillar (CHC), *Crocidolomia binotalis* Zeller (Lepidoptera: Pyralidae), are harmful and economically important caterpillars on cabbage in Indonesia. If suitable control is not undertaken, especially in the dry season, the yield loss caused by both insect pests together may be up to 100% (Sudarwohadi 1975). Since that time, considerable research has been done on bioecology and control of DBM, while less attention was given to CHC. The success of biological control program of DBM by the introduced parasitoid *Diadegma semiclausum* Hellen (Hymenoptera: Ichneumonidae), does not mean that the pest problem on cabbage cultivation has been completely solved (Sastrosiswojo and Sastrodihardjo 1986). In some cases, CHC may become an even more serious problem, particularly during the dry season and in the areas where insecticide use is less. In spite of the economic importance of CHC on cabbage in Indonesia, very little is known of its life history, population ecology and proper control strategy. This paper reviews the research work carried out on CHC since 1981.

Biology

Host Range

CHC infests wild and cultivated crucifers, including cabbage (*Brassica oleracea* var. *capitata* L.), cauliflower (*B. oleracea* var. *botrytis* L.) and Chinese cabbage (*B. campestris* spp. *pekinensis*). CHC occurs to a lesser extent on turnip (*B. rapa* var. *rapa* L.), sprouting broccoli (*B. oleracea* var. *botrytis* L. subvar. *cymosa* Lam.) and radish (*Raphanus sativus* var. *hortensis*) (Gunn 1925, Kalshoven 1981). It has also been reported that mustard (*B. juncea* Coss.), watercress (*Nasturtium officinale*) and an ornamental crop *Clerodendron fragranspeniflorum* Vent. are host plants of CHC (Thayib 1983).

CHC exhibits a marked preference for ovipositing on turnip rape (*B. campestris* ssp. *oleifera* Metzg. Sinisk) and pak choy (*B. chinensis*) (Setiawati 1989).

Life History

The biology of CHC has been studied in the laboratory, including its life cycle and behavior (van den Oever 1973; Othman 1982; Thayib 1983; Setiawati 1989).

Egg stage: The eggs are light green and usually oviposited on the underside of cabbage leaves. Before hatching, the color of the eggs changes to orange, yellowish-brown and dark-brown. The eggs are laid in overlapping masses of 9-120 eggs with an average of 48. The size of egg clusters ranges from 1.0 × 2.0 mm to 3.5 × 6.0 mm with an average of 2.6 × 4.3 mm.

The incubation period for eggs was 4 days (range 3-6 days) at 26.0-33.2°C. The percentage of hatching is 92.4% (range 69.2-100%) (Othman 1982).

Larval stage: The newly hatched larvae are gregarious with black heads and light green body and dark spots. The larvae are characterized by whitish longitudinal stripes, three dorsally and one on each lateral side. The fully grown larvae are 15-21 mm in length.

There are five larval instars. The duration of each successive instar was 2.6 days (range 2-4 days), 2.4 days (range 1-3 days), 2 days (range 1-3 days), 2.3 days (range 1-5 days) and 4.7 days (range 3-7 days), respectively. The total larval period extends to 14 days (range 11-17 days) at 26.0-33.2°C and 54.1-87.8% RH (Othman 1982). However, van den Oever (1973) reported that the larval period varied from 10-14 days at 16-22.5°C and 60-85% RH (Table 1).

The damage caused by CHC on cabbage can be a serious problem because the caterpillars prefer the young leaves and growing point which are succulent, and often devour it completely. This trend is clearer when the larvae enter the third instar stage. If the caterpillars attack cabbage plants during the head formation stage, they will penetrate into the head, make tunnels and the crop will rot.

Pupal stage: Usually pupation takes place on the soil surface. The pupa is yellowish brown and later becomes dark-brown. The size of pupa is about 3 mm wide and 10 mm long. The pupal stage ranged from 9 to 13 days with an average of 10 days at 26.0-33.2°C and 54.1-87.8% RH (Othman 1982). Van den Oever (1973) reported that the pupal period was 13-18 days at 16-22.5°C and 60-85% RH.

Adults: The female moths emerge about 1 day before the males (van den Oever 1973). The adults have black thorax and reddish-brown abdomen. The females bear a curved ovipositor and are generally larger than the males. The moths are nocturnal, but are not attracted by artificial

Table 1. Life cycle of CHC in Indonesia.

Item	26.0 - 33.2°C; 54.1 - 87.8% RH[a]	16.0 - 22.4°C; 60.0 - 85.0% RH[a]
Oviposition period (days)	8.5 (3-19)	several days
Egg incubation period (days)	4.4 (3-6)	(4-5)
Egg viability (%)	92.4 (69-100)	almost 100%
Larval period (days):		
1st instar	2.6 (2-4)	(3-4)
2nd instar	2.4 (1-3)	(2-3)
3rd instar	2.0 (1-3)	(2-3)
4th instar	2.3 (1-5)	(3-4)
5th instar	4.7 (3-7)	-
Total	14.0 (11-17)	(10-14)
Pupal period (days)	10.3 (9-13)	(13-18)
Adult longevity (days)		
Mated male	15.9 (6-30)	-
Mated female	15.2 (8-26)	-
Life cycle (days)	28.3 (26-32)	(30-41)
Sex ratio (male: female)	0.9:1.0	1.0:1.0

[a]Numbers in parentheses indicate range. Adapted from van den Oever (1973), Othman (1982) and Thayib (1983).

light. During the day they hide under the cabbage leaves and when disturbed they will fly briefly. The color pattern of the male forewings is sharper than the females. The males can be easily recognized by a tuft of dark hairs at the anterior margin on both of the forewings. The males have longer body (11.4 mm) than the females (9.6 mm). Visually, the females have larger abdomen than the males.

Mating, oviposition, and fecundity: Thayib (1983) reported that the sex ratio of CHC was male:female, 1:1. The moths mate after 2-3 days from emergence. In the field, mating always happens around midnight until early morning. In the laboratory, mating may occur during the day in dark places after about an hour's darkness. Oviposition usually takes place at night, and at least starting from 1 day after copulation for 2-4 days.

Othman (1982) reported that the females are able to deposit 2-21 egg clusters containing a total of 60-598 eggs when fed with honey and 1-13 egg clusters containing 11-294 eggs when no honey was given. The oviposition period was 3-10 days when honey was given and 1-7 days when not supplied with honey. The life span of mated males and females lasts for 6-30 days and 8-26 days when honey was given, and 3-23 days and 3-14 days when not provided with honey. Thus, the role of diluted honey (honey:distilled water = 1 : 1) is very important in mass-rearing of CHC.

Under laboratory conditions (16-22.5°C and 60-85% RH), van der Oever (1973) reported that the total life cycle of CHC ranged from 30-41 days. However, Othman (1982) mentioned that at 26.0-33.2°C and 54.1-87% RH, the duration of one generation CHC ranged from 26 to 32 days (average 28 days) (Table 1).

Natural Enemies

Parasitoids: Some parastioids of CHC larvae collected from Sindanglaya (Segunung areas) from 1927 to 1931 and preserved in the museum of the Central Research Institute For Agriculture (now Bogor Research Institute For Food Crops) are: *Sturmia inconspicuoides* Bar. (Diptera:Tachinidae), *Inareolata argenteopilosa* Cam. (Hymenoptera:Ichneumonidae), *Mesochorus* sp., *Atrometus* sp. and *Chelonus tabonus* (Sonan). According to van den Oever (1973), *I. argenteopilosa* attacks the second or third instar larvae, while *S. inconspicuoides* attacks the third or fourth instar larvae. The rate of parasitism of both species was low, viz. 1.6% for

I. argenteopilosa and 4.4% for *S. inconspicuoides*. Othman (1982) reported that *I. argenteopilosa* was more predominant than *S. inconspicuoides*. From field-collected larvae, she found that the percentage of parasitism of the *I. argenteopilosa* ranged from 1.1 to 7.2%, whereas the *S. inconspicuoides* ranged from 0 to 4.1%. Under laboratory conditions, *I. argenteopilosa* could parasitize the first to the third larval instars. However, it seemed that the parasitoid preferred the 2-day-old larvae as they had softer and thinner skin than older larvae.

The percentage of parasitism decreased with age of larvae. It seemed that the percentage of parasitism also decreased as the host population increased. The highest rate of parasitism was 31.3% when the parasitoid-host ratio was 1:10. The duration of the life cycle of *I. argenteopilosa* under laboratory conditions (26.0 - 33.2°C and 54.1 - 87.8% RH) was 16-21 days (Table 2). Adult longevity for both mated male and female was 3-17 days.

Table 2. The development periods of *I. argenteopilosa* on 4 - 5-day-old CHC larvae.

Stage		Mean (range) duration (days)
Egg and larva period, on:	4-day-old host larvae	10.3 (8-13)
	5-day-old host larvae	8.3 (7-9)
Pupal period		8.0 (7-9)
Total life cycle, on:	4-day-old host larvae	18.2 (18-21)
	5-day-old host larvae	16.7 (16-17)

Source: Othman (1982)

Predators: Van den Oever (1973) reported that by observations in the field, only predation by a black beetle larva (Coleoptera: Carabidae) was noticed. The predation capacity was unknown.

Pathogens: During a 2-year study on the bionomics of CHC, Thayib (1983) collected diseased larvae affected by bacteria and fungi. Results from isolation and microscopic examination indicated that the dead specimens were infected with *Proteus* spp., *Achromobacter* sp. and *Bacillus* sp. (bacteria), and fungi from the genera *Aspergillus*, *Fusarium* and *Penicillium*. Reinfection trials showed that the pathogen virulence was not consistent, especially when the relative humidity was not high.

Ecology

Geographical distribution

CHC is a common pest of cruciferous crops with a worldwide distribution in tropical and temperate regions. Its area of distribution is reported as South and Southeast Asia, Australia, South Africa, Tanzania and the Pacific Islands (Dammerman 1929; Kalshoven 1981).

Seasonal incidence

Seasonal incidence of CHC on cabbage has been studied in Indonesia at Segunung (altitude 1100 m) (van der Oever 1973; Sudarwohadi 1975; Thayib 1983). The oviposition peaks in February, May and July-August. High buildup of larval populations was in March, June and August (Fig. 1). This coincided with the drier part of the year at Segunung. This also indicates that there is a negative correlation between the CHC populations with rainfall; higher rainfall increases insect mortality.

Although it was not very clear, it may be assumed that there are two oviposition peaks during one growing season (Fig. 1). This means that at least there are two generations of CHC during one growing season. In general, the study indicated that within 90 days of cabbage growing period, the population of CHC larvae tends to increase starting from 2 weeks after planting, peaks at 6-8 weeks later and declines thereafter up to harvest time.

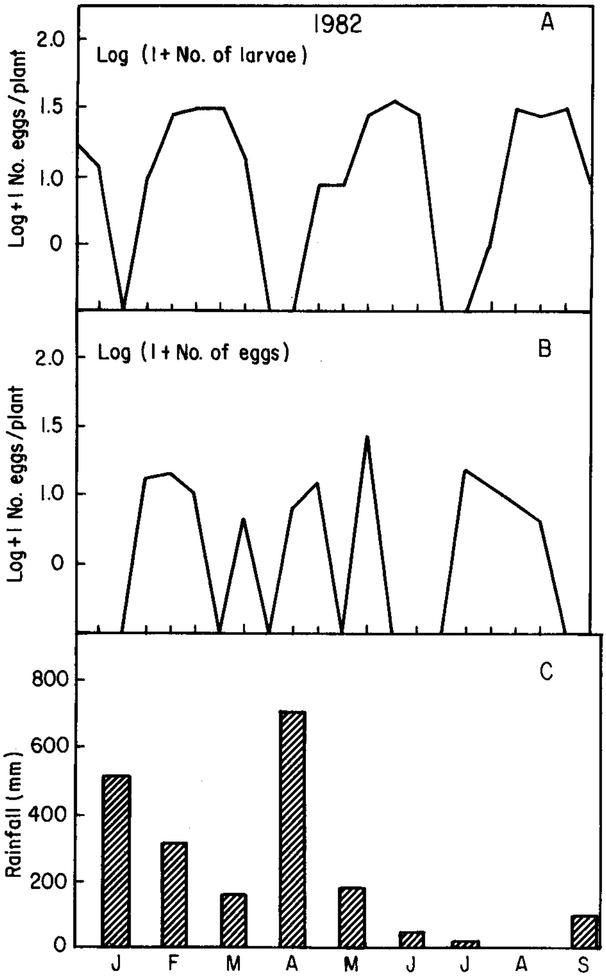

Fig. 1.
(A) Number of CHC larvae/ prepupae per plant, (B) Number of CHC eggs per plant, and (C) Monthly rainfall.

Population distribution pattern

The pattern of population distribution of CHC larvae on cabbage was recently investigated at Lembang by Tohidin (1990). CHC larvae tend to aggregate on cabbage plants. Their spatial distribution on cabbage has the characteristic of being contiguous and follow the negative binomial distribution. The optimal sample size for CHC larvae was 54 plants with one quadrant of sample unit per plant.

Chemical Control

Since up to the present there is no other alternative control for CHC, chemical control is the most common method. Various chemical and microbial insecticides have been recommended for the control of CHC on cruciferous crops.

Commercial preparations of *Bacillus thuringiensis* Berliner (Dipel WP, Bactospeine WP and Thuricide HP) at 1.0 - 2.0 kg formulated product per hectare were reported effective against CHC (Sudarwohadi et al. 1973; Sastrosiswojo 1987; Setiawati and Sastrosiswojo 1989).

Chlorfluazuron and teflubenzuron (insect growth regulators) were effective against CHC at 40 g AI/ha (Sastrosiswojo 1987; Soeriaatmadja and Duskarna 1990). Based on the laboratory study, it was found that *B. thuringiensis* (Dipel WP) and chlorfluazuron were more effective against early instar than late instar larvae of CHC (Setiawati and Sastrosiswojo 1991, in press). The LC_{50} values against second instar larvae of CHC were 42 ppm for *B. thuringiensis* and 424 ppm for chlorfluazuron, whereas against fourth instar larvae they were 755 and 1068 ppm respectively. Chemical insecticides reported to be effective against CHC were permethrin, cypermethrin, decamethrin, profenofos, prothiophos and acephate (Sastrosiswojo 1987; Soeriaatmadja and Duskarno 1990). However, laboratory studies proved that acephate and permethrin may cause a resurgence of *C. binotalis*. Acephate and permethrin induced increases of fecundity of adults by 98 and 93%, respectively (Setiawati 1990). The reasons and mechanism of this resurgence are not fully understood.

Integrated Pest Management Approach

The development and implementation of integrated control of CHC cannot be separated from a DBM program. At present, *D. semiclausum* is an important biological control agent of DBM in Indonesia, especially in areas where it is well established (Sastrosiswojo and Sastrodihardjo 1986). Integration between biological control and the use of selective insecticides based on the control threshold of DBM (0.5 larva/plant) will reduce the amount of insecticde usage by 40-60% (Sastrosiswojo 1987). Thus, the population of CHC may increase, since so far there is no effective biological control agent for CHC. Some alternative control stra-tegies that might be implemented are as follows:

(1) The most rational and primary step is to develop control threshold of CHC. Monitoring may be based on the population of CHC eggs or second-third instar larvae, or visual damage threshold as suggested by Srinivasan (1984 cited by Chelliah and Srinivasan 1986). Research along this line is still being undertaken at LEHRI, Lembang.

(2) Superimposition of damage threshold on the intercrop combination of one row of cabbage and one row of tomato is also advocated as an effective alternative approach to reducing cabbage yields significantly (Chelliah and Srinivasan 1986).

(3) The encouragement of biological control in any IPM program is also important. Although the larval parasitoid *I. argenteopilosa* occurs in Indonesia, the level of parasitism is low. Therefore exotic parasitoids should be introduced to complement the existing ones. Another possibility is the use of pathogens such as entomogenous fungi or viruses. These pathogens should be explored in the country or if possible introduced into Indonesia.

(4) There is doubt that chemical control is still an important key component in an IPM approach. As far as CHC is concerned, the use of insecticides that do not harm or are less toxic to *D. semiclausum* but effective against DBM and CHC is strongly recommended.

(5) Other factors to be considered in the IPM program are monitoring system, sampling technique and sample size. The use of sex pheromone might be important, both for monitoring or mass trapping.

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