

## Role of Parasitoids in Managing Diamondback Moth in the Cameron Highlands, Malaysia

Peter A. C. Ooi

International Institute of Biological Control (IIBC), c/o CAB International Regional Office for Asia, P.O. Box 11872, 50760 Kuala Lumpur, Malaysia

### Abstract

Three major primary parasitoids of the diamondback moth, *Plutella xylostella* (L.), are found in the Cameron Highlands, Malaysia. *Cotesia plutellae* (Kurdjumov) was discovered in the early 1970s, *Diadegma semiclausum* (Hellén) and *Diadromus collaris* (Gravenhorst) were introduced in the mid 1970s from New Zealand and Australia. Field studies in the early 1980s showed that *C. plutellae* was the dominant parasitoid. This was contrary to laboratory studies which showed that *D. semiclausum* was an intrinsically superior parasitoid. In the Cameron Highlands, farmers sprayed insecticides frequently, often at concentrations far exceeding recommended dosages. In 1987, Singapore imposed restrictions on excessive levels of pesticide residues in crucifers. This together with high levels of insecticide resistance in the DBM resulted in farmers switching to the use of *Bacillus thuringiensis*, resulting in an unprecedented development for the management of diamondback moth. Even with reduced usage of chemical insecticides farmers were able to harvest good crops. Reduction in use of chemical insecticides allowed the primary parasitoids to realize their potential. The impact of biological control is manifested in: a) lower population of DBM despite less usage of insecticides; b) *D. semiclausum* became the dominant parasitoid; c) farmers realized that they need not be dependent on insecticides. Hence after more than 10 years, the impact of *D. semiclausum*, which was masked by excessive insecticide usage, was realized. Other parasitoids, predators and microbial agents probably act in consonance to suppress the DBM population. The experience in the Cameron Highlands emphasized the central role of parasitoids in managing diamondback moth. The strategy in managing this pest is to build up a core of effective parasitoids and supplement the action of parasitoids with use of *B. thuringiensis* when necessary.

### Introduction

It was evident from reports of insecticide resistance in diamondback moth (DBM), *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae) (Henderson 1957; Lim 1972; Ooi and Sudderuddin 1978; Sudderudin and Kok 1978), that the approach adopted by cabbage farmers in the Cameron Highlands had to change. As the pest is an exotic insect, a likely approach was to import natural enemies of the DBM from its native home. This approach was attempted in New Zealand (Muggeridge 1930; Hardy 1938) and resulted in significant decline in DBM populations there (Todd 1959). Similarly, parasitoids of DBM were introduced into Australia and contributed to a useful level of control (Wilson 1960). Nearer home, an ichneumonid was introduced from New Zealand to Indonesia in 1950 and was an important parasitoid of DBM (Vos 1953; Sastrosiswojo and Sastrodihardjo 1986). These records suggested that biological control of DBM is feasible.

With that in mind, a biological control program for DBM was initiated in 1975. This paper reviews the status of the biological control program for DBM in Malaysia with a view to establishing a strategy for the role of parasitoids in the overall management of DBM.

## Materials and Methods

To facilitate a review of the biological control of DBM, field data from ecological studies carried out in 1976-78 (prior to release of the major parasitoids) (Ooi 1979a) were compared with data collected from 1988-90 from a similar site in the Cameron Highlands. The site was the MARDI Research Station at Tanah Rata. In the studies, cabbage was grown in overlapping crops to ensure continuous sampling. No insecticide was used in the study. Twenty to thirty cabbages were removed every fortnight to examine for DBM and major parasitoids. Data from both studies were graphed to show population trends of DBM (larvae and pupae) and the number of cocoons of the major parasitoids observed. The population data were also analyzed using the method of Kuno and Dyck (1985), where a cabbage crop was divided into four crop periods. Each period corresponded to 27 days, being the average length of the DBM life cycle in the Cameron Highlands (Ho 1965). This analysis will indicate seasonal changes in the DBM population and allow comparison between two different sets of data. A similar analysis was reported in Ooi et al. (1990) for smaller but similar sets of data. Period I lasts from day 4 to 30, period II from 31 to 57, period III from 58 to 84 and period IV lasts from day 85 to harvest. Data from nine crops grown continuously between 1976 and 1978 were grouped into the respective crop periods, transformed using  $\log(x + 1)$  and averaged. Data from 11 continuous crops grown between 1988 and 1990 were similarly treated. The results were plotted to show the population trend. The regression between number of parasitoid cocoons collected and the respective DBM population was determined using a Lotus spreadsheet.

## Biological Control of DBM in Malaysia

Before the 1970s, little was known of the ecology of DBM in Malaysia. The only control measure available to farmers was application of insecticides and this unilateral approach encouraged development of extensive insecticide resistance in the DBM (Ooi 1986; Ooi and Sudderuddin 1978; Sudderuddin and Kok 1978). Use of chemicals contributed to 30% or more of the total cost of production (Lim 1972). A biological control approach was simultaneously initiated by the Malaysian Agricultural Research and Development Institute (MARDI) and the Crop Protection Branch of the Department of Agriculture.

Studies by Lim and Ko (1975) resulted in the discovery of *Cotesia plutellae* (Kurdjumov) (Hymenoptera: Braconidae) in the Cameron Highlands. It is unlikely that *C. plutellae* is native and could have arrived fortuitously towards the late 1960s. Levels of parasitism averaged 29.6 to 35.8% (Lim 1982) and in another study ranged between 12.3 and 19.1% (Ooi 1979a). The level of parasitism suggested that *C. plutellae* was not a very effective parasitoid. This contrasted with recent studies from Sabah where parasitism averaged 59.3 and 66.6% from two study sites (Tay et al. in preparation). *C. plutellae* was introduced into Sabah from India between 1971 and 1974. Initially, this parasitoid did not have any impact on the DBM population in the Kundasang Highlands and was thought to have failed to establish. However, studies in 1987 showed that this parasitoid was very common and appeared to keep the DBM in check in cabbage farms at Kundasang.

The levels of parasitism by *C. plutellae* in the Cameron Highlands appeared to be similar to that recorded in India (Bhalla and Dubey 1986; Joshi and Sharma 1974), Japan (Uematsu et al. 1987), Philippines (Velasco 1983) and Taiwan (Fan and Ho 1971).

Despite the low incidence of *C. plutellae* in Cameron Highlands, Lim (1986) suggested that this parasitoid is important in the development of an integrated pest management program (IPM) for DBM. This suggestion was tested by Lim et al. (1986) in an insecticide-check experiment. From the results obtained, it could be extrapolated that an IPM program would be better if there were more species of parasitoids acting on DBM at the different immature stages.

Four species of parasitoids were introduced into the Cameron Highlands from India, New Zealand, Australia and Indonesia (Ooi and Lim 1989). Of these, only two established, namely, *Diadegma semiclausum* Hellén (Hymenoptera: Ichneumonidae) and *Diadromus collaris* (Gravenhorst) (Hymenoptera: Ichneumonidae). The third ichneumonid *Macromalon orientale*

Kerrich (Hymenoptera: Ichneumonidae) was not released as it failed to breed in the laboratory. The fourth imported parasitoid *Tetrastichus sokolowskii* Kurdjumov (Hymenoptera: Eulophidae) was introduced into the Cameron Highlands and Kundasang but in both places failed to establish.

Like *C. plutellae*, *D. semiclausum*, *M. orientale* and *T. sokolowskii* attacked DBM larvae. *D. collaris* is a pupal parasitoid which attacks fresh DBM pupae within their cocoons. Details of the biology of *D. eucerophaga* and *T. sokolowskii* under Malaysian conditions are provided by Ooi (1980, 1988).

### Status of parasitoids of DBM

Following the release of three parasitoids in the Cameron Highlands (Ooi and Lim 1989), only *D. semiclausum* and *D. collaris* established. For more than a decade, the impact of both parasitoids was not realized and in the minds of many, the introduction was unsuccessful. In 1987, complaints and rejections of vegetables with high levels of pesticide residues from an importing country encouraged farmers to reduce the usage of insecticides. By 1989, cabbage farmers in most of the Cameron Highlands noted with satisfaction that even with less usage of insecticides, the DBM problem was not serious. A study of the data from 1977 and 1989 showed that the DBM population in 1989 was reduced by about eight times or more as compared with that in 1977 (Fig. 1 and 2). Although the data were from an ecological study site, they

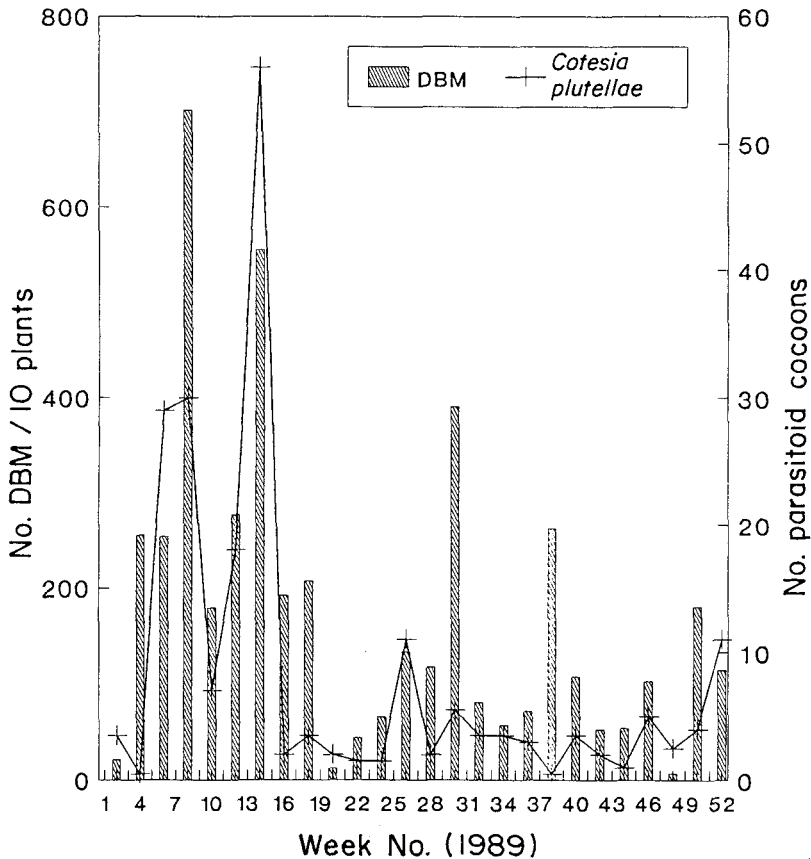


Fig. 1. Populations of DBM and *C. plutellae* (cocoons only) sampled at the MARDI Research Station, Tanah Rata in 1977.

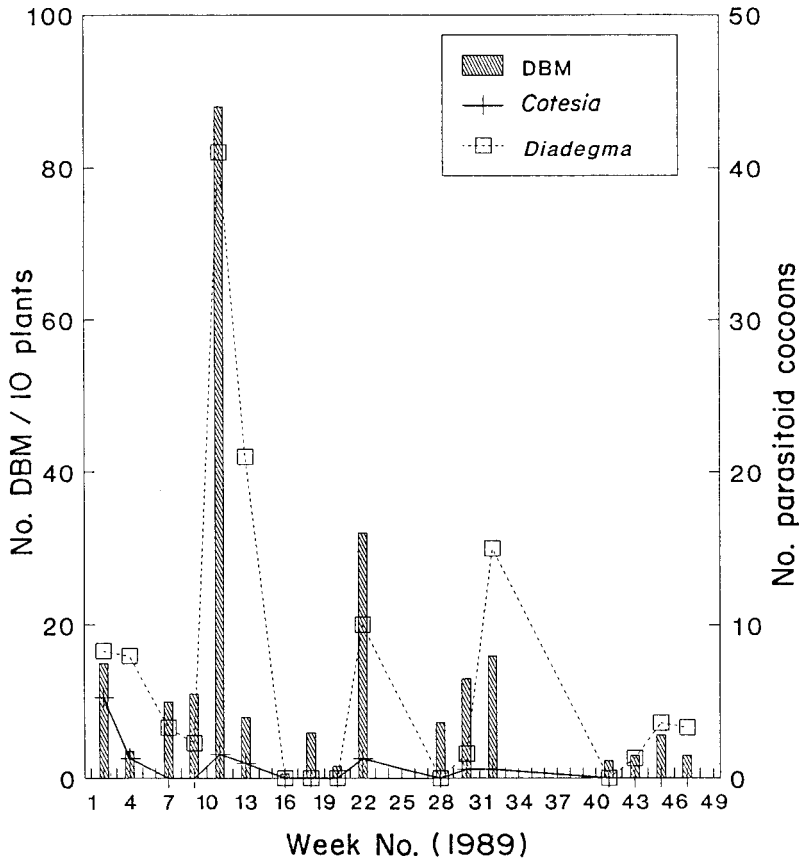


Fig. 2. Populations of DBM and two major parasitoids (cocoons only) sampled at the MARDI Research Station, Tanah Rata in 1989.

suggested that the overall DBM problem was very much reduced following the change in pest management practices. Farmers reported the use of *Bacillus thuringiensis* Berliner to replace chemical insecticides, and this had fewer adverse effects on the parasitoids, particularly the pupal parasitoid.

The differences in populations of DBM became more apparent when the seasonal changes for both periods were compared (Fig. 3). Besides being lower for 1988-90, the graph suggested that the DBM population did not grow as fast as in 1976-78 and also declined sharply after crop period II. A very effective mortality factor is suspected to act on the DBM population in the period 1988-90. As the crop was free of insecticides, the only explanation was the impact of parasitoids.

In 1976-78, the key parasitoid was *C. plutellae* and as noted in Fig. 1 did not appear to suppress the pest population. In the data of 1988-90, the dominant parasitoid was *D. semiclausum* and *C. plutellae* actually became rather rare (Fig. 2). This changeover supported the laboratory studies of both parasitoids reported by Chua and Ooi (1986) and Ooi (1980). *D. semiclausum* was superior in terms of its area of discovery and killing power (Table 1). In 1984, the dominant parasitoid was still *C. plutellae* and Chua and Ooi (1986) were puzzled by the field results. However, following the reduction in use of chemical insecticides, *D. semiclausum* exerted its dominance (Fig. 2). This dominance will continue as long as farmers refrain from unnecessary use of chemical insecticides.

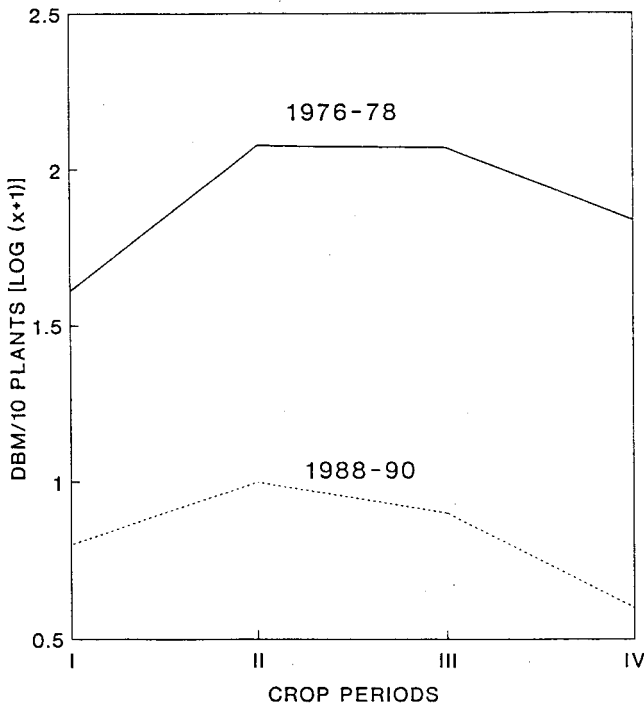


Fig. 3. Seasonal population changes of DBM for 1976-78 (prerulease) compared with that for 1988-90. The results indicate a conspicuous decline in DBM population 11 years after introduction and release of *D. eucero-phaga*.

Table 1. Biological/ecological attributes of two major DBM parasitoids in Malaysia (modified from Chua and Ooi 1986).

Species	Life cycle (days)	Host stage attacked	a	K	Field parasitism		
					Country	Incidence (%)	References
<i>Cotesia plutellae</i>	11-14	larval	0.18	0.09	India	31	Bhalla and Dubey (1986)
					India	36.6	Joshi and Sharma (1974)
					Japan	20-60	Uematsu et al. (1987)
					Malaysia	29.6-35.8	Lim (1982)
					Malaysia	12.3-19.1	Ooi (1979a)
					Philippines	1.9-16.4	Velasco (1983)
					Taiwan	19.6	Fan and Ho (1971)
<i>Diadegma semiclausum</i>	12-19	larval	0.38	0.87	Australia	29	Yarrow (1970)
					Indonesia	5.7-88.9	Sastrosowojo and Sastrodihardjo (1986)

a = area of discovery (searching efficiency). K = Killing power.

A study of the relationship between *C. plutellae* and *D. semiclausum* and the DBM population suggested that both parasitoids were numerically responsive to increasing populations of DBM. Data from 1976 to 1978 showed that the relationship was represented by the linear graph  $Y = 0.07X - 0.29$  ( $R^2 = 0.54$ ;  $df = 41$ ) for *C. plutellae*. In the data set of 1988-90, the relationship was represented by  $Y = 0.06X + 0.11$  ( $R^2 = 0.21$ ;  $df = 43$ ). For *D. semiclausum*, the relationship with DBM was represented by  $Y = 0.33X + 0.12$  ( $R^2 = 0.41$ ;  $df = 43$ ). Although *C. plutellae* was numerically responsive to increasing DBM populations, its *a* and *K* values (Table 1) suggested that it could not keep the pest population down. This is supported by results from studies in other countries which showed that levels of parasitism rarely exceeded 60%. Results from Sabah suggested that further detailed studies (including taxonomy of the insect) are necessary in Sabah to understand the impact of this braconid. *D.*

*semiclausum* possessed a significant positive numerical response and has good searching and killing power which would explain why it became the dominant parasitoid. The impressive impact of *D. semiclausum* on DBM was also reported by Sastrosiswojo and Sastrodihardjo (1986) in Indonesia and by Talekar in Taiwan (pers. comm.).

### Biological Control as Core in DBM Management

The outstanding impact of parasitoids in the management of DBM in the Cameron Highlands has confirmed Lim's (1986) views. The need for key parasitoids should feature strongly in all integrated pest management programs. With a biological control core, it is then possible to integrate with other methods of control including judicious use of insecticides. However, experience in the Cameron Highlands suggests that *B. thuringiensis* should be preferred over chemical insecticides.

More research is necessary to prove if a single key parasitoid is sufficient to manage the DBM. In the Cameron Highlands, a complex of natural enemies is now linked to DBM (Fig. 4). The two major parasitoids, *D. semiclausum* and *C. plutellae*, attack the larval stages of the DBM. Should the larvae escape from the larval parasitoids, there are two pupal parasitoids that may act on the pupae. It is very likely that all the parasitoids work together towards achieving the level of natural biological control observed and no one parasitoid could sustain this impact. Conservation of parasitoids will invariably conserve predators and perhaps sustain the effect of microbial control. Little is known of the impact of predators, and there should be further study into how this mortality factor operates.

While biological control of DBM exists in the highlands, management of the DBM in warmer areas should receive further attention. Following the above strategy, the first step is to develop a complex of parasitoids and other natural enemies of DBM. As such, a program to explore for parasitoids in the warmer parts of its native range (e.g. Mediterranean) should be initiated.

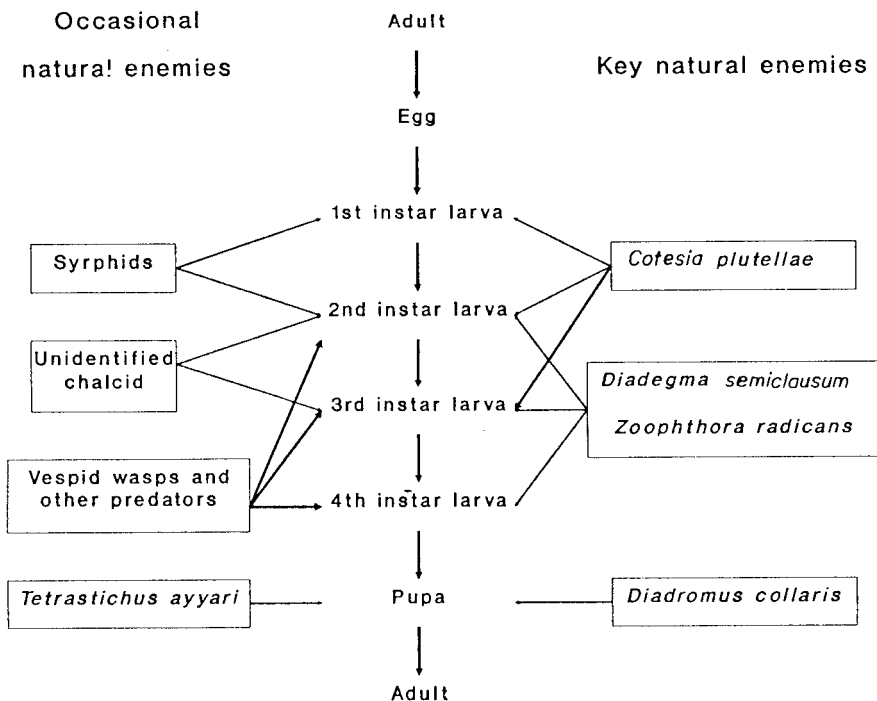


Fig. 4. Diagrammatic representation of linkages between DBM and its natural enemies in Malaysia (adapted from Lim 1982; Ooi 1979b; Ooi et al. 1990).

## Acknowledgments

I am grateful to the Department of Agriculture and the Malaysian Agricultural Research and Development Institute for their encouragement during implementation of the biological control program and its follow-up. Dr. Lim G. S., Dr. Syed Rahman, Ms. Ong P.C., Ms. Ruwaidah helped make the biological control program possible; thanks to Syed for making available data from recent ecological studies. I am grateful to Richard Hill (DSIR) New Zealand and J. Hamilton (N.S.W. Department of Agriculture) for kindly supplying the parasitoids.

## References

- Bhalla, O.P., and Dubey, J.K. 1986. Bionomics of the diamondback moth in the Northwestern Himalaya. *In* Talekar, N. S., and Griggs, T. D. (ed.) Diamondback Moth Management: Proceedings of the first international workshop. Asian Vegetable Research and Development Center, Shanhua, Taiwan, 55-61.
- Chua, T.H., and Ooi, P.A.C. 1986. Evaluation of three parasites in the biological control of diamondback moth in the Cameron Highlands, Malaysia. *In* Talekar, N. S., and Griggs, T.D. (ed.) Diamondback Moth Management. Proceedings of the First International Workshop. Asian Vegetable Research and Development Center, Shanhua, Taiwan, 173-184.
- Fan, S.H., and Ho, K.K. 1971. A preliminary study on the life history, rearing method of *Apanteles plutellae* Kurd. and effects of different insecticides to it. *Plant Prot. Bull. (Taiwan)*, 13, 156-161 (in Chinese with English summary).
- Hardy, J.E. 1938. *Plutella maculipennis* Curt., its natural and biological control in England. *Bull. Entomol. Res.*, 29, 343-372.
- Henderson, M. 1957. Insecticidal control of the diamondback moth, *Plutella maculipennis* on cabbage at Cameron Highlands. *Malayan Agric. J.*, 40, 275-279.
- Ho, T.H. 1965. The life-history and control of the diamondback moth in Malaya. Bulletin No. 118, Division of Agriculture, 26 p.
- Joshi, F.L., and Sharma, J.C. 1974. New record of a braconid, *Apanteles plutellae* Kurdj. parasitising the larvae of *Plutella xylostella* L. and *Trichoplusia ni* Hb. in Rajasthan. *Indian J. Entomol.*, 36, 160.
- Kuno, E., and Dyck, V.A. 1985. Dynamics of Philippine and Japanese populations of the brown planthopper: comparison of basic characteristics. *In* Proceedings ROC-Japan seminar on the ecology and control of the brown planthopper. National Science Council, ROC, 1-9.
- Lim, G.S. 1982. The biology and effects of parasites on the diamondback moth, *Plutella xylostella* (L.) Ph.D. thesis, University of London, 317 p.
- 1986. Biological control of diamondback moth. *In* Talekar, N.S., and Griggs, T.D. (ed.) Diamondback Moth Management: Proceedings of the first international workshop. Asian Vegetable Research and Development Center, Shanhua, Taiwan, 159-171.
- Lim, G.S., and Ko, W.W. 1975. *Apanteles plutellae* Kurdj., a newly recorded parasite of *Plutella xylostella* (L.) in Malaysia. *MARDI Res. Bull.*, 3, 94-95.
- Lim, G.S., Sivapragasam, A., and Ruwaida, M. 1986. Impact assessment of *Apanteles plutellae* on diamondback moth using an insecticide-check method. *In* Talekar, N.S., and Griggs, T.D. (ed.) Diamondback Moth Management. Proceedings of the First International Workshop. Asian Vegetable Research and Development Center, Taiwan, 195-204.
- Lim, K.P. 1972. Vegetable production in Cameron Highlands - an economic study. *Malayan Agric.*, 10, 14-23.
- Muggeridge, J. 1930. The diamond-back moth. Its occurrence and control in New Zealand. *N. Z. J. Agric.* 18: 253-264.
- Ooi, P.A.C. 1979a. Incidence of *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae) and its parasite, *Apanteles plutellae* Kurdj. (Hymenoptera: Braconidae) in Cameron Highlands, Malaysia. *Malaysian Appl. Biol.*, 8, 131-143.

- 1979b. The natural enemies of *Plutella xylostella* (L.) in Cameron Highlands, Malaysia. *Malaysian Agric. J.*, 52, 77-84.
- 1980. Laboratory studies of *Diadegma cerophagus* (Hym., Ichneumonidae), a parasite introduced to control *Plutella xylostella* (Lep., Hyponomeutidae) in Malaysia. *Entomophaga*, 25, 249-259.
- 1986. Diamondback moth in Malaysia. *In*: Talekar, N. S., and Griggs, T. D. (ed.) *Diamondback Moth Management: Proceedings of the first international workshop*. Asian Vegetable Research and Development Center, Shanhua, Taiwan. 25-34.
- 1988. Laboratory studies of *Tetrastichus sokolowskii*. *Entomophaga*, 33, 145-152.
- Ooi, P.A.C., and Lim, G.S. 1989. Introduction of exotic parasitoids to control the diamondback moth in Malaysia. *J. Plant Prot. Trop.*, 6, 103-111.
- Ooi, P.A.C., Sivapragasam, A., Kadir, H. A., and Lim, G. S. 1990. Advances in biological control of DBM in Malaysia. Presented at the Seminar Pengurusan *Plutella xylostella*: Perspektif dan Strategi. Kuala Lumpur, Malaysia. 24 October 1990.
- Ooi, P.A.C., and Sudderuddin, K. I. 1978. Control of diamondback moth in Cameron Highlands, Malaysia. *In*: *Proceedings of Plant Protection Conference 1978*. Rubber Research Institute of Malaysia, Kuala Lumpur, 214-227.
- Sastrosiswojo, S., and Sastrodihardjo, S. 1986. Status of biological control of diamondback moth by introduction of parasitoid *Diadegma eucerothaga* in Indonesia. *In* Talekar, N. S., and Griggs, T. D. (ed.) *Diamondback Moth Management. Proceedings of the first international workshop*. Asian Vegetable Research and Development Center, Shanhua, Taiwan. 185-194.
- Sudderuddin, K. I., and Kok, P. F. 1978. Insecticide resistance in *Plutella xylostella* collected from the Cameron Highlands of Malaysia. *FAO Plant Prot. Bull.*, 26, 53-57.
- Tay, E. B., Sim, C. H., Wong, K. W. and Ooi, P. A. C. 1991. A study of *Apanteles plutellae* and its hyperparasitoids in Sabab, Malaysia (in preparation).
- Todd, D. H. 1959. Incidence and parasitism of insect pests of cruciferous crops in the North Island — evaluation of data, 1955-58 season. *N. Z. J. Agric. Res.*, 2, 613-622.
- Uematsu, H., Yamashita, T. and Sakanoshita, A. 1987. Parasitoids of the diamondback moth, *Plutella xylostella* L. and their seasonal incidence in Miyazaki district, in the southern part of Japan. *Proceedings of the Association for Plant Protection of Kyushu* 33: 136-138.
- Velasco, L. R. I. 1983. Field parasitism of *Apanteles plutellae* Kurdj. (Braconidae, Hymenoptera) on the diamond-back moth of cabbage. *Philipp. Entom.* 6: 539-553.
- Vos, H. C. C. A. A. 1953. Introduction in Indonesia of *Angitia cerophaga* Yraou a parasite of *Plutella maculipennis* Curt. *Contr. Yeu. Agric. Res. Atn, Bogor* No. 134, 32 p.
- Wilson, F. 1960. A review of the biological control of insects and weeds in Australia and Australian New Guinea Technical Comm. No. 1 Commonwealth Institute of Biological Control, Ottawa, Canada. 102 p.
- Yarrow, W.H.T. 1970. Parasites of *Plutella xylostella* (L.) in south-eastern Queensland. *Queensland J. Agric. Animal Sci.*, 27, 321-324.