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Management of Diamondback Moth in Malaysia: Development, Implementation and Impact

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Abstract

With the discovery of the larval parasitoid, *Cotesia plutellae* Kurdjumov, and the successful introduction and establishment of two other exotic parasitoid species, viz. *Diadegma semiclausum* Hellen and *Diadromus* (*Thyraeella*) *collaris* Gravenhorst in the Cameron Highlands, biological control was given greater emphasis in the development of IPM for diamondback moth, *Plutella xylostella* (L.), in Malaysia. An IPM package, based on a three-tiered economic threshold level which takes into account the percentage parasitization of the diamondback moth, was developed in 1987. Results of four trials in the highlands and four in the lowlands established the superiority of IPM over prophylactic control practiced by cabbage farmers. Marketable yields were 5-6% higher, and up to 6-fold increase in profits were obtained in IPM plots. The number of insecticide applications was also significantly reduced from 7 to 9 times in the prophylactic plots to a maximum of only three in IPM plots. No insecticide residue was detected in the crop harvested from IPM plots. Beginning with this first IPM package, two variant packages that take into consideration crop phenology have been developed and are under evaluation. Activities to implement and promote area-wide adoption of the IPM package have been organized, such as seminars, workshops, courses, dialogues, joint trials and field days. A national level committee for vegetable IPM has also been set up to oversee the systematic development and implementation of vegetable IPM country-wide. Over the last 3 years, IPM has achieved significant impact at all levels. The Malaysian government has adopted IPM as a national policy for vegetable pest management. The Malaysian Agricultural Chemical Association (MACA) is receptive to and supports IPM. In a recent census, 54% of the farmers surveyed in the Cameron Highlands are already practicing IPM of diamondback moth and 85% are keen to learn more about the IPM approach.

Introduction

Cultivation of vegetables is an important agricultural activity in Malaysia. More than 50 types of vegetables, comprising both tropical and temperate species, are planted (Ding et al. 1981). The important leafy brassica vegetables are Chinese mustard (*Brassica chinensis* var. *oleifera*) and cabbage (*Brassica oleracea* var. *capitata*).

The major insect pests of leafy brassica vegetables in Malaysia are presented in Table 1. The ranking shows that the diamondback moth (DBM), *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae), is the most important insect pest. DBM was first recorded in Malaysia in 1925. By 1941, it had become widely established all over Malaysia as a serious pest of brassicas (Corbett and Pagden 1941).

Major interest and research on DBM in Malaysia began in the early 1960s as a result of heavy crop losses due to the pest. Outbreaks and high incidences were reported yearly with resurgence occurring every 2-3 years (Lim 1974; Sudderuddin and Kok 1978). Since the 1940s, the main method of control practiced by farmers has been the use of synthetic insecticides. The demand for insecticides has been enormous and seems endless, generally accounting for about 30% of the production costs (Lim 1974). Due to over dependence on chemicals, several pesticide-related problems such as resistance development, hazards to nontarget organisms, environmental pollution, poisoning and residues in crops have surfaced and become serious (Lim et al. 1988).

In the 1970s, an ecological approach was adopted to manage the DBM problem. Research was intensified in biology, ecology and control tactics, particularly biological control, in an attempt to develop a more sustainable approach to manage the DBM problem. We present highlights of the development, implementation and impact of an Integrated Pest Management (IPM) program for DBM in Malaysia.

Development Of IPM

The development of an IPM program for DBM in Malaysia comprised several distinct stages. These ranged from initial appraisal of the problem and examination of strategic options, to component identification, development and integration, and eventual evaluation of interim IPM packages at the farm level. The main stages are described below.

Exploring the available control options

Varietal resistance: Although differences in varietal resistance of cabbages to DBM were known (Weires and Chiang 1973), generally, even the 'resistant' varieties were still inadequate for effective management of the moth under normal field conditions. Moreover, a much greater problem was encountered locally. Here, there was little possibility for selecting and developing resistant materials since cabbage flowering could not be readily induced under local field conditions.

Cultural management: Although Raros (1973) had demonstrated that intercropping of cabbages with tomatoes could reduce infestations of DBM on cabbages, this relationship could

Table 1. Relative importance of the main insect pests of leafy brassica vegetables in Malaysia.

Crop/pests	Ranking in importance
Chinese mustard	
Plutella xylostella	1
Phyllotreta sinuata	2
Agrotis ypsilon	3
Spodoptera litura	3
Cabbage	
Plutella xylostella	1
Hellula undalis	2
Crocidolomia binotalis	2
Myzus persicae	2
Spodoptera litura	3
Agrotis ypsilon	3
Kailan (*Brassica alboglabra*)	
Plutella xylostella	1
Phyllotreta sinuata	2
Spodoptera litura	3
Liriomyza spp.	3

Ranking: 1 = Very important 2 = Moderately important 3 = Occasionally important.

not be reproduced consistently. Moreover, this cultural practice could not be readily implemented locally as the choice of crops for cultivation during a particular period is highly variable, being usually governed by festive seasons and market demands (FAMA 1974). For tomatoes and cabbages, their plantings need not necessarily always coincide. Similarly, other cultural methods (e.g. planting trap crops) will require drastic changes in some other long-standing traditional practices, and such a recommendation is usually not easily accepted.

Novel approaches: Newer and more novel approaches, such as hormonal control (Sato 1968), sterile mating (Bonnemaison 1966) and the use of antifeedants (Findlay 1970; Ruscoe 1972), were still largely of an exploratory nature and mainly confined to laboratory situations. As such, their scope for practical employment was limited. However, there is still current interest in some of these novel approaches, and additional ones such as manipulation of host-finding behavior of DBM parasitoids with kairomones are being studied (Loke et al. 1990).

Biological control: Effective suppression of DBM with such an approach has been reported in Australia, Indonesia, New Zealand and South Africa (Muggeridge 1930, 1939; Ullyett 1947; Vos 1953). Encouraged by these experiences, and noting the existing limitations of the other control components, it appeared that use of natural enemies constituted the most promising alternative component available. The biological control approach, therefore, was given priority consideration.

Initial search for parasitoids

In the past no attempt was made to explore the use of natural enemies against DBM in Malaysia because of the belief that no biological control or parasitoids could exist (in the Cameron Highlands) due to the intensive and indiscriminate use of insecticides. Consequently, all DBM control efforts were devoted solely to the chemical approach, further guided by another belief that no cabbage can be produced without frequent and heavy insecticide application (Lim 1982). Therefore, a thorough and careful parasitoid search was deemed necessary. This was made in 1973, intially, at the MARDI Research Station in Tanah Rata. The search uncovered *Cotesia plutellae*, a larval parasitoid (Lim and Ko 1975). However, no other parasitoid was found, either from the eggs or pupae of DBM.

With the discovery of *C. plutellae*, the first belief was shattered, thus paving the way for the acceptance of biological control agents as a possible alternative component to the existing pesticide dependency. It also opened an avenue for subsequent development of the IPM approach. Until the belief was shattered, IPM for DBM could never be accepted even at the conceptual stage in the earlier days.

Focusing research on biological control

Although *C. plutellae* was initially found in Tanah Rata, it was not known whether the parasitoid was also present in areas where crucifers were cultivated under heavy insecticidal inputs. A number of surveys conducted subsequently revealed it to be both common and widespread in the country (Lim and Ko 1975; Ooi and Sudderuddin 1978; Lim 1982).

Except in the lowlands where parasitism averaged only 12.1%, *C. plutellae* occurred in significant abundance in the Cameron Highlands. Over the various subregions surveyed, Kuala Terla had the highest mean parasitism of 48.6% while Kampong Taman Sedia had the least (12.7%). For the remaining subregions, parasitism of 36.5, 34.0, 30.1 and 18.1% was obtained in Kampong Raja, Tringkap, Bertam Valley and Mensum Valley, respectively. In general, it was very encouraging in that the parasitoid could effect an appreciably high level of parasitism even under heavy insecticidal pressure. Although this suggested possible development of field tolerance to pesticides, subsequent bioassay studies could not confirm it (Lim 1982).

With the discovery of *C. plutellae*, intensive studies were mounted on the parasitoid. These encompassed various aspects on its biology and ecology (Ooi 1979a; Lim 1982), including its impact on DBM (Lim et al. 1986). Continued search for natural enemies subsequently revealed two other parasitoids: an incidental pupal parasitoid *Tetrastichus ayyari* and an unidentified chalcid ectoparasitoid of the family Eupelmidae (Ooi and Kelderman 1977; Ooi 1979a,b). Both these were however of little importance and occurred only in negligible numbers.

Introduction of exotic parasitoids

In spite of its usefulness, natural control by *C. plutellae* was inadequate in providing full suppression of DBM (Ooi 1979b; Lim 1982; 1986; Chua and Ooi 1986; and Lim et al. 1986). Attempts were made in 1975-77 to introduce exotic parasitoids to complement *C. plutellae* (Ooi and Lim 1983). Altogether, four parasitoid species were brought in from Australia, India, Indonesia and New Zealand, viz: *Diadegma semiclausum*, *Diadromus* (*Thyraeella*) *collaris*, *Tetrastichus sokolowskii* and *Macromalon orientale*. Of these, only the first two became established in the Cameron Highlands. *M. orientale* failed to breed in the laboratory and was not released. In total, the number of adult *D. semiclausum*, *D. collaris*, and *T. sokolowskii* released between 1976 and 1978 was 1202. In 1982, 21,225 were released (Ooi 1979a; Ooi and Lim 1983).

Assembling the IPM program

With the acceptance that parasitoids can play a significant role, attempts were then made to begin formulating an IPM program. Initially, the IPM approach as opposed to farmers' practices, where frequent and heavy doses of insecticides were applied, consisted essentially of need-based treatment when the tentative economic threshold of 5 larvae per 10 plants was exceeded. Beyond this level, *Bacillus thuringiensis* Berliner was applied. Other synthetic insecticides were used only when the infestation continued to rise beyond 37 larvae/10 plants. In this first IPM program, the impact of natural enemies was not incorporated in decision-making on pesticide treatment, largely because of inadequate ecological data.

From the first six field trials carried out in the early 1970s in both farmers' fields and experimental farms, it was found that several of the cabbage crops managed with the IPM approach did not prove inferior to those where farmers' practices were adopted (Sivapragasam and Lim 1982; Sivapragasam et al. 1985a,b). The IPM fields, on average, were in fact marginally superior in terms of economic returns.

Improvement of the IPM approach

Over the years as additional information became available, the original IPM approach was continually improved through modifications. The main changes concerned improving decision-making with respect to needed action on treatment. Essentially, these involved refining and improving the adopted thresholds, as well as incorporating the role of parasitoids. For example, the initial thresholds of 5 larvae/10 plants and 37 larvae/10 plants were in later trials modified to 15 larvae and 37 larvae per 10 plants, respectively. These still did not incorporate the contributions of biological control agents. However, later on, parasitoids were included. Here, irrespective of the infestation level of DBM, no insecticide was applied when DBM larvae had at least 50% parasitism level. More recently (1987), however, the thresholds were again modified, respectively, to 4 larvae/plant and 7 larvae/plant with parasitism rate of at least 40% as a subparameter (Table 2). When the first threshold is reached only *B. thuringiensis* would be applied. Conventional chemical insecticides are used only when the second threshold of 7 larvae/plant is reached. Results of four trials in the highlands and four in the lowlands clearly established the superiority of IPM over prophylactic control practiced by cabbage farmers.

Table 2. An outline of the interim IPM program for DBM in Malaysia.

These main steps are designed to help achieve the following objectives:

1. Make a decision on whether to spray or not.
2. Manage applied pesticides judiciously.
3. Encourage build-up and enhance action of biological control agents.
4. Encourage adoption of good agricultural practices.

Spray decision

The decision to spray or not to spray is based on:

1. Economic Threshold Level (ETL) of DBM.
2. Level of parasitization by parasitoids.

Sampling of DBM and Natural Enemies

To obtain the necessary data for spray decision-making, weekly sampling is carried out. The procedure is as follows:

1. Counting of DBM larvae on 60 plants/0.1 ha plot using an alternating U-shaped sampling system.
2. Counting of parasitoid cocoons and pupae from 60 plants.
3. Dissection of 60 or available number of 3rd/4th instar DBM larvae for determination of level of parasitization.

Thresholds adopted

1. No spray – if number of DBM larvae < 4/plant
2. No spray – if number is > 4 but < 7 and level of parasitization is > 40%.
3. Spray – Use *B. thuringiensis* if number is > 4 but <7 and level of parasitization is < 40%. Example: Bactospeine at the rate of 1.14 kg/ha.
4. Spray – Use synthetic insecticides if number is > 7.

Marketable yields were 5-60% higher and up to 6-fold increases in profits were obtained in IPM trial plots. The number of insecticide applications was also significantly reduced from 7 to 9 times in prophylactic plots to a maximum of only three applications in IPM plots (Fig. 1 and 2).

In general, the series of IPM trials conducted between 1987 and 1990 has shown that IPM can provide a higher net revenue when compared to farmers' practice of using chemicals prophylactically without any regard for natural enemies. IPM also required fewer numbers of sprays and yet was able to secure marketable heads. No insecticide residue was detected in the crop harvested from IPM plots.

To date, experimental studies with IPM have thus shown it to be both promising and highly encouraging. Even without considering the intangibles such as reduced general environmental pollution, fewer upsets of existing natural balance and ecological stability, etc., the decline in insecticidal inputs alone is sufficient to favor IPM over the existing chemical approach of farmers. Clearly, over the long term the ecological benefits are likely to prove highly significant.

Implementation Of IPM for DBM

The implementation of IPM by farmers can only be realized through concerted and sustained support of both research and extension. Relevant personnel, particularly those in extension, would need to help farmers overcome their fears and any related negative perceptions, and to guide them to 'think IPM.' Implementation of IPM must therefore have a holistic approach, taking

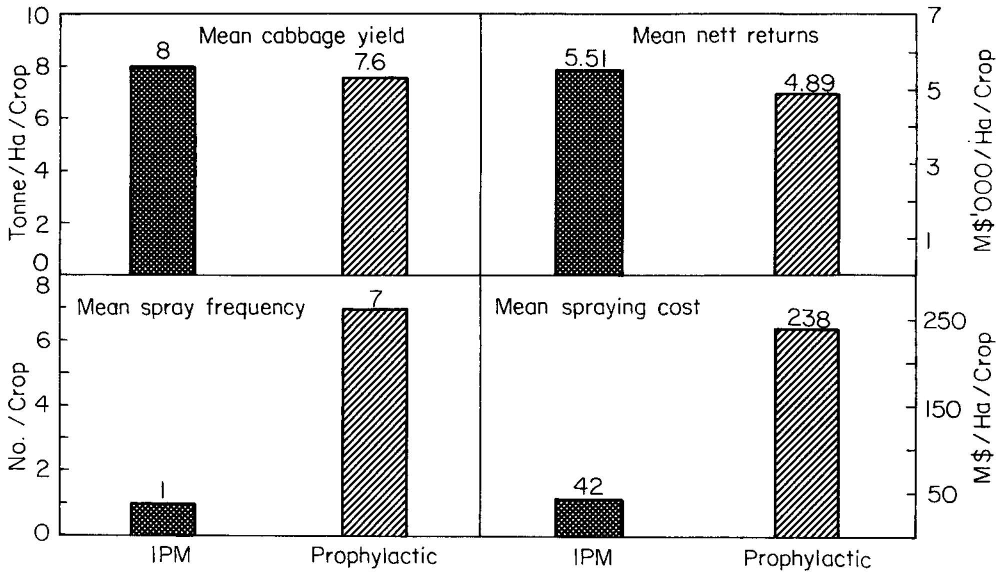

Fig. 1. Summary of IPM trials in the Cameron Highlands.

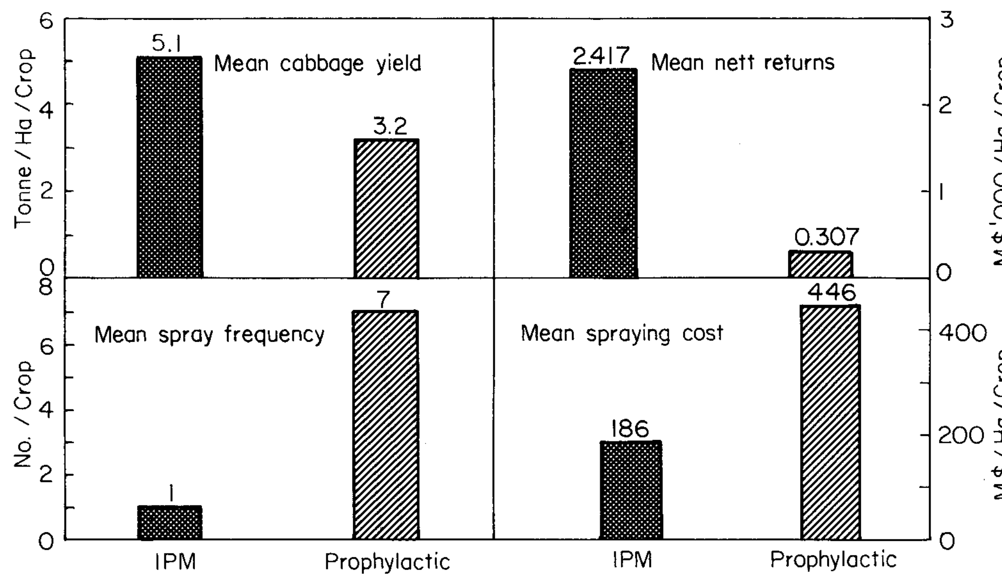

Fig. 2. Summary of IPM trials in Jalan Kebun (lowlands).

into consideration the diverse but related functions of different agricultural agencies, especially the research-extension-farmer linkages which exist in the country.

Extension of IPM for DBM

Presently, this early stage IPM program for DBM is being gradually extended to extension agents and farmers. Some early efforts have involved organizing training courses on IPM for extension agents, seminars on IPM of DBM, dialogue sessions with farmers and field demonstrations of successful trials. In such sessions, farmers were guided on the role of key beneficial agents and how to recognize them in the field. It is expected that increasing efforts will continue to be expended in this aspect in the future.

Research support

The current IPM technology for DBM is not static. Rather, as it is implemented it will also be modified and improved as new research findings continually become available. For example, two 'new' IPM packages for DBM which take into consideration crop phenology have been formulated and are being evaluated for possible implementation (Table 3). Research support, therefore, constitutes a fundamental aspect in ensuring the constant improvement and continued success of implementation of IPM of DBM.

In general, Malaysian research in DBM IPM is largely borne by the Malaysian Agricultural Research and Development Institute (MARDI). MARDI has a network of 28 research stations spread over the country. At least five of these are deeply involved with research on both highland and lowland vegetables.

Table 3. New IPM packages for DBM.

Crop age	Economic threshold level (ETL)	Decision
1. Current MARDI DBM IPM Package		
Week 1-10	<4 DBM larvae/plant	No spray
	>4<7 and parasitization >40%	No spray
	>4<7 and parasitization < 40%	Spray microbial insecticides (*B. thuringiensis*)
	>7	Spray conventional insecticides
2. New DBM IPM Package (A) under evaluation		
Week 1-4	<4 DBM larvae/plant	No spray
	>4<7 and parasitization > 40%	No spray
	>4<7 and parasitization < 40%	Spray microbial insecticides
	>7	Spray conventional insecticides (*B. thuringiensis*)
Week 5-10	<8 DBM larvae/plant	No spray
	>8<14 and parasitization >40%	No spray
	>8<14 and parasitization < 40%	Spray microbial insecticides (*B. thuringiensis*)
	>14	Spray conventional insecticides
3. New DBM package (B) under evaluation		
Week 1-4	<2 DBM larvae/plant	No spray
	>2<4 and parasitization > 40%	No spray
	>2<4 and parasitization < 40%	Spray microbial insecticides (*B. thuringiensis*)
	>4	Spray conventional insecticides
Week 5-10	<4 DBM larvae/plant	No spray
	>4<7 and parasitization > 40%	No spray
	>4<7 and parasitization < 40%	Spray microbial insecticides (*B. thuringiensis*)
	>7	Spray conventional insecticides

Presently, MARDI has two research divisions (Fundamental Research and Horticulture) which are responsible for research pertaining to production and pests of vegetables. Straddling these divisions is a pool of crop protectionists (entomologists, pathologists, nematologists and weed scientists) who are actively involved in basic and applied research. Under the jurisdiction of these two divisions a task force on IPM of vegetable was specially set up to help develop and implement IPM of DBM.

Local network and external assistance

Local networking is important for effective implementation of IPM. A National Committee for Vegetable IPM with IPM of DBM as its first target, has been set up. MARDI and the Department of Agriculture are the two lead agencies involved in developing, implementing and coordinating the IPM programs nationwide.

External assistance, undoubtedly, could also help greatly in the implementation of IPM of DBM in Malaysia. An excellent example is seen in the case of the FAO Intercountry IPM Program for Rice. Until this network came into effect, implementation and adoption of rice IPM was relatively slow. However, it made great strides when the network provided appropriate training assistance. Undoubtedly for DBM IPM in Malaysia this aspect again constitutes a crucial requirement that could greatly expedite its implementation.

Another important area of assistance which is needed entails receiving expertise for specialized technical aspects. Linkage with AVRDC in this aspect has been fruitful and beneficial.

Apart from the above two broad areas of assistance, others such as material support are not really crucial. This is mainly because much of the material support essential to both research and extension of IPM of DBM is already available in Malaysia.

Impact Of IPM OF DBM

Recognition and acceptance

Over the last three years, IPM of DBM in cruciferous crops has achieved significant impact. The DBM IPM program is now viewed as a guiding model for further development of IPM for other vegetable pests. Due recognition has been received from both public and private sectors. The Malaysian government has adopted IPM as a national policy for vegetable pest management. The Malaysian Agricultural Chemicals Association (MACA) is receptive to and supports IPM of DBM.

Adoption by farmers

A recent survey of some 60 farms in the Cameron Highlands revealed that 54% of the farmers interviewed are already practicing some form of IPM of DBM and 86% are keen to learn more about it. This healthy change in attitude together with a corresponding increase in awareness of the role of natural enemies augur well for the adoption of the IPM approach.

Establishment and build-up of parasitoids

Monitoring of the establishment, conservation and build-up of natural enemies in various crucifer-growing areas such as the Cameron Highlands and Kundasang (Sabah) has shown that parasitoids of DBM are present and doing well.

Increase in crucifer planting

That IPM of DBM has made great strides is also reflected by the fact that the growing of crucifers, particularly cabbages, in the Cameron Highlands has regained momentum with many farmers taking up the crop again (Chay 1990).

Discussion

Developing and implementing a full IPM program for DBM has been a slow process. Many constraints were encountered and these had to be overcome. For instance, research had to be pursued with a holistic perspective. While specialist IPM research needs to be continued and strongly supported, it must also involve close collaboration with the farmers so as to be able to establish those elements of IPM that are likely to be useful in practice (Way 1985).

Another important constraint is the dearth of information concerning the many social and market factors that can influence pest control decisions and actions of the farmers. To date, most research on DBM has centered on biological aspects only. But effective adoption of the IPM technology requires knowledge that extends well beyond this. Thus, to overcome this important constraint, studies must now be initiated to cover the aspects pertaining to better understanding of the vegetable farmer, such as his knowledge, perception, attitude and practices. Arising from these will then be a truer understanding of the farmers' aspirations and constraining factors, which could lead to an improvement in communicative processes for translating IPM for adoption.

To date, crucifer farmers in Malaysia are generally unaware of IPM. Therefore these growers must be guided to 'think IPM'. This may be best achieved through practical demonstrations as well as training which actually involves farmer participation. Here, it needs to be emphasized that training has to be 'on-farm'.

The extension support for vegetables is presently still inadequate. In a survey in Peninsular Malaysia, it was found that only 25% of the vegetable farmers received some extension support services from governmental agencies. An urgent need, therefore, is for increased government support to improve such services for more effective implementation of IPM of DBM.

Presently, there is considerable influence on farmers' control practices through services provided by representatives of agrochemical companies. Usually this is a 'single track' approach of relying only on chemical pesticides. Unless strongly counteracted by increased extension services, this trend of dependency by farmers on pesticide salesmen, and hence pesticides, will remain, thereby slowing down the adoption of IPM of DBM.

Despite the problems and shortcomings addressed above, IPM of DBM in Malaysia has made much headway. A working package is now available, and with further refinements a more pragmatic package, based on a core of biological control, should be ready for area-wide adoption in the very near future.

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