

INTRODUCTION OF *DIADEGMA SEMICLAUSUM* FOR THE CONTROL OF DIAMONDBACK MOTH IN NEGROS ORIENTAL¹

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ABSTRACT

Surveys on natural parasitism of eggs and larvae of Diamondback moth *Plutella xylostella* L. (Lepidoptera: Yponomeutidae) were conducted in the Canlaon vegetable area in Negros Oriental from June 1993 to March 1994. Average egg parasitism by naturally occurring *Trichogramma* sp. ranged from 0 to 68 %. In contrast, not a single larval parasitoid was found throughout the survey period.

To contribute to the control of Diamondback moth in the Canlaon area, rearing of *D. semiclausum* was initiated in 1993 and field releases started in December of the same year. First results of monitoring the release areas showed that the laboratory reared *D. semiclausum* were able to establish strong and stable field populations. Within a short period after the introduction of *D. semiclausum* to Canlaon, average larval parasitism rates of more than 60 % could be realized without further releases.

To support the successful establishment of *D. semiclausum*, farmers are presently trained to replace synthetic insecticides with *Bacillus thuringiensis* Berliner.

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INTRODUCTION

The production and consumption of cruciferous vegetables in the Philippines ranks second to the one of vegetables of the solanaceae family. The most important of the cruciferous vegetables in the elevated areas of the Philippines is head cabbage. However, Chinese cabbage, broccoli, cauliflower, mustard and others are also grown (Magallona 1986, Anonymous 1994).

A major constraint in the production of crucifers in the Philippines as well as in other countries with similar climatic conditions is the Diamondback moth (DBM), *Plutella xylostella* L. (Lepidoptera: Yponomeutidae). Its ability to rapidly develop resistance to practically all insecticides has made it the most destructive pest of cabbage. As the DBM becomes increasingly insecticide-resistant, farmers resort more and more to the indiscriminate use of insecticides, often in total disregard of recommended dosages and spray intervals. They even mix these and experiment with other, presumably more potent, chemicals.

To stop this vicious trend, researchers all over the world are looking for biological means to manage DBM. Of the numerous attempts that were made in various countries to introduce an exotic parasitoid to control DBM, the introduction of *Diadegma semiclausum* Hellen (Hymenoptera: Ichneumonidae) has proven to be one of the most promising for higher elevations (Waterhouse and Norris 1987, Talekar and Shelton 1993). The introduction of *D. semiclausum* is reported to have successfully eased the problem of DBM in countries like Indonesia, Malaysia and Taiwan (Talekar and Shelton 1993).

In the Philippines, joint efforts of various agencies including the Philippine-German Biological Plant Protection Project (PGBPPPP) led to the import of *D. semiclausum* from Indonesia and Taiwan, and to the start of its release in 1990 in the vegetable areas of Benguet and the Mountain Province, where almost 80% of the Philippine crucifers are produced. First reports on its establishment were positive (Amend and Mangali 1992, Cardona 1992, Pölking 1992) and in surveys conducted in 1992 and 1993, Amend *et al.* (1994) found *D. semiclausum* well established and wide spread in Benguet and the Mountain Province, and noted a substantial reduction of the DBM population.

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To extend the benefits of *D. semiclausum* also to other Philippine cabbage production areas, the vegetable area of Canlaon City in Negros Oriental was selected as site for *D. semiclausum* release by the PGBPPP in 1993. Canlaon City is located on the slopes of the Mt. Canlaon, an active volcano, at an elevation of approximately 600 m above sea level. Various crucifers and other highland vegetables like carrots, leaf onions and lettuce are cultivated here in an area of about 1000 ha extending from an altitude of 600 to 1100 m (Wyrwal, 1993). Canlaon is considered the most important vegetable production area of the Visayas.

A socio-economic study conducted in the Canlaon area by the PGBPPP in 1993 revealed that cabbage farmers spray their crops with insecticides at an average rate of 1.7 applications/week. This means that they spray their crops every four days (Wyrwal, 1993). The survey further showed that cash costs for insecticides consume nearly 40 % of the total variable cash costs of an average cabbage producer.

It is hoped that within a short time after the introduction of *D. semiclausum* in the Canlaon area the DBM population will be reduced to a level that will allow cabbage production using a distinctly lower number of sprayings and with less toxic insecticides. This paper summarizes the activities of the PGBPPP in Canlaon to date and presents the first results of the introduction of *D. semiclausum*.

NATURAL PARASITIZATION OF DBM BEFORE THE INTRODUCTION OF *D. SEMICLAUSUM*

The abundance of natural enemies, particularly parasitoids of DBM in the Philippines before the introduction of *D. semiclausum*, was comprehensively studied only in the cabbage production areas of Benguet and the Mountain Province. Barroga and Morallo-Rejesus (quoted by Barroga 1979) found *Apanteles* sp. (Hymenoptera: Braconidae), *Microplitis* sp. (Hymenoptera: Braconidae) and *Nythobia plutella* Viereck (Hymenoptera: Ichneumonidae) in Buguias, Benguet in a survey conducted in 1972/1973. Polking (1992) listed six species of the order Hymenoptera as parasitoids of DBM in Northern Luzon: the two Braconidae *Apanteles plutellae*¹

¹ According to new nomenclature: *Cotesia plutellae*

Kurdjumov and *Microplitis* sp., the two Ichneumonidae *Itoplectis* sp. and *Tranosema* sp. and two unidentified *Diadegma* sp. (Ichneumonidae), different from *D. semiclausum*. Of these parasitoid species, he found *A. plutei* to be the most abundant and important for the natural control of DBM. He noted, however, that the abundance of *A. plutei* was negatively correlated with the intensity of insecticide use. Carl (1990) found *A. plutei* in La Trinidad the only species parasitizing DBM in a survey in the Benguet cabbage areas. Of about 1000 DBM larvae from La Trinidad and Sayangan, only 7% were parasitized by *A. plutei* and 0.3% by a *Diadegma* sp., and of about 700 DBM pupae, none was parasitized in samples taken by Sastrosiswojo (1990). Like Pölking (1992), the authors attributed the extremely low abundance of DBM parasitoids to the high insecticide use in the vegetable areas of Benguet and the Mountain Province.

In the Canlaon cabbage area, Barroga and Morallo-Rejesus (quoted by Barroga, 1979) found *A. plutei*, *Microplitis* sp. and *N. plutei* in a survey in 1972/1973. Other data on DBM parasitization in the Canlaon area were not reported. Since the intensity of insecticide use against DBM in Canlaon in recent years was nearly the same as in Benguet and the Mountain Province, however, it may be assumed that the populations of naturally occurring parasitoids in Canlaon were also extremely reduced if not wiped out.

To obtain some base line data on the natural parasitization of DBM in Canlaon before the introduction of *D. semiclausum* the PGBPPP conducted a survey from 1993 to 1994. The survey consisted of two parts: one on the natural parasitization of DBM eggs and the other on the natural parasitization of DBM larvae. The first part was conducted from June 1993 to March 1994, while the second part was conducted from June to December 1993 before the first releases of *D. semiclausum*. DBM eggs and fourth instar larvae were collected weekly from various fields in barangays Gaboc and Lumapao. The field samples were brought to the laboratory and incubated.

The results of the survey are summarized in Tables 1 and 2. Except for June 1993, parasitized eggs were found in all DBM egg samples collected from the fields. Average parasitization rates varied from 17% in July 1993 and January 1994 to 68% in October 1993. The highest parasitization rate per single field of 87 % was measured in October 1993

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(Table 1). The predominant species parasitizing DBM eggs was identified as *Trichogramma chilonis* Ishii (Hymenoptera: Trichogrammatidae).

Egg parasitism by naturally occurring populations of *T. chilonis* seems to be an important mortality factor of DBM in the Canlaon area, at least at certain times of the year. To examine whether the use of *T. chilonis* or other *Trichogramma* sp. could be incorporated in a DBM management program, laboratory and field studies were and still are being conducted by the PGBPPP, the Bureau of Plant Industry, Manila, and the Biologische Bundesanstalt, Darmstadt, Germany (Wuhrer, 1993).

Table 1: Natural parasitization of DBM eggs in the Canlaon area (June 1993 - March 1994)

Month	No. of fields surveyed	Total no. of eggs collected	Percentage of eggs parasitized (min. - max. per single field)
June '93	3	248	0% (0 - 0%)
July '93	4	331	17% (0 - 36%)
August '93	0		
September '93	3	466	46% (40 - 52%)
October '93	14	4 573	68% (43 - 87%)
November '93	11	1 552	52% (29 - 65%)
December '93	12	1 203	46% (34 - 75%)
January '94	8	1 031	17% (7 - 41%)
February '94	16	2 870	23% (6 - 53%)
March '94	19	3 637	33% (4 - 71%)
Total	89	15 911	
Mean			34%

While egg parasitism reached quite high levels in single fields and egg parasitoids were consistently present - except for June 1993 - not a single larval parasitoid was found in samples taken from June to December 1993 (Table 2). While it would not be legitimate to conclude from these findings that no larval parasitoids at all were existing in the Canlaon area prior to the introduction of *D. semiclausum*, it may be stated that larval parasitoids were virtually absent and totally ineffective in the control of DBM.

Table 2: Natural parasitization of DBM larvae in the Canlaon area (June-December 1993)

Month	No. of fields surveyed	Total no. of larvae collected	No. of parasitoids found
June '93	3	258	0
July '93	4	404	0
August '93	0		
September '93	5	481	0
October '93	10	862	0
November '93	6	584	0
December '93	7	502	0
Total	35	3 091	0

During the survey period from 1993 to 1994 *P. xylostella* was indeed the main insect pest of cabbage in the Canlaon area, particularly in well maintained and regularly sprayed crops. In harvested fields where insecticides were no longer applied, other lepidopterous pests like *Crociodomia binotalis* Zeller, *Heliothis armigera* (= *Heliocoverpa armigera*) Hubner and *Spodoptera litura* F. were also found in large numbers.

PRODUCTION AND RELEASE OF *D. SEMICLAUSUM* IN THE CANLAON AREA

In order to produce *D. semiclausum* for field releases a rearing station was set up in Canlaon City by the PGBPPP in cooperation with the City Mayor, the City Agriculturist and the Regional Department of Agriculture, Region VII. The actual rearing started in November 1993, following the method described by Konig *et al.* (1993), and the first releases were made during the last week of December 1993. The monthly outputs of the rearing station and the number of *D. semiclausum* that have been released since then are listed in Table 3.

Table 3: *Diadegma* production and releases in the Canlaon area (November 1993 - August 1994)

Month	No. of <i>Diadegma</i> produced	No. of <i>Diadegma</i> released
November '93	14	0
December '93	2 756	632 ¹⁾
January '94	2 890	2 051
February '94	5 642	3 354
March '94	5 067	3 099
April '94	4 544	2 138
May '94	5 076	2 111
June '94	4 723	2 047
July '94	5 387	1 962
August '94	5 293	1 222 ²⁾

¹⁾ Last week of December

²⁾ Additional release of 1142 *Diadegma* in Valencia-Timbaos

To ensure success in the establishment of *D. semiclausum* the following scheme was adopted for the releases of the parasitoid: Several

release areas were selected in the barangays of Canlaon City. A prerequisite for an individual release area was that there should be an all-year-round planting of cabbage. In one release area four to five release fields with preferably overlapping growth periods were selected. In each release field, *D. semiclausum* was then released four to five times in weekly intervals beginning two to three weeks after transplanting. The collaborating farmers were requested to apply the biological insecticide *Bacillus thuringiensis* Berl. (*B. t.*) instead of the usual synthetic insecticides. The farmer cooperators were advised to use *B. t.* because of its low toxicity towards adult *D. semiclausum* (Idris and Grafius, 1993) and because of its non-toxicity to man.

Each release was made with adult *D. semiclausum* and consisted of 200 - 300 female and 100 - 150 male wasps per field (equivalent to a sex ratio of two to one). The release of *D. semiclausum* in its adult stage allowed manipulation of the sex ratio, and losses of cocoons due to predation were avoided (Amend *et al.* 1994). A sex ratio of two to one was chosen to ensure a high rate of female progenies of *D. semiclausum* in the field.

The sizes of the release fields ranged from 700 to 2000 m². It was assumed that with releases of 300 - 450 adults/release local field populations of *D. semiclausum* would be created that would subsequently spread also to neighboring fields. Depending on the output of the rearing station, releases in one area were finished before starting releases in another area, or two release areas were served at the same time. After releases in one area were finished, the development of the *D. semiclausum* population was monitored.

The above procedure will be continued until *D. semiclausum* has dispersed to all cabbage areas of Canlaon.

PARASITIZATION OF DBM LARVAE AFTER THE INTRODUCTION OF *D. SEMICLAUSUM*

Comparison of Monitoring Methods

To find an appropriate method for monitoring the parasitization of DBM larvae by *D. semiclausum*, two methods of data collection were compared, after field releases of *D. semiclausum* started:

(1) One hundred fourth instar larvae of DBM were collected from each sample field at each sampling date and brought to the laboratory. They were kept in airy containers and fed daily with fresh cabbage leaves until pupation of either DBM or *D. semiclausum* took place. The rate of parasitism was then computed using the following equation:

$$\frac{\text{No. of } Diadegma \text{ cocoons}}{\text{No. of DBM pupae} + \text{No. of } Diadegma \text{ cocoons}} \times 100 = \% \text{ parasitism.}$$

(2) In the same sample fields, 25 randomly chosen cabbage plants per field were inspected and the numbers of DBM pupae and *Diadegma* cocoons were recorded. The rate of parasitism was computed using the above equation.

D. semiclausum prefers to parasitize second instar larvae (Vos, 1953). The collection and incubation of fourth instar larvae should therefore reflect fairly accurately the actual parasitism in the field. The data pairs obtained with the two methods were grouped according to ranges of 0 - 20, 21-40, 41-60, 61-80 and 81-100 % parasitization obtained with the method of fourth instar larvae collection. The average rates of parasitism were then computed for the data pairs in each group.

The result of the comparison is shown in Figure 1. In each group, the second method gave a higher rate of parasitism than the first one with the difference between two means ranging from 8 to 23%. Since we assume that the methods of collecting and incubating larvae is quite accurate, it can be concluded that the parasitization rate is consistently overestimated when using the method of counting the numbers of DBM pupae and *Diadegma* cocoons in the field. This result is not surprising as the *Diadegma* cocoons still stick to the cabbage leaves many days after the *Diadegma* adults have emerged and differentiation cannot be made between an empty cocoon and one with the adult still inside without removing the cocoon from the plant. Therefore, using the second monitoring method, *Diadegma* cocoons are counted regardless of whether they are empty or full, while DBM pupae are only counted when they have not yet emerged.

Nonetheless, we decided to use the second method for our field monitoring because the collection and incubation of larvae is very time consuming, while the counting of DBM pupae and *Diadegma* cocoons in the field is not. Also, by counting the number of pupae and cocoons/25 plants/field some information on the population density of DBM is gathered at the same time. During the early and late crop stages, the examination of 25 cabbage plants often yields less than 20 DBM pupae and *Diadegma* cocoons. To obtain reliable values for the percentage of parasitism in such cases, more plants have to be checked until at least a total number of 20 individuals has been found. These individuals must be recorded separately and only used for the computation of the percentage of parasitism.

First Results of *D. semiclausum* Releases in Canlaon

Releases of *D. semiclausum* in the Canlaon area started at the end of 1993. To check the success of the releases, some fields were closely monitored. Results of the monitoring in four fields with *Diadegma* releases are presented in Figure 2. The fields were located in the barangays Gaboc and Pula and the monitoring took place from February to June 1994.

In April, when some of the release areas were already saturated with *D. semiclausum*, we started monitoring parasitism also in fields without actual *Diadegma* releases but located in the neighborhood of previous release fields. Results of the monitoring in four such fields without actual releases are summarized in Figure 3. The fields were located in the barangays Gaboc and Lumapao and the monitoring took place from May to August 1994.

Fig. 2: DBM larval parasitization after releases of *D. semiclausum* (Means of 4 fields, Canlaon, Febr.-July 1994)

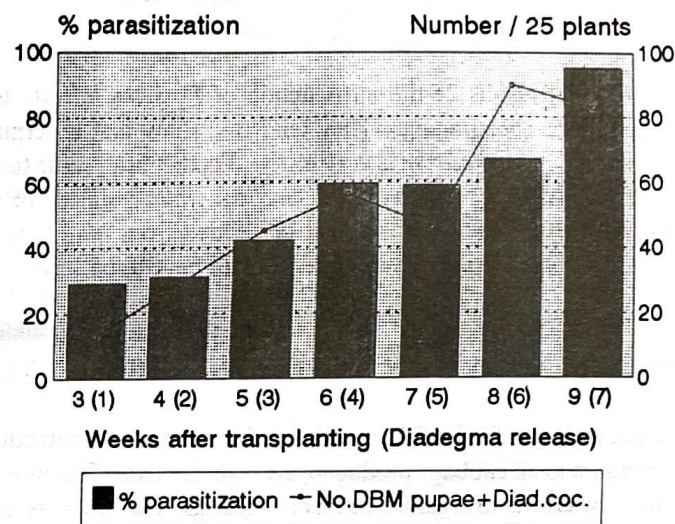
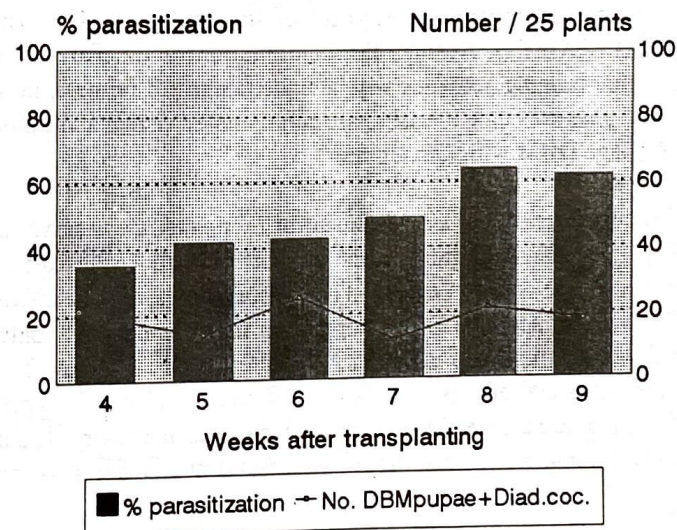


Fig. 3: DBM larval parasitization without actual releases of *D. semiclausum* (Means of 4 fields, Canlaon, May-Aug. 1994)



As shown in Figure 2, average DBM larvae parasitization reached up to more than 90 % in fields with *D. semiclausum* releases. In fields without actual releases, parasitization reached up to over 60% (Fig. 3). The data demonstrate that the laboratory reared *Diadegma* were able to establish strong and stable field populations, and that within a short period after the introduction of *D. semiclausum* to Canlaon, high parasitization rates could be realized even without further *Diadegma* releases.

These initial results of the introduction of *D. semiclausum* to the Canlaon area are encouraging. They tend to show that a permanent establishment of *D. semiclausum* is very likely. Whether after some time the releases of laboratory reared *Diadegma* can be stopped or some augmentative or inoculative releases will be needed from time to time to maintain the *D. semiclausum* populations will still have to be seen.

TRAINING ACTIVITIES AND FURTHER PROSPECTS

At present the PGBPPP is still in the process of introducing *D. semiclausum* to all cabbage producing areas of Canlaon. This process is accompanied by efforts to organize farmers' trainings. The first season-long training of Canlaon cabbage farmers, also called Farmers Field School, was conducted from April to July 1994. The training was facilitated in collaboration between the PGBPPP, the Regional Crop Protection Center, Mandaue, the Regional Department of Agriculture, Cebu, and the national integrated pest management program of the Philippine Government (KASAKALIKASAN). Besides the continuation of the Farmers Field Schools, other training activities will be undertaken. All farmers, in whose fields *Diadegma* are being released, are continuously visited and trained on how to manage DBM with *Diadegma*.

The introduction and establishment of *D. semiclausum* serves as the basis of a management program for the control of DBM. As the experiences in the highlands of Northern Luzon and other countries show, *D. semiclausum* can effectively reduce the DBM population to an extent that only few insecticide applications are needed to avoid economical losses. To fully realize the beneficial effects of *D. semiclausum*, however, a switch to insecticides that are compatible with the parasitoid is necessary. The use of *B. t.* in this context has been proven successful in Canlaon and several

other parts of the world. The main target of the farmers' trainings is therefore to encourage the use *B. t.* instead of other insecticides. The cooperation of farmers in this respect is vital to a successful establishment of *D. semiclausum*. In a later stage of the process, when the DBM population in Canlaon has actually been reduced, farmers can be taught to spray only when necessary.

All activities of the PGBPPP and the cooperating offices should lead to the development of a practical IPM program for the Canlaon cabbage farmers. The biological control of DBM with *D. semiclausum* together with the implementation of a complementary integrated pest management program will help to minimize the use of insecticides in cabbage production. Thus, risks to consumers, hazards to farmers' health and the contamination of the environment will be reduced and at the same time the income of farmers will be increased.

REFERENCES

- AMEND, J., MANGALI, T., 1992: Field releases of the parasitoid *Diadegma semiclausum* (Hellen) (Hymenoptera: Ichneumonidae) against *Plutella xylostella* L. (Lepidoptera: Yponomeutidae) in seed patchay in Northern Luzon. The Philippine Journal of Plant Industry, 57, 53-62.
- AMEND, J., MANGALI, T., EMAGUIN, D.P., 1994: Establishment of *Diadegma semiclausum* (HELLEN) (Hymenoptera: Ichneumonidae) in the Philippine Cordillera: status in 1992 and 1993. The Philippine Journal of Plant Industry, 59, 103-108.
- ANONYMOUS, 1994: Philippine agribusiness factbook and directory. Center for Research and Communication, Pasig, Manila, 527 pp.
- BARROGA, S.F., 1979: Biology, ecology and control of Diamondback moth *Plutella xylostella* L.. In PEST CONTROL COUNCIL OF THE PHILIPPINES (PCCP), 1979: Development of pest management in the Philippines. 10th anniversary publication of the PCCP.

- CARDONA, E.V., 1992: Field releases of *Diadegma semiclausum* in Benguet (Highland), Philippines. Paper presented at the AVNET workshop, Bambang, Indonesia, 22-26 September 1992, 12 pp.
- CARL, K., 1990: Vegetable pests and their natural enemies and proposals for the introduction of biological control agents. Report to the Philippine-German Biological Plant Protection Project, Bureau of Plant Industry, Manila, 18 pp, annex.
- KÖNIG, K., DEOGRACIAS, L., AMEND, J., 1993: Mass-rearing and utilization of *Diadegma semiclausum*. Brochure, Philippine-German Biological Plant Protection Project, Bureau of Plant Industry, Manila, 18 pp.
- IDRIS, A.B., GRAFIUS, E., 1993: Differential toxicity of pesticides to *Diadegma insulare* (Hymenoptera: Ichneumonidae) and its host, the Diamondback moth (Lepidoptera: Plutellidae). J. Econ. Entomol., 86, 529-536.
- MAGALLONA, E.D., 1986: Developments in Diamondback moth management in the Philippines. In TALEKAR, N.S., GRIGGS, T.D. (eds) 1986: Diamondback moth management. Proc. 1st Int. Workshop, Shanhua, Taiwan, Asian Vegetable Research and Development Center, 471 pp.
- PÖLKG, A., 1992: Die Kohlmotte, *Plutella xylostella* L. (Lepidoptera: Plutellidae), in Nordluzon (Philippinen) - Ansätze zu ihrer integrierten Bekämpfung. Hartung-Gorre Verlag, Konstanz, Germany, 156 pp, annex.
- SASTROSISWOJO, S., 1990: Mass rearing of *Diadegma eucerocephala* and *Apanteles plutellae*, and development of the biological and integrated control of the Diamondback moth on cruciferous crops in the Philippines. Report to the Philippine-German Biological Plant Protection Project, Bureau of Plant Industry, Manila, 17 pp, annex.
- TALEKAR, N.S., SHELTON, A.M., 1993: Biology, ecology, and management of the Diamondback moth. Annu. Rev. Entomol., 38, 275-301.

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- VOS, H.C.C.A.A., 1953: Introduction in Indonesia of *Angitia cerophaga* GRAV., a parasite of *Plutella maculipennis* CURT.. Contrib. Gen. Agric. Research Station, Bogor, Indonesia, No. 134, 32 pp.
- WATERHOUSE, D.F., NORRIS, K.R., 1987 Biological control - Pacific prospects. Inkata Press, Melbourne, p 177-191.
- WYRWAL, G., 1993: Socio-economic key parameters in vegetable cultivation in selected areas of Negros Oriental, Philippines. Report to the Philippine-German Biological Plant Protection Project, Bureau of Plant Industry, Manila, 117 pp.
- WÜHRER, B., 1993: Wahl von wirksamen *Trichogramma*-Arten bzw. -stämmen zur Bekämpfung der Kohlschabe *Plutella xylostella*, des Auberginenfruchtbohrers *Leucinodes orbonalis* sowie des Baumwollkapselwurms *Heliothis armigera*. Abschlussbericht. Report submitted to the Philippine-German Biological Plant Protection Project, Bureau of Plant Industry, Manila, Philippines, 46 pp.