Ecological impact of *Brassica* IPM implementation in Indonesia

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Abstract

In Indonesia, *Brassica* vegetables such as cabbage and Chinese cabbage are heavily infested with diamondback moth (DBM), *Plutella xylostella* (L.) and sometimes with cabbage head caterpillar (CHC), *Crocidolomia binotalis* (Zeller). *Diadegma semiclausum* Hellén is the most important larval parasitoid of DBM and becomes a key component of IPM programs on DBM. In 1999, studies were conducted at Lembang (RIV) and at Pangalengan in West Java to observe the ecological impact of IPM implementation versus a conventional pest management system on cabbage, using a paired treatment comparison. The faunal diversity in sweep net samples was higher in the IPM system compared with the conventional system (expressed by D values: 0.83 at Lembang and 0.59 at Pangalengan). The population of *D. semiclausum* increased in the IPM system by 34% at Lembang and 53% at Pangalengan. The abundance of soil dwelling predators (Coleoptera, Araneida, Hemiptera and Orthoptera) in the IPM system at Lembang and Pangalengan, increased by 84% and 68% respectively. Two species of soil microorganisms known as important biological control agents, namely *Trichoderma* sp. and *Bacillus* sp., were higher in the IPM system. IPM implementation on cabbage was superior to the conventional system in terms of (i) reduction of costs for insecticide usage by 79% at Lembang and 64% at Pangalengan and (ii) increase in marketable yield by 57% at Lembang and 19% at Pangalengan in the IPM system.

Keywords

cabbage, faunal diversity, *Plutella xylostella*, *Crocidolomia pavonana*, *Diadegma semiclausum*

Introduction

The Food and Agriculture Organization of the United Nations (FAO) (1989) defines sustainable agriculture and rural development as: “The management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development conserves land, water, plant and animal genetic resources, in an environmentally, non-degrading, technically appropriate, economically viable and socially acceptable manner.” The definition stresses that management of resources can meet the human needs without destroying environment and should enhance the quality of the environment.

“Sustainable farming system” has become a popular term and is a most important issue in the field of agriculture to those people who have an interest in agricultural sustainability and who are concerned about conventional farming systems that rely heavily on synthetic chemicals and other off-farm inputs (Untung 1995). The problems associated with conventional farming practices are now widely recognised and include pest resistance to pesticides, the problem of pesticide residues in food, human and environmental hazards and harmful side effects for beneficial insects (Sastrosiswojo 1996b).

Arthropod biodiversity is an important component in the development of sustainable agriculture because of its role in maintaining soil fertility, crop pollination and control of arthropod pests (Sosromarsono & Untung 2001). Biodiversity forms an important part of an agroecosystem that includes both the living organisms and non-living components that interact within cultivated fields (Ooi 1997).

Overcoming the problems created by conventional farming systems has been by the implementation of integrated pest management (IPM), which is also considered as part of a sustainable farming system (Untung 1995). The general objective of IPM programs has been the development of improved ecologically-oriented pest management systems that optimise, on a long term basis, costs and benefits of crop protection (Huffaker & Smith 1980).

In Indonesia, the IPM concept was officially adopted in 1979 and was followed with the strengthening of the plant protection service. Following the Presidential Decree No. 3/1986, which banned 57 broad-spectrum pesticides for use on rice, the National IPM Programme was launched in 1989 for rice and secondary food crops (soy bean) and, in November 1991, for vegetables (Sastrosiswojo 1996a). An evaluation of the benefits of the IPM training program for cabbage growers in 1994 showed significant results such as: (1) reduction of insecticide applications (61–81%); (2) rate of DBM parasitism increased by up to 80%; (3) marketable yields were higher (8–16%) and (4) profit increased by $834/ha, in the IPM system versus the conventional system (Sastrosiswojo 1996b). Results of a recent study to assess the impact of IPM training on cabbage growers (Londhe *et al*. 1999) showed that IPM training had a positive and significant impact on cabbage yield. In addition, detailed costs and returns analysis by location (East Java, West Java and North Sumatra) showed higher yields and net revenues for farmers with IPM training.

Implementation of the IPM concept and technology on cabbage, through conducting IPM Farmer Field Schools (FFS) in ten provinces of Indonesia since 1992 to 1999, proved that the IPM system provided a higher net revenue when compared with conventional farmers' practice. The IPM system also required fewer numbers and amounts of pesticide sprays, but was able to secure healthy and higher quality of cabbage yields. More importantly, less pesticide residues were left on the harvested cabbages (Sastrosiswojo 1995, 1996b; Londhe *et al*. 1999). However, the ecological impact of cabbage IPM implementation has never been studied.

This paper evaluates the ecological impact of IPM implementation on cabbage in Bandung district, Indonesia. The biodiversity of insect fauna in the cabbage community treated with different pest control strategies (an IPM system versus a conventional system) was studied.

Materials and methods

In 1999, field experiments were conducted at two locations in Bandung District, West Java: at the Vegetables Experiment Station of Research Institute for Vegetables (RIV) at Lembang and in a farmer's field at Pangalengan. Cabbage (cv. Green Coronet) was planted on July 15, 1999 at Lembang and on August 17, 1999 at Pangalengan. Cabbages were harvested on September 24, 1999 (at Lembang) and on November 17, 1999 (at Pangalengan). In each location, the experiment used paired treatment comparisons (Chiarappa 1971) to compare the IPM system with the conventional system (designated Non-IPM) (Table 1). The treatments tested in each location were: (a) IPM technology developed at RIV Lembang (Sastrosiswojo 1995) and (b) Conventional system (Non-IPM), using application of agronomic factors and pest control commonly practised by the local farmers. Each plot size was 500 m^2 and contained approximately 1400 cabbage plants. Each plot was divided into five sub-plots, 100 m^2 each.

Assessments were made every week, starting from two weeks after planting. Organisms were counted or collected in small numbers to avoid disruption of the faunistic community. Three major groups were collected or counted: the fauna on cabbage plants, aerial forms and soil forms. Fauna was collected by hand or by sweep netting and then placed in killing containers. Aerial forms were collected using sweep nets, 20 sweeps per sub-plot. The soil inhabiting fauna was collected using pitfall traps, two traps per sub-plot. The value of species diversity (D) was determined by the following equation (Michael 1984):

$$D = \frac{\text{Number of species recorded}}{\sqrt{(\text{Total number of individuals})}}$$

Population study

Weekly counts of major insect species were conducted on 10 cabbage plants, which were systematically selected. Ten samples of IV instar DBM larvae were dissected to estimate levels of DBM larval parasitism by *D. semiclausum. S*oil samples were taken weekly from each sub-plot. Major soil microorganisms, thought to play an important role as biological control agents or decomposers of organic matter, were identified and their abundance estimated. The numbers of insecticide sprays and the amount of insecticide used during the growing season were recorded for each plot. The marketable yield of cabbage per plot was recorded at harvest time.

Table 1. Components of the IPM system and non-IPM systems applied to cabbage plots at Lembang and Pangalengan, 1999

IPM system	
A. Cultural control:	Use of Dolomite (4 t/ha).
B. Balanced fertilisation:	Stable manure: 30 t/ha; fertilisers used: 250 kg/ha TSP, 100 kg/ha Urea, 250 kg/ha ZA and 200 kg/ha KCl
C. Biological control:	*Diadegma semiclausum* is a core component of IPM.
D. Control threshold (CT):	DBM: 5 caterpillars/10 plants CHC: 3 egg clusters/10 plants
E. Monitoring of agroecosystem	Once per week Analyses of agroecosystem
F. Use of insecticide	Based on monitoring and control threshold level (CTL) of DBM and CHC Type of insecticide: selective (spinosad)
Conventional system (Farmers' practice)	
A. Cultural control	No liming
B. Fertilisation:	At Lembang 30 t/ha stable manure, 250 kg/ha TSP, 300 kg/ha Urea, 300 kg/ha ZA, 250 kg/ha KCl and 250 kg/ha NPK At Pangalengan 42 t/ha stable manure, 6 t/ha chicken manure, 20 t/ha mushrooms waste and 700 kg/ha NPK.
C. Biological control	Neglected
D. Control threshold	Neglected (calendar system)
E. Monitoring of agroecosystem	Neglected
F. Use of pesticides	At Lembang 2 times per week, mixtures of profenofos, *B. thuringiensis* var. *aizawai,* lambda cyhalothrin and antracol At Pangalengan 2 times per week, alternate use of fipronil, diafenthiuron, imidacloprid and abamectin

Results and discussion

Faunistic study

The diversity of the fauna sampled with a sweep net in the IPM plot was relatively higher than that of the Non-IPM plot (Table 2). This is indicated by the values of D in the IPM and Non-IPM plots (0.83 and 0.59 respectively). One possible reason was the use of the selective insecticide, spinosad in the IPM plots, while more toxic insecticides such as lambda cyhalothrin and fipronil were used in the Non-IPM plots. The toxicity of spinosad against humans and the environment is very low (Dow AgroSciences 2001).

The high diversity of fauna found in the IPM system in this study, and in cabbage communities in general, may increase the ecosystem stability. Consequently, IPM should also minimise pest outbreaks. It is very important to conduct studies of insect biodiversity before interventions are recommended (Ooi 1997).

Both macroarthropods and microarthropods were caught in the pitfall traps. The numbers of arthropods caught were always higher in the IPM plots than in the Non-IPM plots (Table 3). The data show that the use of the IPM system on cabbage crops increased the number of arthropods by 59% at Lembang and 96 % at Pangalengan compared with the conventional system.

Table 2. Diversity of insects sampled by sweep net from cabbage crops managed either with an IPM system or with a conventional (Non-IPM) system at Lembang and Pangalengan, 1999

Site (elevation)	Mean number of species		Total number of individuals		Species diversity (D)*	
	IPM	Non-IPM	IPM	Non-IPM	IPM	Non-IPM
Lembang (1250 m)	3.0	2.0	8.0	7.0	1.06	0.76
Pangalengan (1400 m)	6.0	4.0	101.0	89.0	0.60	0.42

* D values were counted based on formula given by Michael (1984)

Table 3. Mean number of arthropods caught in pitfall traps in a cabbage crop managed with either an IPM system or a Non-IPM system (conventional system) at Lembang and Pangalengan, 1999

Site (elevation)	Number of individuals caught in pitfall traps*		
	IPM system	Non-IPM system	Difference (%)**
Lembang (1250 m)			
Macroarthropods	87.5	43.1	103.0%
Microarthropods	4551.8	2876.7	58.2%
Total individuals	4639.3	2919.8	58.9%
Pangalengan (1400 m)			
Macroarthropods	62.5	57.7	8.3%
Microarthropods	4282.2	2160.8	98.2%
Total individuals	4344.7	2218.5	95.8%

*Total number of individuals from eight sampling occasions (means of five replications at each observation)
**$((N_{IPM}-N_{non\text{-}IPM})/N_{non\text{-}IPM})$

Population study

At both Lembang and Pangalengan, the most important cabbage pests were DBM and CHC. At Lembang, the black cutworm (*Agrotis ipsilon* Hübner) was also common, while at Pangalengan, the potato leafminer *(Liriomyza huidobrensis* Blanchard) was common. In the IPM managed plots, the selective insecticide, spinosad, was applied only when the population of DBM larvae and/or egg clusters of CHC surpassed the control threshold. The thresholds used were 5 larvae/10 plants for DBM and 3 egg clusters/10 plants for CHC (Sastrosiswojo 1987, 1996a). Application of the IPM system on cabbage, both at Lembang and Pangalengan, effectively suppressed the population of DBM and CHC. In the IPM system, DBM numbers were reduced by 47% at Lembang and 34% at Pangalengan, while CHC numbers were reduced by 22% at Lembang and 62% at Pangalengan, compared with the conventional system (Table 4).

Table 4. Total numbers of DBM (*Plutella xylostella*) and CHC (*Crocidolomia pavonana*) in IPM and Non-IPM plots at Lembang and Pangalengan, 1999

	Lembang		Pangalengan	
	IPM	Non-IPM	IPM	Non-IPM
DBM	6.9	13.1	10.6	16.1
CHC	1.8	2.3	1.5	3.9

Diadegma semiclausum Hellén is the most important parasitoid of DBM larvae and was introduced into Indonesia in 1950 (Vos 1953). Now *D. semiclausum* is well established in almost all of the highland cabbage growing areas and has become the core component of IPM on cabbage (Sastrosiswojo 1996b).

In this study, *D. semiclausum* was the only parasitoid found in the cabbage plots at Lembang and Pangalengan. The fluctuations in numbers of *D. semiclausum* followed the populations of DBM at both locations (Table 5). The use of a selective insecticide (spinosad) based on the control threshold of DBM in the IPM system, did not appear to disturb the role of *D. semiclausum* as a biological control agent of DBM. The parasitism of DBM by *D. semiclausum* increased by 34% at Lembang and 53% at Pangalengan in the IPM plots compared with the Non-IPM plot. *D. semiclausum* suppressed effectively the population of DBM during one growing season of cabbage.

Table 5. Mean number of *P. xylostella* larvae per cabbage (DBM) and % parasitism (% P) of DBM larvae by *D. semiclausum* in the IPM and Non-IPM plots at Lembang and Pangalengan, 1999

		Days after planting										
		14	21	28	35	42	49	56	63	70	77	84
Lembang												
IPM	DBM	0.4	0.3	0.6	1.6	0.4	1.8	0.5	0.2	0.8	0.2	0.3
	% P	0.0	0.0	45.0	10.0	37.5	11.1	25.0	25.0	11.1	25.0	50.0
Non-IPM	DBM	0.3	0.5	1.1	4.5	2.8	1.0	0.3	0.3	1.0	0.7	0.6
	% P	0.0	0.0	20.0	11.1	10.0	33.3	0.0	25.0	19.1	17.7	23.1
Pangalengan												
IPM	DBM	5.9	0.0	1.6	0.1	2.2	0.1	0.0	0.5	0.2	0.0	0.0
	% P	0.0	0.0	32.0	20.0	0.0	0.0	0.0	0.0	32.0	12.5	0.0
Non-IPM	DBM	2.7	5.2	4.9	0.4	0.7	0.8	0.3	0.3	0.8	0.0	0.0
	% P	0.0	0.0	17.3	20.0	0.0	25.0	0.0	0.0	0.0	0.0	0.0

Four orders of predatory arthropods were found in the pitfall trap studies: Coleoptera (43%), Araneida (24%), Hemiptera (18%) and Orthoptera (16%) (Table 6). Implementation of the IPM system increased the abundance of predatory arthropods by 84% at Lembang and 68% at Pangalengan (Table 6). The study suggests that the intensive use of insecticide usually practised by the cabbage farmers may have adversely affected the populations of soil predatory arthropods. Consequently, the populations of DBM, CHC and other insect pests may increase with intensive use of insecticides.

The soil fauna was observed on the soil surface and within the soil of cabbage communities treated with the IPM system and the conventional system (Non-IPM). The most common orders present were Collembola, Diplura and Acarina. There was a significant difference between the IPM system plots and the conventional system plots in terms of abundance and composition of soil fauna (Table 7).

At Lembang, the most abundant components of the fauna on the soil surface of the cabbage plots were Collembola (72%), followed by Diplura (26%) and Acarina (2%). In the soil samples, the most dominant component fauna was also Collembola (73%), followed by Diplura (22%) and Acarina (5%). In general, the application of the IPM system was able to increase the population of soil fauna by 59% on the soil surface and by 56% in the soil compared with the conventional system (Non-IPM).

At Pangalengan, results of the study indicated that the most abundant component fauna on the soil surface of cabbage community were Collembola (84%), followed by Diplura (14%) and Acarina (2%). Observation on the soil samples showed that dominant components of the fauna were Acarina (50%), Collembola (39%) and Diplura (11%). Similarly, implementation of the IPM system increased soil fauna by 71% on the soil surface and by 113% in the soil compared with the conventional system (Non-IPM).

Table 6. Population of predatory insects in IPM and Non-IPM (conventional system) plots at Lembang and Pangalengan, 1999

Populations	Lembang		Pangalengan	
	IPM	Non-IPM	IPM	Non IPM
Coleoptera	3.1	2.3	2.9	2.6
Araneida	2.2	0.6	2.4	1.4
Hemiptera	2.0	0.3	1.7	1.0
Orthoptera	1.5	1.2	1.4	0.3

Table 7. Mean abundance of soil fauna (a) on the soil surface and (b) in the soil of cabbage plots managed with IPM system or Non-IPM (conventional system) at Lembang and Pangalengan, 1999

Stratum sampled	Order	Lembang		Pangalengan	
		IPM	Non-IPM	IPM	Non-IPM
Soil Surface	Collembola	198.6	121.4	255.7	110.0
	Diplura	65.7	48.6	34.3	27.2
	Acarina	7.2	1.4	7.7	1.4
Soil	Collembola	138.8	80.0	102.5	57.5
	Diplura	36.3	28.8	25.0	18.8
	Acarina	8.8	7.5	132.5	77.5

Although there are many soil microorganisms that can play an important role as biocontrol agents of soilborne diseases, only two species were identified from the soil samples taken from the experimental cabbage plots. Counts of known species of biocontrol agents during the study revealed that *Trichoderma* sp. was by far the most common species present, followed by *Bacillus* sp. *Trichoderma* sp. is a soil fungus that actively decomposes organic matter in the soil by producing a cellulose destruction enzyme. The development of *Trichoderma* sp. and *Bacillus* sp. in the soil is much faster than other soil microorganisms, especially those responsible for soilborne diseases.

It is assumed that the mechanism in suppressing the population of soilborne diseases by both species is antibiosis. Results from the present study showed that implementation of the IPM system had only a minor effect, with the population of *Trichoderma* spp. in the soil increasing by only 6% at Lembang and 7% at Pangalengan compared with the conventional system (Table 8).

Table 8. Population of *Trichoderma* spp. in the soil sample taken from cabbage community treated with IPM system and Non-IPM (conventional system) at Lembang and Pangalengan, 1999

Populations	Lembang		Pangalengan	
	IPM	Non. IPM	IPM	Non IPM
Trichoderma spp.	5.87×10^4	4.71×10^4	4.88×10^4	4.26×10^4

The insecticide used in IPM plots, at both Lembang and Pangalengan, was spinosad (Success 25 SC). The insecticides used in Non-IPM plots (conventional system) at Lembang included profenofos (Curacron® 500 EC) and lambda cyhalothrin (Matador® 25EC), while at Pangalengan, fipronil (Regent® 50 SC), diafenthiuron (Pegasus® 500 SC), imidacloprid (Confidor® 200SL) and abamectin (Agrimec® 18 EC) were used in rotation (alternate use) every three days. The total number of insecticide sprays in the Non-IPM plots was 22 times during one growing season of cabbage. Insecticide application in IPM plots was only undertaken when the DBM population or population of egg clusters of CHC surpassed their control thresholds.

The study showed that implementation of the IPM system reduced the number of insecticide sprays by 82% at Lembang and Pangalengan, compared with the conventional system (Table 7). In addition, the amount of insecticides used was also reduced by 90% at Lembang and by 95% at Pangalengan. In terms of money, the cost for insecticides used was 79% at Lembang and 64% at Pangalengan. The marketable yield of cabbage in IPM plots was 13.7 t/ha at Lembang and 43.4 t/ha at Pangalengan (Table 9).

The marketable yield of cabbage in Non-IPM plots (conventional system) was 8.7 t/ha at Lembang and 36.6 t/ha at Pangalengan. The yield of cabbage at Lembang was very low, presumably because of low soil fertility and the high incidence of clubroot (*Plasmodiophora brassicae* Wor.). The figures show that marketable yield of cabbage in the IPM plots increased by 57% at Lembang and 19% at Pangalengan when compared with the conventional system.

Table 9. Use of insecticides and marketable yield of cabbage in the IPM system and the Non-IPM (conventional system) at Lembang and Pangalengan, 1999

Treatments	Lembang		Pangalengan	
	IPM	Non-IPM	IPM	Non-IPM
Number of insecticide sprays	4	22	4	22
Amount of insecticide used (L/ha)	2.25	66.00	2.25	41.25
Cost of insecticide (Rp x 10^6)	1.6	7.6	1.6	4.4
Marketable yield (t/ha)	13.7	8.7	43.4	36.6

Conclusions

Based on these studies, conclusions can be made regarding the ecological impact of the IPM implementation on cabbage at Lembang and Pangalengan as follows:

(a) Faunistic study: the IPM system increased faunal diversity: in consequence it will minimize pest outbreaks compared with the conventional system (Non-IPM).
(b) Population study: Major insect pests on cabbage during the study were the diamondback moth and cabbage head (cluster) caterpillar. The populations of DBM and CHC were effectively suppressed by IPM implementation. Rates of parasitism of DBM larvae by *D. semiclausum* increased by 34 to 53% in the IPM system. The abundance of soil inhabiting predators (macroarthropods) in the orders Coleoptera, Araneida, Hemiptera and Orthoptera was 68 to 84% higher in the IPM system. Implementation of the IPM system also increased the abundance of soil fauna (microarthropods) in the orders Collembola, Diplura and Acarina, both on soil surface and in the soil. The soil microorganisms (bio-control agents) identified in this study were *Trichoderma* sp. and *Bacillus* sp. The abundance of both species increased by 6% to 7% in the IPM system.
(c) Insecticide used: IPM implementation significantly reduced the number of insecticide sprays (82%), amount of insecticides used (90 to 95%) and the cost of insecticides used (64 to 79%).
(d) Cabbage yield: marketable yields were 57% at Lembang and 19% at Pangalengan higher in the IPM system compared with the conventional system.

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