17 Areawide Pest Management for Non-rice Food Crops in South-east Asia

M.D. HAMMIG,[1] B.M. SHEPARD,[2] G.R. CARNER,[2]
R. DILTS[3] AND A. RAUF[4]

[1]Department of Applied Economics and Statistics, Clemson University, Clemson, South Carolina, USA
[2]Department of Entomology, Soils, and Crop Science, Clemson University, Clemson, South Carolina, USA
[3]Regional Advisor, Environmental Services Programme, Medan, North Sumatra, Indonesia
[4]Department of Plant Protection, Bogor Agricultural University, Bogor, West Java, Indonesia

Introduction

This chapter focuses on pest management in South-east Asia, specifically Indonesia. The authors of this chapter have been working with colleagues in Indonesia since the mid-1980s, and have been involved with the development of pest management policy by the government of Indonesia as well as the implementation of pest management strategies by Indonesian farmers. Our experience includes activities in the Philippines and other countries in the region, but home base – away from home – has predominantly been Indonesia. Most of the discussion that follows emanates from field activities in Indonesia in which one or more of the authors have been engaged; however, the circumstances with respect to farming systems, crops, agronomic issues and pest complexes are very similar across the region. Therefore, extrapolation of recommended approaches has potential for benefit far beyond Indonesia.

This chapter contains a compendium of pest management practices for food crops other than rice: mainly vegetable crops. While the most important food crop in Indonesia is rice, where over one-third of Indonesians' food budget is spent, nearly one-fourth is spent on fruits and vegetables (USDA/ERS, 2006). Rice is the staple food throughout the country but, since the late 1980s, as average incomes have grown and Indonesians recognize the nutritional importance of vegetables in the diet, vegetable consumption has been steadily growing.

Major vegetables produced include cabbage, potatoes, tomatoes, shallots, chillies, beans, assorted greens, aubergine and onions. Production of all these vegetable crops is found throughout the Indonesian archipelago. Many vegetables are grown in highland areas where vegetable rotations dominate the agricultural landscape, but many are also produced in lowland areas, in rotation with rice during relatively dry periods when rice is not produced.

Price volatility and losses due to pest infestations are major concerns for vegetable growers. On average, vegetables are high-value crops, but the likelihood of losses – either in the marketplace or in the field – causes vegetable production to be relatively risky compared with rice. These uncertainties are important factors affecting farmer choices of crop mix. Pest infestations occasionally wipe out production of certain vegetables, forcing farmers to opt for different crops. For example, leafminers, *Liriomyza huidobrensis*, exotic to Indonesia, substantially reduced plantings of potatoes in many areas in the early 2000s until natural enemy populations became established to suppress the pest. Farmers, fearing losses due to the pest, altered their crop mix to replace potatoes, even when market prices were high, with other vegetables.

Cropping choices are also driven by anticipated returns from vegetable markets. Price volatility is mitigated by diversity of cropping patterns in most areas. Spreading the market risk across crops gives the farmer a cushion to protect against the danger of frequently low prices. Thus the vegetable production landscape, particularly in highland regions, is characterized by a mosaic of small (about 1000 m^2) plantings of a variety of vegetable crops in changing rotations throughout the year.

There are notable exceptions to this cropping pattern in certain areas; farmers in a few areas of Indonesia concentrate on one particular crop. Shallots, for example, are produced along the north central coast of Java in rotations with rice, with little variation in cropping systems year after year. In some locations, large landholdings are dedicated to a particular crop such as potatoes or cabbages to serve export markets, to other islands within Indonesia or to neighbouring countries.

Other important non-rice food crops also are found in these production systems, including soybeans and maize. These are grown for animal as well as human food, and are most often found in rotation with rice during the dry season.

Management of pests is a persistent problem for all these crops, regardless of where they are found in the country. Because vegetables are potentially very profitable as compared with rice, farmers are typically willing to invest significant resources on chemical pesticides, often to the detriment of a sustainable IPM system. Excessive use of these chemicals is widespread and pervasive. Spraying as often as every 2–3 days is common practice for most vegetable crops. Pesticides are applied as ‘cocktails’ of assorted insecticides, fungicides and others, with little regard to label instructions and complete disregard for proper application procedures.

The attendant environmental, health and food safety problems become serious issues for government agencies, university researchers, extensionists, NGOs, international institutions and others who are concerned with the broad context of agricultural sustainability. Thus, efforts are driven by government policy and implemented by a large number of local and international experts, working in concert with farmers to find better more ecologically and economically sustainable ways to manage pests.

Areawide Pest Management in Indonesia: the National IPM Training Programme

Areawide pest management (AWPM) in Indonesia is centred on its National IPM Training Programme, initiated in 1989. The story of the development and implementation of the National Programme is well documented (Hammig, 1998; Thornburn, 2007). The need for a different approach to crop pest management became an important national political issue as a result of widespread rice crop failures in the 1970s and 1980s. Indonesian scientists, working with international experts, met with the then-President Suharto and explained that excessive use of chemical insecticides was the root cause of outbreaks of the brown planthopper, *Nilaparvata lugens*, because of destruction of indigenous natural enemies that normally kept the planthopper in check. Shortly after that meeting, Suharto promulgated a Presidential Instruction in March 1986 that banned 57 insecticides from use on rice, eliminated large government subsidies for pesticides, and declared that IPM would be the national pest management policy. The impacts of this policy are dramatically demonstrated in Figs 17.1 and 17.2, which illustrate the coincidence of reduced pesticide use, reduced numbers of planthoppers and steadily increasing rice production.

To implement this policy, a major effort was undertaken to develop a training programme that would reach as many farmers as possible in the most important rice-growing regions of the country. With assistance from the US Agency for International Development, the United Nations Food and Agriculture Organization and the World Bank, a programme was developed that marshalled the resources of key agencies of Indonesia's Ministry of Agriculture and several universities to implement a programme to train farmers in the principles of IPM, with the goal of reducing farmers' dependence on synthetic chemical pesticides and improving pest management in farmers' fields.

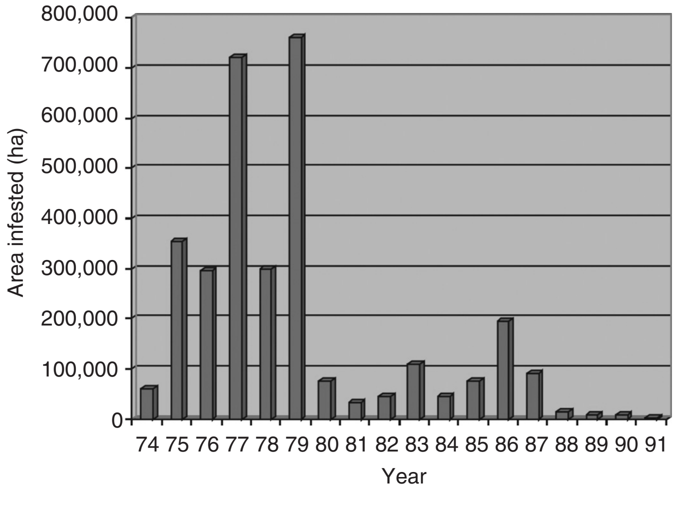

Fig. 17.1. Brown planthopper infestation levels in rice in Indonesia, 1974–1991 (from Kenmore, 2006).

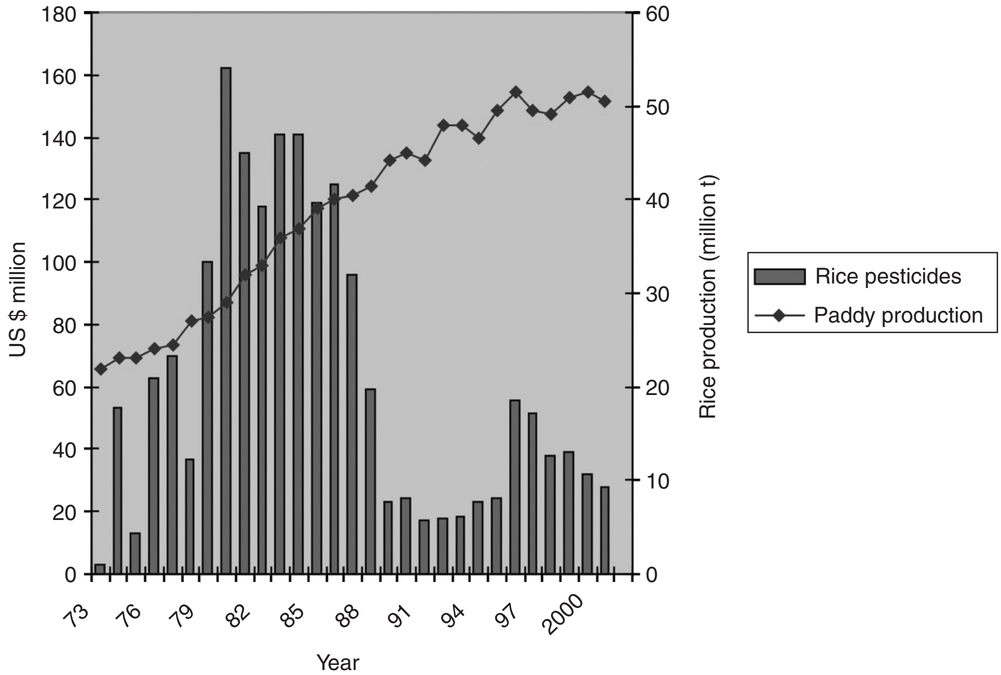

Fig. 17.2. Rice pesticide expenditures and paddy production in Indonesia, 1973–2001 (from Kenmore, 2006).

The National IPM Training Programme used curricula developed specifically for local conditions. Trainers who had, themselves, received training from national and international experts and who recognized the value of farmers' indigenous knowledge, worked with farmer groups, meeting weekly and taking careful note of the ecological conditions of the field: pests, natural enemies, plant health, etc.

The Farmer Field School (FFS) approach was based on four basic principles: (i) grow a healthy crop; (ii) conserve natural enemies; (iii) visit the field regularly (Gallagher, 1990); and (iv) farmers become IPM experts in their own fields (Dilts, 1990). The main paradigm shift was that farmers carried out research/demonstrations in their own fields in a participatory manner rather than receiving recommendations from extension workers, as is the model in most Western societies, and was the norm in Indonesia prior to IPM training.

By the end of the World Bank-supported training effort in 1998, over 1,100,000 farmers were trained in rice IPM, along with over 2300 pest observers and 4000 agricultural extension workers. Furthermore, and a key factor for the subsequent expansion of IPM training, over 21,000 farmers were trained as IPM trainers and, by 1998, were conducting a majority of the FFSs (Hammig, 1998).

Following the National Programme's focused training efforts of the 1990s, IPM training programmes continue to thrive throughout Indonesia, though support for these efforts is no longer from central government authorities as much as from local agencies, some universities and farmer groups with assistance from NGOs and experienced FFS veterans (Pontius *et al.*, 2002). The scope of FFSs also broadened to include plantation crops, soil ecology, participatory plant breeding and local policy advocacy.

Areawide Pest Management in Indonesia: Non-rice Food Crops

Integrated pest management training in rice was the first step toward an areawide approach to pest management in Indonesia that significantly differed from the traditional command and control approach through which packages of inputs, including pesticides, were forced upon farmers by poorly trained extension workers with a common list of instructions that did not take into account variation of local conditions. These command and control programmes succeeded in introducing improved crop varieties and rice production expanded, but they can also be blamed for the excessive pesticide use that led to periodic pest-induced crop failures.

Though the IPM training programme was initially targeted at rice, by the mid-1990s training had been expanded, largely due to farmer demand, to address pest management issues associated with secondary crops grown in rice rotations, and highland vegetables (Oka, 2003). Because pest problems are typically more complex than with rice, in general, farmers' methods for controlling crop pests include exceedingly high frequencies of chemical spray applications, so impacts of training programmes can be even more dramatic than for rice. The National Programme included nearly 3000 FFSs for over 30,000 vegetable farmers (FAO, 2000).

As the FFS model became well known across Indonesia, expansion of training to non-rice areas has emerged through local community efforts. Training for non-rice food crops follows the same basic principles as for rice. However, vegetables – which are for the most part exotic plant species– present different challenges for crop scientists and trainers. IPM approaches differ among crops and pests as trainers and technical support experts seek effective alternatives to chemical controls. Participatory farmer training continues throughout Indonesia, and farmer enthusiasm for training continues to expand. Teams of scientists are working in collaboration with farmer groups to develop pest control approaches appropriate to local conditions that emphasize the importance of natural control agents (Shepard *et al.*, 1999).

The post-Suharto era has significantly changed the political landscape in Indonesia. For 2007, the national Ministry of Agriculture has allocated budget support for over 2000 IPM FFSs, to be implemented by local governments and local farmer organizations. Local governments have much more authority than they had in the past, and programmes for issues like IPM training have devolved to local officials. In some areas, such as West Sumatra, the provincial government has aggressively pursued IPM programmes with a target of reaching all farmers in the province. The Provincial Director of Agriculture has voiced his desire for 'a completely organic Province'. 'Farmer Organic Institutes' have been established in several locations in West Sumatra to support the organic initiative, and over 20 farmer field laboratories producing biological agents are functioning in support of IPM programmes. FFSs for both organic rice and vegetable production are being implemented with government support.

In other areas, such as West Java, subdistrict governments specify budget allocations for vegetable IPM training with more limited ambitions (Hammig *et al.*, 2006). And, in some areas, university scientists, in collaboration with international experts and local farmers, are pursuing research and training activities in important vegetable-producing regions.

The challenges facing farmers, trainers and scientists include development of effective, economical pest management approaches across the host of crops that have been subjected to pest control programmes almost exclusively dependent on synthetic chemicals. These challenges are being addressed in a variety of ways, always with farmer fields as the focus of attention.

Areawide Pest Management Approaches for South-east Asia

Secondary food crops in Indonesia include those non-rice food crops (*palawija*) that are grown in rotation with rice and vegetable crops in upland areas where rice is not present. Development of sound, integrated pest management (IPM) practices for these *palawija* and vegetable crops in Indonesia is much more challenging than for rice. Unlike rice, which has been cultivated for thousands of years and has co-evolved into a relatively stable system, *palawija* and vegetable crops arrived in Indonesia much later.

On a per unit area basis, these latter crops receive more pesticides than any other crop. Applications of pesticides every 2–3 days are common, and this has created all of the classic symptoms of pesticide overuse that have occurred in many crops around the world. Vegetable farmers are led to believe through local habit and aggressive marketing that pesticides reduce risk, and are likely to try any new pesticide in hopes of higher yields or less damage. Frequent calendar-based 'cocktail' applications in Indonesia stem from a general lack of understanding of diseases, insect pests, weeds, natural enemies, crop compensation and agronomic factors. Many plant-feeding species targeted by farmers do not cause yield losses but instead serve as food for a large complex of natural enemies (Shepard *et al.*, 1999, 2001). Also, the impact of pesticides on the health of Indonesian farmers can be significant (Murphy *et al.*, 1999; Kishi, 2002). Thus, expanded farmer training in IPM is essential for sustainable vegetable and soybean production.

Soybean

Description of the problem and need for an AWPM approach

Soybean in Indonesia is considered a major *palawija* crop. This crop is the most important *palawija* crop, with over 1,407,000 ha grown in Indonesia. A large proportion of soybean is used for human consumption. Even with this large planting area, Indonesia still imports between 600,000 and 800,000 t of soybean annually. This crop is an important protein source and includes food items such as tofu, tempe and others.

The most important insect pests of soybean in Indonesia are the pod-boring insects, *Etiella zinckenella* and *Helicoverpa armigera*, the corn earworm (CEW). Of these, *E. zinckenella* is by far the most important, based on field surveys carried out by personnel and collaborators with the Clemson University Palawija IPM Project. The stemfly, *Melanagromyza sojae* and the seedling fly, *Ophiomyia phaseoli* can also be locally important, as can pod-sucking bugs such as *Nezara viridula* and *Riptortus linearis*. Foliage feeders such as *Spodoptera litura*, *Omiodes indicata* and loopers – mainly *Chrysodeixis chalcites* – are often targeted by farmers for insecticide sprays because they are large and conspicuous, but these insects rarely cause yield losses. Application of broad-spectrum insecticides that target this foliage-feeding complex may have a profound effect on indigenous biological control agents that may be keeping pod-borers and pod-sucking bugs under control in the absence of these chemicals.

There is an abundance of natural enemies in the soybean systems, which effectively regulate populations of most of the plant-feeding species. The parasitoid complex is particularly rich on some plant-feeding species (Shepard and Barrion, 1998). However, it is apparent from our pest and natural enemy surveys that some key pests are lacking an effective complement of parasites, predators and pathogens. For example, the pod-boring pyralid, *E. zinckenella*, has relatively low levels of parasitism. Only three parasitoid species (*Phanerotoma philippinensis*, *Baeognatha javana* and *Temelucha etiellae*) were frequently encountered (Shepard *et al.*, 1999). No pathogens were found in larval populations of *E. zinckenella*.

In other parts of the world, it has been shown that chemical insecticides can cause resurgence of several species of lepidopteran pests of soybean (Shepard *et al.*, 1977). In most cases, the rapid increase in pest populations was due to the destruction of natural enemies. Therefore, it is important to understand that application of chemical insecticides, whether targeting pod- and stemborers or foliage feeders, may cause non-pests to be elevated to primary pest status.

Farmer participatory research to test IPM strategies

Field studies were carried out with farmers to identify strategies for inclusion in IPM training programmes (Shepard *et al.*, 2001). Soybean is usually grown after rice (during the dry season). The following results were obtained from field studies.

- *Etiella* and *Helicoverpa* populations were higher in late-planted soybeans.
- In the late-planted soybean, applications of insecticides caused an increase in pest insect populations and a concurrent increase in damage by *Helicoverpa* and *Etiella*.
- Yields were lower in late-planted soybeans.
- Insecticides reduced populations of *Etiella* but also decreased numbers of several important insect predators, such as *Pardosa pseudoannulata*, *Paederus fuscipes* and ants.

Conclusions from these studies underline the importance of planting as early as possible to escape build-up of pod boring pests such as *Etiella* and *Helicoverpa*.

Little information is known about stem flies and their importance in soybean production. Results from our studies with this potential pest revealed the following:

- Yield reductions by the stem fly, *M. sojae*, could not be detected except when the stem was attacked below the hypocotyl, but there was little justification for insecticide treatments.

- Although chemical insecticide treatments were aimed at stem flies, these chemicals caused populations of *S. litura* to resurge, which adversely affected populations of major predators.
- No yield reductions were caused by *S. litura*. Therefore, it may be a beneficial insect providing food for natural enemies that attack more serious insect pests.

Any IPM strategy that is used in soybean, as with other crops, must involve farmers. Field exercises developed with and carried out by farmers will serve to illustrate the principles and practices of IPM. Of all the secondary food crops, soybean stands out as the one in which good agronomic practices are sadly lacking. Often, entomologists focus their research on methods for controlling pests without first understanding that 'growing a healthy crop' is often the most important constraint to production.

Secondly, devising field studies with farmers illustrated that foliage-feeding pests, such as loopers, *Omiodes* sp., geometrids, lymantriids and *S. litura*, rarely cause yield losses. Understanding the role of natural enemies in soybean also is key to the success of a sustainable IPM programme on soybean. Only then can strategies be devised to conserve those biological control agents that normally keep pests under control and which cost the farmer nothing.

Many data sets are available showing that farmers who plant their crops later than most farmers around them are most likely to be impacted by pod-feeders such as *E. zinckenella* and *Helicoverpa* (van den Berg *et al.*, 2000). Thus earlier, more synchronized planting among farmers could result in significant reduction in losses due to pod-boring insects.

Evaluation of the AWPM programme

About 1.5 million ha of soybeans are harvested annually in Indonesia. Government programmes that encourage planting and development of improved production systems will stimulate increased plantings in the future. Though we cannot estimate the economic impact of a specific IPM strategy for soybean, we can make some rough estimates of what impacts will be as strategies are developed.

Currently, over 10% of production costs are for pesticides and their application. According to Indonesia's Central Bureau of Statistics data, about Rp 46.5 billion (~ US$5 million as of September 2007) are spent annually on insect pest control on soybean. Most of these pest control expenditures occur in the major growing areas in Java and Sumatra where IPM programmes are concentrated.

Data from field surveys in East Java conducted in 1996 provide a frequency distribution of sprays, showing that farmers applied from zero to eight sprays through the season, with an average of 3.4 for the 100 farmers surveyed (van den Berg *et al.*, 1998). The majority (70%) of insecticidal sprays were applied during the first 45 days after planting, before pod-set, and aimed mainly at defoliators. Because these pests cause little if any yield reduction, it is clear that use of insecticidal sprays can be reduced without causing economic losses. Thus, IPM strategies that reduce the number of pesticide applications have immediate and direct pay-offs to farmers by reducing their costs of production and consequently increasing their profits. If IPM strategies enhance yields as well – which is likely as a result of the programme focus to 'grow a healthy crop', including attention to basic agronomy – then the benefit is increased.

Cabbage

Cabbage is planted to over 67,000 ha in Indonesia, second only to soybean among *palawija* crops, with a total of 1,417,000 t produced annually. This crop is produced mainly in the upland areas of Java, Sumatra and Sulawesi.

The major pest of cabbage in Indonesia is the cabbage head caterpillar (CHC), *Crocidolomia pavonana* (Sastrosiswojo and Setiawati, 1992). The diamondback moth (DBM), *Plutella xylostella*, is generally kept under good control by the parasitoid, *Diadegma semiclausum*, when chemical insecticides are avoided. *Hellula undalis* and the looper complex can be important locally but are not widespread problems.

Diadegma semiclausum was first introduced into Malaysia (Ooi, 1986), and later into Indonesia for DBM control. This parasitoid was later distributed to most of the major cabbage-growing areas (Sastrosiswojo, 1996). Even in areas where the parasitoid is firmly established, farmers do not recognize its importance in biological control of DBM, and routine applications of mixtures of chemical insecticides are still made. This action invariably causes resurgence of populations of DBM by reducing parasitoids and other important natural enemies that normally keep it under control.

Interestingly, one can ascertain the spray history of a cabbage field depending on the presence or absence of dense populations of DBM. High populations are usually indicative of heavy chemical sprays; the presence of high levels of CHC usually indicates few or no chemical sprays. This underscores the importance of considering CHC along with DBM in developing an effective IPM programme for cabbage (Sastrosiswojo and Setiawati, 1992). When chemical sprays for DBM are decreased or terminated altogether, CHC often cause heavy damage. Therefore, as Sastrosiswojo and Setiawati pointed out, the key to successful IPM in cabbage must include a strategy for dealing with CHC: indigenous natural enemies are not able to keep CHC in check.

Another major challenge for cabbage IPM is development of strategies that can help suppress the corn earworm (CEW), *Helicoverpa armigera* and *Hellula*. The latter mostly occurs in lowland cabbage. Although these pests are sporadic and localized, our extensive surveys throughout major vegetable-growing areas revealed heavy populations of CEW in central Java, south Sulawesi (Malino) and in east Java (Batu).

Farmer participatory research to test IPM strategies

Field tests were conducted to determine whether hand-picking egg masses and larval clusters of CHC, along with spot applications of *Bacillus thuringiensis* (*Bt*), was a practical approach for CHC control (Shepard and Schellhorn, 1997). Applications of *Bt* and concurrent elimination of chemical sprays would allow *D. semiclausum* and other natural enemies to operate fully against DBM and CHC.

Tests were carried out in Alahan Panjang, West Sumatra (April–July 1995) and in Jaringan Tani, Tanah Karo, near Berastagi, north Sumatra (May 2–July 28 1995). Treatments included: (i) collection of CHC egg masses and larval clusters up to

30 days after transplanting seedlings, then hand-picking plus spot spraying with *Bt* (after about 30 days, the egg masses are difficult to find); (ii) hand-picking throughout the season and spraying the entire plot with *Bt*; (iii) standard farmer practice; and (iv) untreated control.

Use of the second of these options resulted in over 90% of the cabbage heads being rated as marketable. The farmers' usual practice provided the highest yields (about the same as hand-picking and spot spraying), but eight *Bt* and chemical sprays were applied, as compared with only seven spot *Bt* treatments when egg masses and larval clusters were hand-picked. We concluded that results might have been better by applying *Bt* using a backpack sprayer rather than using the small, hand-held sprayer that we used for these studies. In the untreated control plots, nearly 40% of the heads were severely damaged by CHC and were considered unmarketable.

Results were more impressive in north Sumatra, where a backpack sprayer was used to apply spot sprays of *Bt*. This study, planned and executed with personnel from World Education, revealed that yields and marketability of cabbage were significantly lower in the untreated plots. However, the usual practice of farmers in the area called for weekly applications (12) of chemicals. Only seven spot sprays with *Bt* were required in the hand-picking/*Bt* spot spray treatment. Thus, the profitability of hand-picking eggs and larval clusters plus spot spraying with *Bt* may be a viable approach in areas where cabbage fields are small and not much time is required to search the field for egg masses and larval clusters. Considerable build-up of natural enemy communities of both DBM and CHC should result from this approach.

Shallot/Onion

Of all the vegetable crops in Indonesia, shallots are most heavily sprayed with chemical pesticides. In the large shallot-producing areas of Brebes, in central Java, it is common for farmers to apply chemical insecticides every other day. This has resulted in high levels of resistance in the target pest (*Spodoptera exigua*), and the only viable control tactic is hand-picking larvae from the plants.

The major pest of shallots during the dry season is *S. exigua*. During the rainy season, fungi are most important, notably *Alternaria*, *Colletotrichum* and *Peronospora destructor* (Meity Sinaga, personal communication). Weeding is normally carried out on an 'as needed' basis, most often simultaneously with hand-picking of *S. exigua* larvae. Aphids (*Neotoxoptera formosana*) can be locally important in the highlands, but we have not observed them in high numbers in most major production areas.

A heavy infestation of an agromyzid was found on shallots in Alahan Panjang, west Sumatra. This leaf-mining fly was first recognized as a pest in Indonesia in the mid-1990s (Shepard *et al.*, 1997), and is now widespread on the islands of Java, Sumatra, Bali and South Sulawesi. The fly was identified as *Liriomyza huidobrensis* (Blanchard). The extent to which these infestations affected yields has not been determined but, judging from the severity of infestations, yield losses were substantial. More recently, heavy infestations of another exotic leaf miner species, *L. chinensis,* were observed in Brebes, central Java in 2000.

In the Philippines, the most important soil-borne diseases are *Sclerotium cepivorum*, *Fusarium oxysporum* and *Phoma terrestris*, and the use of fungicides for control of these pathogens has been unsuccessful (Gapasin *et al.*, 2003). Anthracnose is one of the most important diseases of onions in the Philippines and, at present, the only effective means of control is through intensive fungicide applications. Purple nutsedge and horse purslane are the most important weed pests of onion (Miller *et al.*, 2005).

Farmer participatory research to test IPM strategies

Major outbreaks of *S. exigua* occurred in the Brebes (central Java) area, where chemical insecticides were often applied every other day. Heavy damage by *S. exigua* was also prevalent in west Sumatra (Alahan Panjang), Batu (east Java), Probolinggo (east Java), Cisantana and Pangalengan (west Java). The microbial control agent, a nucleopolyhedrovirus (SeNPV), was discovered in populations of *S. exigua* in Cimacan, in the Puncak, west Java, through routine field surveys of shallots (Hammig and Rauf, 1998).

A result from preliminary tests in the Puncak revealed that damage to leaf onion (*bawang daun*) was significantly lower when the SeNPV was applied in farmers' fields. We then tested the virus in the Brebes area in collaboration with Pak Karsum, a shallot farmer in Ciledug, central Java. Results were so impressive that Karsum asked for the SeNPV from our laboratories at Bogor. We worked with him closely to develop production techniques, and soon after he was able to mass-produce the material and carried out tests in his own fields. A unique feature of the biological control system is that the microbe is easily mass-produced because of a ready supply of *S. exigua* larvae that are collected daily by women, an activity that is carried out as part of an effort, along with chemical insecticides, to control the pest.

Field applications of the SeNPV against *S. exigua* by Karsum have been highly successful. Because of these tests, he changed his pest control strategy to SeNPV, instead of chemical insecticides, for control of *S. exigua*. He has now shared this technology with farmers from six other villages. The FAO Action Research Facility in Brebes also worked closely with other farmers in the area to help them understand how the microbial agent works and how to best use it in a programme that helps restore other natural enemiesfor long-term stability of the system.

We carried out field tests using randomized, replicated plots at farmer-level production and application techniques in Ciledug using a crude preparation of the SeNPV. Six experiments (three pairs) were carried out from 5 July until September 1996, to assess the SeNPV's potential at different *S. exigua* population levels.

Yields were compared from the six treatments: (i) SeNPV plus hand-picking of larvae; (ii) chemical insecticide plus hand-picking; (iii) SeNPV alone; (iv) hand-picking of larvae alone; (v) insecticides alone; and (vi) untreated controls. Yields from these plots are shown in Fig. 17.3. Clearly, SeNPV and SeNPV plus hand-picking of larvae, provided the best control methods for *S. exigua*.

During the late-season planting, with heavy pressure from *S. exigua*, yields from the untreated control plots were nearly zero. Plots using hand-picking alone significantly improved yields, but highest yields were obtained when SeNPV was carried out along with hand-picking. The SeNPV treatment alone was as good as insecticides

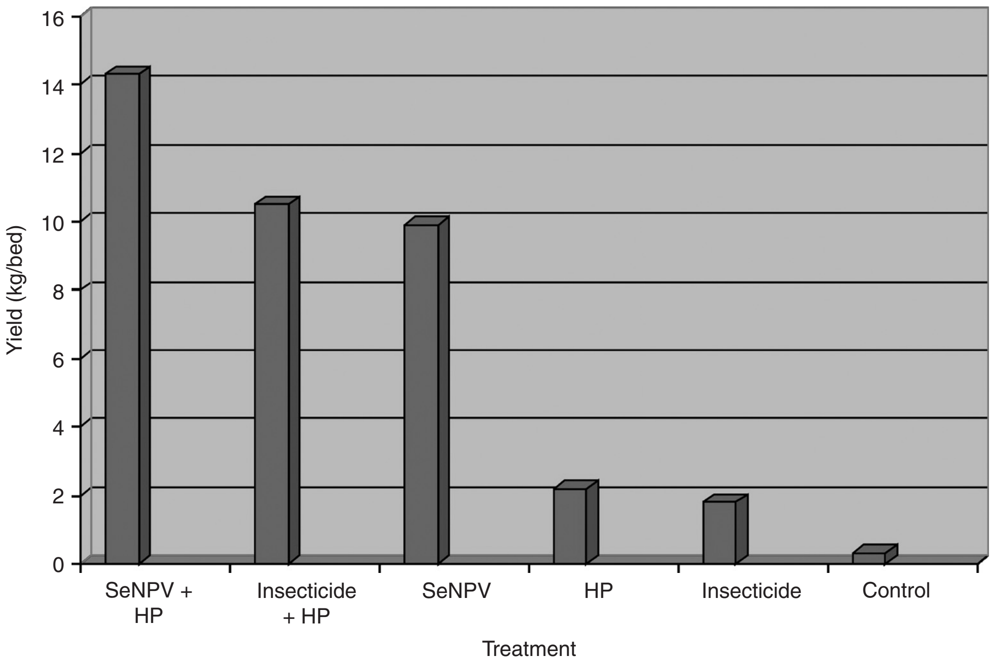

Fig. 17.3. Yields of shallots treated with combinations of SeNPV, insecticides and hand-picking, Ciledug, West Java, September 1996.

plus hand-picking, which was common farmer practice before the IPM system was introduced.

A programme for farmer production and use of SeNPV has been developed and is being carried out in Alahan Panjang, west Sumatra (Zamzami and Djoni, personal communication). Our project supplied the inoculum and training for the West Sumatra Plant Protection Agency staff from laboratories at Padang and Bukittinggi. They, in turn, have trained 150 shallot farmers. These farmers are currently testing the SeNPV in their own fields. A farmer field seminar for biological control was conducted in Alahan Panjang to bring together farmers, trainers and researchers from all of the major shallot-growing areas of Indonesia, to share experiences and design plans for expanding the understanding and use of SeNPV. Over 10,000 farmers currently use the SeNPV as part of their control programme on shallots in West Sumatra (Zamzami, personal communication).

In summary, the use of SeNPV has excellent potential for providing long-term control of S. exigua, while stabilizing the shallot ecosystem by allowing natural enemies to recolonize the areas. Farmer training in IPM is the key to the success of the programme.

The fundamental comparison of common farmer practice with the IPM alternative, based on the use of SeNPV virus, is shown in Table 17.1. The data were obtained from field studies conducted in the Ciledug subdistrict of Cirebon District, central Java. This area is typical of the major shallot-growing area of Indonesia that

Table 17.1. Comparison of common farmer insect control practice with IPM system for shallots in Java, per hectare, autumn 1996.

Activity	Common practice	IPM
Insect control sprays (n)	21	14
Hand-picking (n)	49	12
Cost of insecticide (US$)	647	0
Cost of virus (US$)	0	4.30
Spray application labour (US$)	452	302
Hand-picking labour (US$)	528	130
Yield (t)	9.38	15.71
Price/t[a] (US$)	172	280
Net benefit of IPM[b] (US$)	0	3976

[a] The price/t used here is the price quoted for the farm level, based on quality, as of November 1996.

[b] The net benefit of IPM is calculated by summing the cost differences between IPM and common practice and the difference in total return based on yields and price premiums.

includes Tegal and Brebes districts, as well as Cirebon. The irrigated production system used is also common in Probolinggo, east Java; another important shallot area. In combination, these areas account for about one-third of all shallot production in Indonesia.

The use of fungicides is largely unsuccessful for the control of soil-borne pathogens of onions. However, *Trichoderma* spp. are know for their antagonistic effects against these fungal pathogens. In the Philippines, *Trichoderma* isolates were as effective as chemical fungicides in reducing the incidence of these soil-borne diseases. VAM (vesicular arbuscular mycorrhizae) has been found to be an economically and environmentally friendly supplement that can help reduce fertilizer input and assists onion plants in tolerating infection from soil-borne pathogens and nematodes (Gergon *et al.*, 2003). For control of anthracnose, the combination of cultural and chemical control reduced the number of fungicide applications (Alberto *et al.*, 2003).

For weed control, IPM CRSP in farm studies showed that one application of the correct herbicide followed by timely hand-weeding controlled weeds as well as the farmer practice of two herbicide treatments followed by three hand weedings. Weed control costs were reduced by 15–70% without reducing weed control efficacy. Another weed management technique, rice straw mulching, was shown to be effective in on-farm studies. Weed growth was reduced by 60%, yields were increased by 70% and weed control costs reduced by 50% (Miller *et al.*, 2005).

Evaluation of the AWPM programme

The IPM system, based on the use of the SeNPV virus together with hand-picking, provides a dramatic opportunity for economic benefits to farmers. Insecticide costs are eliminated and hand-picking requirements are reduced. These factors alone imply that production costs can be reduced by US$1100/ha. In addition to these cost savings, evidence from field studies implies that crops produced under the IPM system have higher yields and improved quality over the common farmer practice. The combination of the yield boost and the price premium paid for high-quality product results in an additional US$2800/ha gain from IPM. Thus, the net benefit is about US$4000/ha.

These data showing the economic benefits from the IPM system in shallots were obtained during the dry season, when insect pests are the major problem for shallot growers. In the regions where the irrigated production system is found, shallots are considered primarily a *palawija* crop and rice is planted during the wet season. Therefore, these very dramatic economic benefits of IPM will be realized on the majority of the shallot crops produced in these key production areas. In addition, health benefits from development of IPM should be substantial (Kishi *et al.*, 1995).

A study was conducted, in 1998, comparing farmers using SeNPV with conventional growers. The results of this study show that many farmers have adopted SeNPV as a viable option for insect control in shallots, and that those farmers realize a significantly higher profit margin compared with farmers who still rely on chemical pesticides. These results show actual farmer practice, rather than experimental results. The difference using the SeNPV was > US$700/ha. Details of the 1998 study are given in Table 17.2.

Chilli

This crop is by far the most important of all the vegetable crops in Indonesia, with production of nearly 900,000 t in 2005 (FAO, 2007). However, development of a sound IPM programme for chillies is the most challenging. Numerous pests, including insects, mites and plant pathogens (Vos and Frinking, 1998) attack the crop. In addition, inappropriate agronomic practices are often major constraints to achieving maximum production. For example, farmers often plant in low, wet areas, thus hindering healthy growth due to poor soil drainage.

Major arthropod pests include mites (*Polyphagotarsonemus latus*) and *Helicoverpa armigera* (CEW). Thrips and aphids may be important locally as vectors of plant viruses. Occasionally, *S. litura* causes farmers to spray insecticides, but this insect feeds mostly on leaves and probably causes little damage in most cases. CEW, on the other hand, selectively feeds on the pods. The gall fly, *Asphondylia* sp., can cause significant pod loss but the impact of this pest, as with CEW, is highly variable between seasons and locations. Recent information from west Sumatra suggests that parasite levels build up during the season and only early-season fruits are affected. The fruit fly, *Bactrocera* (= *Dacus*) *dorsalis* seems to be ubiquitous, but the incidence of pod attack is usually not high in the major chilli-growing areas of Indonesia. More details of the agronomic factors and pests of chillies on Java were reported by Vos (1994). *Colletotrichum, Phytophthora, Alternaria, Cercospora* and

Table 17.2. Comparison of shallot growers who use the microbial agent (SeNPV) to control insect pests with growers who follow conventional chemical-based practice, Cirebon, west Java and Brebes, central Java, September 1998.

Item	SeNPV users (n = 17)	Conventional growers (n = 52)
Area and yield		
Area harvested (m^2)	1847.1**	1473.1
Yield (kg/1000 m^2)	678.4	597.0
Pest control		
Pesticide applications/season	11.9***	17.4
SeNPV applications/week	2.4	0
Production costs (US$/1000 m^2)		
Land rent	6.10	6.75
Irrigation fee	0.42	0.33
Total fertilizer cost	10.27	12.26
Insecticide	2.05***	9.88
Fungicide	3.43***	7.27
Herbicide	0.50***	0.97
Seed	115.00**	88.82
Labour costs (US$/1000 m^2)		
Land preparation	11.58	10.68
Planting	0.66	0.70
Cultivation	1.82	1.61
Hand-picking	6.90	5.87
Pesticide application	4.23***	7.68
Fertilizer application	1.35***	2.03
Watering	10.88	10.94
Weeding	2.61	3.33
Irrigation maintenance	1.54	1.53
Other costs	1.06	0.83
Harvesting		
Transportation	1.02	0.75
Security	3.47	2.05
Tying labour and materials	0.37	0.40
Returns		
Price received (US$/kg)	0.62	0.57
Gross return (US$/1000 m^2)	393.48**	309.26
Profit (US$/1000 m^2)	205.80*	134.58

*significantly different at 90% confidence, **significantly different at 95% confidence, ***significantly different at 99% confidence.

Pseudomonas – and viruses – are usually among the most important groups of pathogens.

Farmer participatory research to test IPM strategies

Field tests conducted in western Sumatra demonstrated that seedbed height and control of soil pH with lime were effective in reducing the incidence of bacterial wilt. Insecticide sprays were not effective in increasing yields. This study was carried out in an area where CEW was not an important pest. In other areas, the use of HaNPV (*Helicoverpa armigera nucleopolyhedrovirus*) might be a viable tactic for replacing chemical pesticides. Virus diseases that are prevalent in many parts of South-east Asia may be managed using resistant varieties currently under development at the Asian Vegetable Research and Development Center in Taiwan.

Yardlong Bean

Also known as the snake, asparagus or Chinese long bean, and second only to chilli in terms of area planted among vegetables, yardlong beans are an important part of the Indonesian diet. Major insect pests are the pod borer, *Maruca vitrata* (= *testulalis*) and aphids (usually *Aphis craccivora*). The extent to which *M. vitrata* causes economic losses is not understood, and varies widely according to location and market supply and demand. *Maruca vitrata* damaged an average of only about 3 cm along the length of maturing pods, but caused much more severe damage in younger ones. Economic losses from *M. vitrata* damage in yardlong beans in west Sumatra were estimated at about 25% (Zamzami, personal communication). Aphids are important both as direct feeders on blooms and pods, and also as virus vectors. Sucking bugs are usually present in the crop, but their importance may be overemphasized. *Ophiomyia phaseoli* also can cause yield reductions locally.

Farmer participatory research to test IPM strategies

A field study, carried out by the Clemson Palawija IPM Project, FAO and the Provincial Plant Protection laboratory in Padang, west Sumatra, compared: (i) farmers' usual practice; (ii) no treatment but with good cultural practices; and (iii) designated 'action windows' that we 'generated' for aphids (over 100 per hill), pod borer (over 10% of pods damaged), anthracnose (over 10% infected leaves) and leaf spot (over 10% infected leaves).

Yields from the farmers' practice treatment and the IPM 'action windows' treatment were about the same, although the farmers' treatment called for eight sprays as compared with 2 in the IPM treatment. The major difference was in the 'untreated' control, where *O. phaseoli* and aphids seriously reduced yields.

Another field study carried out with personnel from the University of Lampung revealed that late-planted yardlong beans were more severely attacked by CEW than those planted early. This difference was not as obvious for *M. vitrata*. In tests at the Muara field station in Bogor, mosaic virus reduced the plant population by 50%. IPM strategies must include tactics for dealing with aphid-borne viruses. Untreated longbean plots near Ciloto resulted in over 50% losses due to direct feeding by the aphid, *A. craccivora*. Recent results indicate that 'spot' treatments versus treatment of the entire plot with aphicides may conserve natural enemies, but this approach requires that the crop be monitored at least twice weekly.

Aubergine

The major insect pest of aubergine is the fruit and shoot borer, *Leucinodes orbonalis* (EFSB). In some areas, this insect is the limiting factor to aubergine production. Farmers may apply insecticides 50 times or more in a single growing season (Miller *et al.*, 2005). In spite of frequent pesticide applications, yields are reduced by more than one-third due to this pest. Also, leafhoppers also may be important locally. Of the plant diseases, bacterial wilt is most common. Losses to bacterial wilt in central Luzon consistently reached 30–80%.

Farmer participatory research to test IPM strategies

Data from on-farm research in the Philippines showed that simply removing damaged fruits and shoots reduced infestations by EFSB and, if carried out at harvest time, labour costs were reduced. This resulted in a net incremental benefit of US$2500/ha when conducted weekly, and of US$1000/ha for biweekly removal (Miller *et al.*, 2005). The second approach is the identification of aubergine resistant varieties.

Bacterial wilt-susceptible aubergine grafted on to resistant rootstock (EG 203) increased resistance to the disease by 30% and yields were higher. The stale seedbed technique, which includes sequential harrowing or harrowing followed by a non-selective herbicide at biweekly intervals carried out during the fallow period between the rice and onion crops, was effective in reducing purple nutsedge tuber populations by 80–90% (Miller *et al.*, 2005).

Tomato

Diseases such as early and late blight, powdery mildew, bacterial wilt, *Alternaria* and viruses are the major constraints to tomato production. Insects that vector viruses include thrips, aphids and whiteflies. CEW and, sometimes, *S. litura* often feed directly on the fruit.

Farmer participatory research to test IPM strategies

In some parts of Indonesia staking of tomatoes is not a common cultural practice, and incidence of fungal diseases is high due to contact of plants with soil. Field tests in farmers' fields have demonstrated that staking decreases disease incidence and increases yield. Many farmers in some areas have readily accepted this cultural practice.

In the Philippines, tomato plants do not survive well under the constant high-moisture conditions during the rainy season. Farmer participatory field tests have shown that grafting tomato on to resistant aubergine rootstock greatly increases survival and crop yields.

Citrus

Surveys were carried out in a large citrus-growing area in the Karo District of north Sumatra. Heavy infestations of fruit flies (20% of the fruit was infested) were observed. The fruit fly was identified as the papaya fruit fly, *Bactrocera papayae*. All growers in the area were reporting high levels of fruit loss from this pest. In addition to fruit flies, we observed lepidopteran larvae, *Citripestis sagittiferella*, in about 3% of the fruit.

Farmer participatory research to test IPM strategies

A fruit fly management plan must include participation by all the citrus growers in the area. Due to the intensity of citrus growing in the region, the only effective strategy would be an areawide approach. Without participation by all farmers, reinfestations of fruit flies would continue to occur in IPM-managed areas. Tactics to be included in this management plan should include sanitation activities, spot spraying of protein bait, traps to monitor adult fruit fly populations and early harvesting of fruit.

Field research and demonstration projects for most of the crops listed above have shown that substantial reductions of pesticide applications are possible without jeopardizing yields. Table 17.3 summarizes results from field tests conducted in the mid-1990s in west Java, central Java and Sumatra, applying IPM principles with specific recommendations for each crop, and with broad applicability throughout the country. Given the potential reductions in pesticide applications, shown in Fig. 17.4, associated environmental and human health benefits justify a policy commitment to expand IPM training to areas where these crops are concentrated.

Some of the IPM tactics that could have a major impact if adopted on a wide area are listed in Table 17.3. One constraint is that information about tactics found useful in one area is often not transferred to another. A mechanism to transfer information from one area to another would greatly expedite adoption on a wider scale. The IT component of the IPM CRSP will be helpful in this regard. We have found that workshops that allow participants from different countries, and regions within

Table 17.3. IPM tactics[a] that could have major impacts if adopted areawide in South-east Asia.

Crop	Tactics
Tomato	Varieties resistant to viruses and fungi
	Staking (with appropriate variety)
	Pruning
	Grafting
Chilli	Resistance to viruses
Aubergine	Straw mulch
	Grafting
	Host plant resistance to nematodes
	Bt-transgenic plants
	Monitoring EFSB with pheromones for timing treatments
Shallot	Microbial control of *Spodoptera exigua* with SeNPV
Onion	VAM and *Trichoderma*
	Straw mulch
	Pheromone traps for timing interventions (*Spodoptera litura*)
	SlNPV (insect virus of *S. litura*)
Cabbage	Field scouting for *Crocidolomia*
	Microbial control/spot spraying
	Hand-picking egg masses/larval clusters
	(also conserves natural enemies for DBM)
Soybean	Early planting in the dry season
	(to avoid pod borers/*Etiella and Helicoverpa*)
	Avoiding needless sprays for defoliators
Yardlong bean	Spot treatments for aphids (for papaya fruit fly control)
Citrus	Sanitation (removal/destruction of infected fruit)
	Protein bait sprays
	Traps to monitor population
	Early harvest
All vegetable crops	Weed control using stale seedbed technique

[a] The tactics listed here are not all-inclusive.

countries, to come together and exchange information may be one way of exchanging information among researchers. At another level, participatory field studies with farmers will be the most appropriate way to determine whether the various tactics are applicable for specific locations and socio-economic settings.

Socio-economic and Environmental Impacts of IPM

The impact on crop yields of IPM systems that reduce use of chemical inputs is positive in most cases, translating into higher gross economic returns. Evidence from field

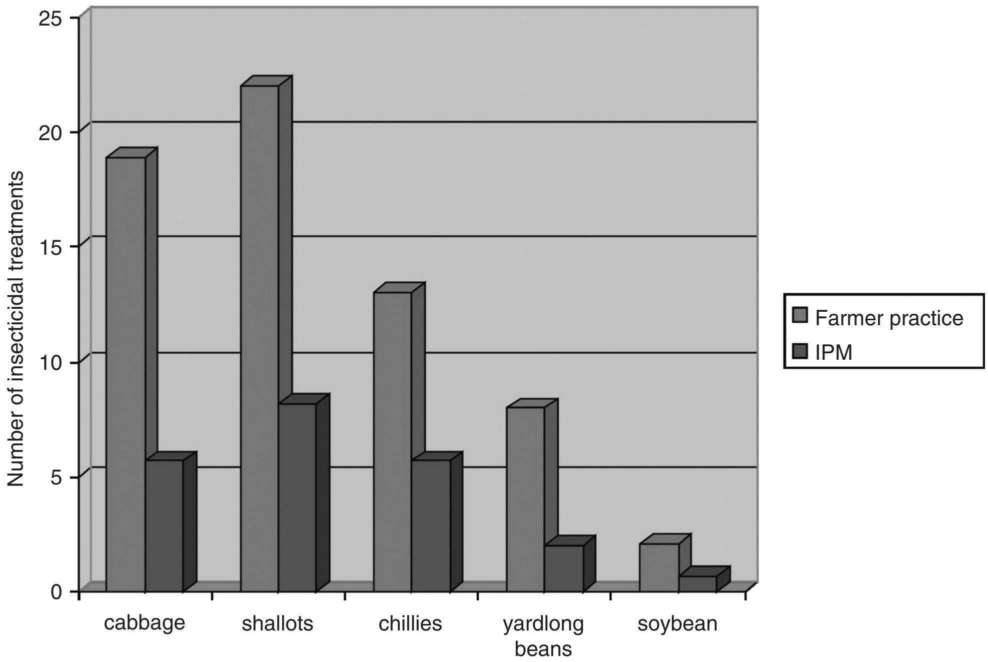

Fig. 17.4. Numbers of pesticide applications per crop per season made by vegetable farmers using their normal practice as compared with IPM practices.

sites where farmer groups use the IPM approach shows that costs of inputs decrease because of dramatically reduced outlays for pesticides. Thus, IPM farmers may enjoy higher profits than their traditional counterparts (Hammig *et al.*, 1997). Much of the economic evidence is anecdotal, but results from Indonesia consistently show improved returns by IPM farmers. A report by van den Berg (2004) synthesized 25 IPM impact evaluations. Although most of the examples featured rice, they also included vegetables. The conclusion was that farmers who had participated in FFSs reported substantial and consistent reductions in pesticides attributable to the effects of the IPM training. Further, more pesticide reductions and higher farm-level revenues were realized in vegetables than with rice.

Clearly, the anticipated economic bottom line is a key determinant of farmers' adoption of alternative production practices. Therefore it is important that analysts address long-term adoption patterns and the persistence of the benefits of IPM training. A survey of west Java vegetable farmers, some with IPM training and others without, showed that the former employed more sustainable farming practices as compared with the latter, even years after the training had occurred (Norvell and Hammig, 1999).

The IPM training routine includes comparisons of fields employing IPM and traditional farmer practice. These comparisons are not just of what is happening to pests and crop yields, but also of the impact on market returns. Farmer groups keep careful accounts of their expenses, and the comparison of IPM and non-IPM results is the focus of group discussions during the training process. There is no doubt that areawide adoption of IPM is contingent on positive results in the marketplace. If adequate returns are not assured, then the traditional practice will dominate, even after training. Fortunately, sound application of IPM principles invariably results in better bottom lines for farmers.

There are greater benefits from IPM than simply those offered by higher market returns. Farmers relying on chemical pesticides pose a significant danger to themselves, their families and their neighbours, not to mention the environment of rural areas. Sustainable IPM systems reduce human health and ecological risks by reducing the volumes of many of the most toxic chemicals applied to crops. In a study from Vietnam, Murphy (2002) showed the correlation between frequency of pesticide applications and farmer illness. Kishi *et al.* (1995) found that IPM-trained farmers in Indonesia apply fewer pesticide applications to their crops and, when they do apply pesticides, they use less toxic chemicals than comparable farmers who have not participated in IPM training.

Impacts beyond the farm gate are meaningful components of comprehensive impact assessments. The highland vegetable areas of Indonesia, in almost all cases, are situated upstream from major population centres. USAID/Jakarta has recognized the critical importance of upland water catchment areas and agricultural practices on urban water systems and has funded an Environmental Services Project (ESP) that, in cooperation with the Government of Indonesia, is mounting a comprehensive effort to improve water quality in selected urban centres through improved land and agricultural management.

IPM programmes are integral components of the ESP effort. Examples of this linkage include IPM training in west Java focused in the watershed feeding Jakarta and surrounding communities. Jakarta's fresh vegetable markets are served from the mountainous region immediately to the south of the city. Local governments, Bogor Agricultural University and international collaborators have been working with farmers in that region to reduce the runoff of harmful chemicals through IPM training for selected vegetable crops. Evidence from Shepard *et al.* (2001) shows the potential. Unfortunately, meaningful changes are constrained by the relatively slow process of farmer education. Local government budgets for IPM training are limited, so reaching large numbers is a slow process (Hammig *et al.*, 2006). Similar programmes are in development in watershed areas in central Java (Progo River) and east Java (the Malang vegetable area and the Brantas River).

In north Sumatra, the headwaters of the Deli River that provide water to Medan, the provincial capital, are another area of concentrated vegetable production. The *Lembah Gulen* (vegetable valley) at the foot of Sibayak volcano is a relatively small area composed of two villages, where the population is almost entirely dependent on vegetable production for its livelihood. Traditional production systems are similar to those observed elsewhere. Tomatoes, cabbage, shallots, chillies and other vegetables are grown in continuous rotations.

Prior to the ESP project, production systems were chemical-intensive, and farmers were frustrated by poor response to their control efforts. IPM training was first introduced in 2006, and farmers are now eagerly adopting different approaches (Hammig *et al.*, 2006). At the time of this writing, budget cuts to the ESP have reduced resources available for IPM in *Lembah Gulen*; however, farmers themselves are carrying on the programme with some continuing support from the NGO, Farmer Initiatives for Ecological Literacy and Democracy (FIELD) (Weinarto, personal communication).

In north Sulawesi, the Lake Tondano watershed provides another example of the link between upland vegetable production systems and urban centres. The lake is located in a mountain valley, and the Tondano River flows from the lake to Manado, another provincial capital. It drains into the Molucca Sea at Bunakan, an Indonesian National Marine Park. The mountain slopes surrounding Lake Tondano are covered by vegetable fields, with the usual mix of crops growing all year round.

An earlier USAID/Jakarta watershed management project, focused on environmental stewardship by local communities, spearheaded an effort to motivate local groups to seek better ways of improving the conditions of their environment. IPM training formed a part of this effort and, with assistance from scientists at Sam Ratulangi University, training programmes were initiated for onion, cabbage and tomato growers in the area in 1997 (Sembel,1998). Vegetable IPM continues to be a high-priority activity for farmers and university scientists working in the area.

Once farmers experience training for one of the selected crops, they recognize the need for training on the other crops they plant as well. This presents a challenge to IPM farmers and IPM trainers. Each crop has different pest management problems, and proposed alternatives for one crop may not be applicable to another. Therefore, the key to obtaining significant widespread impact is to establish a continuous process of field monitoring, research and experimentation, with the farmer as the central figure. Farmers can be introduced to IPM principles through training, and they can access technical support in critical times of need, but the greatest impact occurs when farmers themselves perform their own experiments, and learn with experience how an ecological balance can be maintained in their fields while they continue to obtain positive economic returns.

Gender roles are important in determining socio-economic impacts of IPM. In South-east Asia, gender roles in agriculture vary from region to region. In some areas, field work activities are differentiated by gender. For example, planting, weeding, harvesting and/or pest management tasks such as spraying or hand-picking of pests may be jobs for which gender is the first order of selection. In the shallot fields of central Java, the traditional pest control practice is for women to hand-pick egg masses from the plants at the same time that men apply chemical sprays. Within the household, women are responsible for child rearing and common household tasks. Men do most of the heavy lifting, but by no means all.

Data from the Philippines indicate that, in Nueva Ecija province, women manage the household and farm budgets in the overwhelming majority of cases (Hamilton *et al.*, 2005). Therefore, IPM training, if it is to be effective, must be sensitive to gender roles in the production and management of the crops. Decision making is the essential foundation of IPM, so it is essential that the key decision makers be informed of the ramifications of their choices. In the South-east Asia context, trainers include both men and women, and they are sensitive to the need to ensure that there is no gender bias in selection of training groups. However, recognizing the need does not mean that overcoming obstacles to attaining the ideal gender mix in IPM training is easily done.

Tanzo (2006) highlights some of the key gender-related issues she has observed for IPM training in the Philippines. Domestic tasks overlap with field activities. In the field, women are frequently found weeding, handling pesticides and hand-picking pests. Household tasks include clothes washing, food preparation and family health care. Women are more involved in vegetable pest management than with rice because of their frequent roles in field monitoring and hand-picking. They are exposed to pesticides both in the field and while washing pesticide-soaked clothing. Daily schedules often conflict with IPM training programmes, so few women, relative to their importance in the decision making process, take advantage if IPM training opportunities.

Impacts of AWPM efforts in Indonesia, implemented over the nearly 20-year history of IPM training, have yielded important benefits to farmers, the environment and consumers of farm products. Evidence of these benefits is apparent from many studies addressing a range of issues. However, in Indonesia and other countries in South-east Asia with similar demographics, where over 40% of the population is involved in production agriculture, the process of spreading the IPM message is slow. The best sign suggesting that there is significant momentum within the IPM paradigm comes from farmers who have embraced IPM and who are the primary motivators for engaging their peers.

Conclusions

Areawide pest management (AWPM) in South-east Asia is addressed through massive training of farmers in the region in the principles of integrated pest management. South-east Asia is characterized by large numbers of farmers operating on small plots. Production systems involve substantial amounts of labour input, which often puts farm labourers at risk from exposure to harmful chemicals. Mechanical devices that replace labour in western agriculture are rare in the South-east Asia region. Technological advances have made an impact, mainly through improved plant varieties and cultural practices to enhance yields. IPM programmes in the region seek to reduce the harm caused by some of these practices that have become entrenched because of misguided national programmes that disregarded local peculiarities. IPM training has taken hold throughout the region as a means of establishing the farmer as the primary decision maker and to equip him or her with an understanding of the critical relationship between agricultural output and field ecology. Training programmes in all South-east Asian countries are aggressively spreading the message to 'grow a healthy crop'.

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