Thailand DoAE - FAO Vegetable IPM
Regional Training on Biological Control

(9-20 July 2007, Khon Kaen, Thailand)

Department of Agricultural Extension (Thailand)

FAO Inter-country Programme for IPM in Vegetables in South and Southeast Asia

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Report compiled by:

Areepan Upanisakorn, Damien Cupitt, Lim Guan Soon &Tattanakorn Moekchantuk

Executive Summary

The Regional Training on Biological Control (RTBC), co-organized by Thailand DoAE and the FAO Vegetable IPM Programme, was held in Khon Kaen from 9-20 July 2007. Twenty six participants from nine countries (Bangladesh, Cambodia, China, Indonesia, Lao PDR, Nepal, Philippines, Thailand and Vietnam) participated.

The activities included (i) country presentations, (ii) classroom lectures and laboratory/field practical training by resource persons, (iii) panel discussions by different stakeholders (farmer, extension and research agencies, and the commercial sector), (iv) field visits to observe on-going farm level application of biological control (BC), (v) interviewing farmers on their BC perceptions and practices, and (vi) developing training session guides and BC project proposals for follow-up by country participants.

For classroom lectures and laboratory practical training by resource persons, electronic/hard copies of the presentations and supplementary materials were provided to participants. In the case of field visits, these involved excursions to successful commercial GAP/Safe Vegetable farm and to Mitr Phol Sugar Company. The practical exercises at Khon Kaen Pest Management Center and National Biological Control Research Center focused on production techniques for predatory bugs, parasitoids and microbial agents that are being produced and distributed to farmers. Participants were given the production protocols of these biological control agents (BCA) and had ample opportunity with hands-on practise of these techniques.

In general, the RTBC has enabled participants to:

- *Gain in-depth knowledge of BC principles, approaches and the potentials*
- *Enhance their capacity to identify, mass produce and utilize different BCA (microbials, parasitoids and predators), including how to monitor and evaluate their field performance*
- *Appropriately harness suitable BCA to build robust IPM programmes*
- *Develop training modules and session guides to train farmers on BC in Farmer Field School (FFS)*
- *Develop BC project proposals for possible funding support*
- *Establish networking among participants, including resource persons, in the area of BC.*

Evaluation by participants of the RTBC at the end of the training indicated that the course was well organized, highly informative and successful. Participants not only have learnt a lot about BC but have also enjoyed and made many useful contacts for future consultation and collaboration in BC.

1. Background

Integrated pest management (IPM) is an approach that uses a combination of techniques to effectively suppress pests in an economically and environmentally sound manner. It is a decision-making process that requires farmers to identify and monitor pest populations and then use the information obtained to decide the timing of treatments (that integrate a variety of control tactics), and finally evaluating the results.

An important element of a robust IPM strategy is making optimal use of biological control (BC), which is the use of natural enemies to regulate pest populations to a level where they do not cause economic yield loss. The need for more use of BC is now well recognized at national and international levels. However, in many countries the technical knowledge and skills for the production and sustainable utilization of BC options are still inadequate to warrant its widespread adoption. A need has been identified by representatives of member countries participating in the FAO Regional Vegetable IPM Programme (hereafter referred to as FAO Vegetable IPM) to review the principles and concepts of BC, mass production of biological control agents (BCA) and their utilization in field pest management, and to develop regional BC collaborations among the participating countries.

To address the above concerns, a “Regional Training on Biological Control” (or RTBC), was jointly organized by the Biological Control Group, Pest Management Division, DoAE-Thailand and FAO Vegetable IPM to provide training in BC for participants from member countries of the FAO Vegetable IPM. The primary goal is to inform participants on what BC options are feasible, equip them with the tools and know-how to mass produce BCA, and to enable participants to develop national BC strategies that are both functional and sustainable within an IPM programme implementable by farmers. The specific objectives of the training are:

- To learn the concepts and principles of BC and how they can be utilized to build robust IPM strategies;
- To exchange experiences and knowledge on in-country BC programmes with other participating countries;
- To be able to identify potential BCA for production and learn how to mass produce and apply them, and in the case of arthropod parasitoids/predators, how to also monitor and evaluate their effectiveness in the field;
- To enhance capability of IPM facilitators in seeking out relevant BCA to manage important insect pests and diseases they presently encounter; and
- To develop simple training modules, curriculum, session guides, reference materials, and methodologies to train farmers on BC in Farmer Field School (FFS) and other post-FFS activities.

In the conduct of the RTBC, the active interactions of participants would be given priority. Emphasis will be given to discussions, hands-on workshops and practicum, and study visits to both public and private sector-led BC initiatives. These will be supported by lectures to provide the needed technical background information that participants need to know.

On completion of the training workshop, the envisaged outcomes are that all the participants would:

- Master the concepts and principles of BC.
- Be able to determine suitable strategies for the development, production and utilization of BCA that farmers themselves can be involved.
- Understand the importance and roles of support institutions (public, private sectors and producers’ organizations) with respect to the development of BCA products, including the education of farmers and extension workers, product quality control, certification and marketing.
- Become familiar with the available technical resources, including establishing a network of national and regional contacts of BC expertise.

- Become aware of the International Standards for Phytosanitary Measure (ISPM)/Code of Conduct for the import and release of BCA.
- Be able to plan towards strengthening, expanding and development of BC projects in their home countries.

Annex 1 provides more details on the background, programme structure, participants, resource persons and the organizational arrangements of the RTBC.

2. Opening Ceremony

The local representative, Mr. Sangar Faijaroenmongkol (Director, Khon Kaen Pest Management Center), extended a brief welcome to all in attendance. This was followed by the introductory remarks from Ms. Lawan Jeerapong (Director, Pest Management Division, DoAE) who explained the rationale of the RTBC. Mr. Preecha Somboonprasert (Director, Bureau of Agricultural Product Quality Development, DoAE,) then gave the opening speech on behalf of the Director General of DoAE and declared open the RTBC. Following this, Mr. Jan Willem Ketelaar (CTA, FAO Vegetable IPM) gave an opening remark urging all to share their experiences and to learn from one another during the RTBC.

The full texts of the above opening speeches are as given in *Annex 2*.

3. Introduction and Expectations by Participants:

At the outset, following the opening ceremony, Ms. Tattanakorn Moekchantuk facilitated the introduction of the participants and Ms. Areepan Upanisakorn explained to them the background, objectives and envisaged programme activities of the RTBC.

In order to know what the participants would be expecting from the RTBC, a participatory session was carried out to obtain their feedback with the aim to use the information to improve and shape the *modus operandi* in the conduct of the RTBC as it progressed. Among others, the major expectations of the participants, both individually and as a group, were as follows:

Individual expectations:

- To learn new BC/IPM information to implement them with farmers
- To help one another to develop session guides and country specific programme on BC/IPM
- To exchange experiences and techniques in BC
- To participate actively and be innovative during sessions of the RTBC
- To develop networking with fellow participants and other resource persons concerning BC/IPM

Expectations as a group:

- More focus on practical work than lecture style learning
- Learning atmosphere having lots of knowledge sharing, active participation in a relax manner, full of fun and joyful
- Whatever homework to be done would be balanced and not excessive
- Clear communication and understanding among all involved

- All group members exhibiting earnestness to learn, are productive and amicable when participating in discussions

4. Country Presentations

Each participating country presented and shared the experiences of the national initiatives in BC, including an initial needs assessment for strengthening on-going and to-be-developed BC programmes within the context of vegetable IPM. The main aspects of coverage included the national agricultural system (geography, topography, ecosystems and crops), major pests and the management methods, background to IPM and BC efforts, and the challenges to BCA production and utilization. The following are summaries for each of these country presentations.

4.1 Bangladesh

Bangladesh has made significant progress in popularizing IPM at the farm level since the country became a formal member of the FAO Inter-country IPM Programme in 1981. Insect pests of rice have received much of the attention during this time while pest management in vegetables have been considered more difficult due to the greater complexity of pests, large number of vegetable crops and inavailability of appropriate IPM technologies.

In spite of farmers facing many constraints in vegetable production, the cultivated areas of vegetables and their production have continued to increase. However, this has been made possible by the indiscriminate and overuse of chemical pesticides, and to a lesser extent, also the inputs of chemical fertilizers.

For commercial eggplant production, the chemical pesticide inputs are particularly high during the summer season. In many cases, daily applications are made in order to produce marketable fruits. With the overuse, coupled with no withholding period between harvest and sale, consumers are inevitably exposed to high levels of pesticide residues in their diets. The situation is especially serious, because unlike cereals, vegetables are consumed soon after harvest with little time for the chemicals to degrade. A recent socioeconomic survey in Jessore District showed that 98% of the eggplant farmers relied solely, in absence of any other alternatives, on pesticides to control the eggplant shoot and fruit borer (ESFB). More than 60% of the farmers sprayed their eggplant crop 160 times or more in a crop period of 6-7 months.

To counteract these practices, Bangladesh Agricultural Research Institute (BARI) has developed several IPM technologies on different pest problems of vegetable crops with assistance from several donor-aided projects. Now, different government organization (GO) and non-government organization (NGO) extension personnel are promoting those technologies throughout the country. Examples for some of these are described below:

<u>Eggplant</u>: ESFB, jassid, bacterial wilt and little leaf are the major problems associated with eggplant cultivation in Bangladesh. Control of ESFB is based mainly on pheromone/bait mass trapping of the male moths with locally-made water traps, and practising crop hygiene through removal/destruction of infested fruits and shoots. Innundative releases of the egg parasitoid *Trichogramma chilonis* and larval parasitoid *Bracon hebetor* are made every ten days and biopesticide products such as neem are applied to reduce jassid and whitefly. Control of bacterial wilt disease is dependent on growing eggplants that are grafted on resistant wild *Solanum* sp.

Tomato: A key constraint of tomato production is the tomato leaf curl virus, which can cause total crop loss. This is attributed to the high efficiency of the vector, *Besimia tabaci,* and the high susceptibility among available varieties. Two resistant/tolerant lines containing the Ty-2 resistance gene have been developed and these also produce higher yields than conventional varieties. Another constraint is the fruit borer, *Helicoverpa armigera,* which can be controlled by applying neem along with sequential releases of *T. chilonis* and *B. hebetor* at ten days interval.

Cabbage: Leaf eating lapidopterous pests like cabbage worm and diamondback moths (DBM) are the main constraints for cabbage production. Hand picking, applications of biopesticides (especially *Bacillus thuringiensis* or *Bt*) at action threshold level and inundative releases of the egg parasitoid *Trichogramatoidea bactrae* and larval parasitoid *B. hebetor* at ten day intervals, can effectively manage these insect pests.

Cucurbit crops: The melon fly, *Bactrocera cucubitae,* causes severe losses in cucurbit crops. Pheromone bait traps (cuelure) combined with mechanical control can effectively and economically control it. Releases of *T. chilonis* and *B. hebetor* at ten days interval will maintain low populations of other insect pests including *Spodoptera litura, S. exigua* and the pumpkin caterpiller.

Problems: The major constraints being encountered are: (i) non-availability of IPM materials at field level, (ii) inadequate supplies of BCA, (iii) lack of awareness about IPM practices by vegetable growers, and (iv) interference of pesticide dealers and related personnel.

Recommendations:

- IPM materials like pheromone, traps, and bio-pesticides should be made easily available to the farm communities.
- For steady supply of BCA at the farm level, several regional bio-pesticide mass production centers should be established.
- Awareness of growers and consumers concerning IPM and food safety should be enhanced through mass media coverage, training, workshops, conferences, etc.
- Latest IPM technologies should be included in the FFS curriculum.
- Production models of vegetables that are free of toxic pesticides should be developed in the major vegetable production areas of the country.
- The private sector should be encouraged to do business with IPM-friendly materials.
- Both local and export marketing channels for (toxic) pesticide-free vegetable products should be developed.

4.2 Cambodia

Crucifer crops including cabbage, cauliflower, Chinese radish, and Chinese kale are the most important vegetables in Cambodia after rice. According to the Ministry of Agriculture, Forestry and Fisheries (MAFF), the estimated area devoted to vegetable farming in 2004 was about 34,433 ha with a production of 32,847 tons. Crucifer crops are mainly grown in lowland areas along the Mekong River and around Tonlesap Lake, and constitute an important source of income for the Cambodia farmers.

The most destructive pest of crucifers in Cambodia is DBM. To control it, farmers frequently apply chemical insecticides, averaging about 15 times per crop. Sometimes, this could reach as many as 30 applications per crop. Also, farmers would often mix 2-4 different kinds of pesticides, resulting in dosages of 50-60 ml/17 liters of water in a single application (as was noted by the FAO Vegetable IPM Programme Phase II, 2002).

Because of overuse of pesticides to control DBM, many undesirable problems have resulted, such as high production costs, presence of toxic pesticide residues on market produce, health hazards to farmers and consumers, reduced ecological diversity in the sprayed fields, and environmental pollution.

An environment-friendly alternative control for DBM is using the parasitoid *Cotesia plutellae*. Other important natural enemies are two species of predatory ladybird beetles, one spider, and one ground beetle. In the field, their population densities are suppressed because of excessive spraying of insecticides by farmers. Among them, *C. plutellae* is most promising since it can be easily reared in large numbers for field releases against DBM. Moreover, greenhouse studies have revealed that the average DBM infestation on cabbage from planting to harvesting was 8.8 per plant in the presence of *C. plutellae* as compared to 16.1 per plant without the parasitoids, suggesting the latter to be an important mortality factor of DBM.

Results of an open field experiment on cauliflower in Porpeal Kher village (Kandal province) comparing the treatment with releases of *C. plutellae* with that of ‘farmer practice’ revealed that the latter had significantly higher level of DBM infestations than the former which had an average of only 4 DBM/plant from planting to harvesting. There was however little difference in the percentage leaf damage between the two treatments, being 15.1% and 16.6%, respectively. Abundance of *C. plutellae* was significantly higher in the release treatment (0.8 per plant) compared to only 0.1 per plant in the ‘farmer practice’ plot. It was also observed to have dispersed to fields in the surrounding areas. In general, *C. plutellae* was found to survive well in the field with little or no chemical pesticide application and is thus potentially useful as a control agent for DBM.

4.3 China

China is located in east Asia with a land area of 9.6 million square kilometers. The total area devoted to agriculture is 130 million hectares. The major crops are rice, wheat, corn, potato, vegetables, fruits, soybean, tea, herbs and flowers. Major pests include *Nilaparvata lugens* (or brown planthopper, BPH), rice blast, locust, aphid and DBM. The crop protection strategies include crop diversity, BC, physical control and chemical control.

Biological control and IPM development in vegetables were initiated by FAO and the government of China in 2003. Since then about 300 FFS have been conducted in the provinces of Yunnan, Guangxi and Shandong as well as Beijing and Shanghai city. More than ten thousand farmers have graduated from the field schools, resulting in decreased pesticide use, protection of crop yields and maintaining crop ecosystem biodiversity.

By 2005, about 10% of the total cultivated area was practising IPM, using bio-rational means such as predatory mites, entomopathogenic microorganisms, sex pheromones and agricultural antibiotics.

The main method of BC is the use of arthropod natural enemies of which China has rich varieties. From field surveys, over 1,000 species of natural enemies have been found on rice, 960 species on corn, 840 species on cotton and 360 species on vegetables. *Trichogramma* spp., *Amblyseius barkeri, A. cucumeris, Oudemans spp,* and *Encarsia formosa* are widely utilized in grain, fruit and vegetable crops.

Concerning entomopathogenic microorganisms, there are over 60 factories producing *Bt* in China with an annual output of 30,000 tons that are applied to 300 million hectares.

The major insect pests that are targeted include DBM, cabbage worm, corn borer and cotton bollworm in vegetables, fruits, rice, cotton, maize and tea. At present, about 20 viral pesticides are utilized by farmers or are in the demonstration phase. Ten viral pesticide products are used to control pests of vegetables, fruits, cotton, forest plants and pastures, and covering an area of 100 million hectares. The major virus used is nuclear polyhedrosis virus (NPV), which has been commercialized and used mainly for the control of cotton bollworm, tobacco caterpillar and the beet armyworm. Entomopathogenic fungi used in China are mainly *Beauveria bassiana* and *Metarhizium anisopliae*. The former is wildly used against corn borer, soybean pod borer, pine caterpillar and locust.

Sex pheromones are widely used to control DBM, tobacco caterpillar, beet armyworm, *Tryporyza incertulas, Heliothis assulta* and *B. dorsalis.* Annually, 20 different agricultural antibiotics amounting to 60,000~70,000 tons are also used.

To date, the primary problems and challenges encountered are:

- Enterprises involving BCA are still limited, hence their production and market availability are unstable
- Technologies and operating procedures for BCA production are not well developed and quality control is lacking.
- BCA are presently too costly and they act rather slowly
- Knowledge of farmers in BC is still limited and training is necessary to educate and encourage them in the proper utilization of BCA

4.4 Indonesia

Indonesia is an archipelago country made up of more than 13,000 islands located along the equator. The larger islands are Borneo, Sumatra, Papua, Celebes and Java. Indonesia is an agrarian country; more than 60 % of the population are farmers. The largest crop grown is rice. Climatically, Indonesia has two main seasons; dry (April to September) and wet (October to March).

Indonesia was once the largest rice exporter in the world, a status achieved through the use of new varieties of rice that can be cultivated twice a year, use of organic fertilizers, improved irrigation systems, and the application of chemical pesticides.

Although chemical insecticides have helped to boost rice production to satisfy domestic markets, their use have resulted in the development of insecticide resistance by BPH in 1984, leading to resurgence and serious outbreaks of the planthopper. To combat this problem, in 1986 Indonesia prohibited the use of 55 insecticide groups and adopted the IPM system for rice production.

Since the implementation of the FAO Inter-country IPM Programme in 1987, all provinces in Indonesia have practised IPM. The Department of Agriculture adopted the IPM approach and set up the following strategies: (i) Conduct training-of-trainers (ToT) with field officials, (ii) Offer the diploma programme, and (iii) Conduct FFS and implement IPM. FFS were not only conducted for rice, but also for palawija, vegetables (chilli, onion), citrus and spices (including ginger). Field schools for organic chilli and cabbage were also conducted.

Within the IPM systems, preference was given to BCA as alternatives and pesticides only considered as last resort when all other strategies are not effective. The BCA incorporated were *Trichogramma* sp., *Diadegma semiclausum*, *Hemiptarsenus* sp,.

Beauveria sp, *Metarhizium* sp, *Nomurea* sp, NPV, *Trichoderma* sp. *Glyocladium* sp, and *Pseudomonas flourescens*.

In general, BCA are produced in villages by groups of 20-25 farmers; such groups are known as "*bioagent posts*". Presently, there are 77 posts set up and about 5,000 farmers utilizing these facilities. Many kinds of BCA are produced by field laboratories and "*bioagent posts*" and are used by vegetable and rice farmers.

The Indonesian Government strongly supports the IPM approach. However only about 20% of the farmers have graduated from FFS training, mainly because there is insufficient fund to facilitate the IPM training. Consequently, uptake of IPM practices is not as fast as desired while lack of follow-up guidance has resulted in some IPM farmers returning to conventional practices of pesticide-based agriculture.

4.5 Lao PDR

Vegetable, rice and coffee production supports 76% of the population in Lao PDR. The major vegetable crops in the dry season (October-April) are cabbage, Chinese kale, onion, leaf lettuce, tomato, cucumber and yard long bean. In the wet season (June-September) vegetable cultivation is reduced as most farmers produce rice and the total land area available to agriculture is limited by flooding. However there is potential for expanding cash crops such as tomatoes.

The major agricultural production areas are around Vientiane Capital and extend to areas of higher elevation such as Vang Vieng and Kasi. Significant cultivation is also carried out in the Mekong River areas in Salavan, Champasak and the Bolaven Plateau. According to the 2004 statistics of the Government, the total cultivated area is 107,200 ha with overall production of 670,600 tons.

The major pests in rice are BPH, rice bug and rice thrips, while flea beetle, DBM, aphids, *Pieris* sp, cut worms, webworms and armyworms infest the vegetable crops. Coffee berry borer (CBB) and the coconut hispine beetle (CHB) are the main pest of coffee and coconut, respectively.

Applying chemical pesticides has been a common practice in some areas. However, BC with parasitoids, predators and entomopathogens are increasingly being promoted, particularly *D. semiclausum, Cotesia spp, B. bassiana, M. anisopliae, Trichoderma hasianum* and *Bt.* Presently, efforts are being made to mass produce some of these BCA in Lao PDR but their quality still remains a concern.

4.6 Nepal

Nepal is a mountainous country, located geographically between China and India. Because there is great variation in land elevation, diverse agricultural systems are being practised. The major crops cultivated include rice, wheat, maize, millet, cauliflower, cabbage, brinjal, cucurbits, mango, litchi and apple, and the main pests are BPH, rice whitefly (*Aleurocybotus occidus*), red ant, cutworm, *H. armigera*, DBM and ESFB.

In 1997, the IPM-FFS concept of training farmers was introduced into Nepal by FAO. The approach empowers farmers with decision-making skills by encouraging them to observe and monitor the crop ecology, discuss, and make decisions on follow-up actions. Since then, eight full season-long ToT courses have been completed, with follow-up training and graduation of 100,000 farmers. All these activities have resulted in about 15-25% yield increase in cereals and up to 100% for vegetables. The increase was achieved without any significant increase in the crop producing area. Other achievements included strengthening of the IPM extension approach, enhancement of technical knowledge of extension workers and farmers, leadership development in IPM trainers, linkages between GOs and NGOs, international linkages, and increase in employment opportunities of people concerned.

Presently, the constraints encountered are excessive bureaucracy and lack of coordination and holistic vision, poor mobilization of IPM trainers (hence, limited adoption of the IPM technologies), and lack of financial resources. At the farm level, the root causes remain because still many farmers have poor understanding of BC and IPM technologies and look to the immediately visible effects of wide-spectrum chemical pesticides.

To help address some of the constraints, the IPM Trainers Association Nepal (TITAN) has formulated the following strategies during 2007-08:

- Strengthen the capacity of technical staff through participation in this RTBC in Khon-Kaen, Thailand.
- Train 20 IPM trainers on applied BC to increase their capacity to train farmers in FFS.
- Organize study visit by a team of IPM trainers to areas in the regions (possibly Thailand) where BC has been successfully applied.
- Actively transfer technical knowledge and skills to farming communities through FFS, followed by programmes on farmer science and research.
- Conduct a workshop to formulate future strategies on IPM and BC.

4.7 Philippines

The Philippines, made up of 7,100 islands, measures 305,000 km^2. It has a population of 76 million from 17 political regions which consist of 82 provinces, 103 cities and 1,478 municipalities. The Phillippines has three major islands, Luzon in the north, Visayas in the central part and Mindanao in the southern tip.

The Philippines is an agricultural country growing various tropical and semi-temperate crops divided into three agricultural production systems such as highland, midland and lowland production systems. The highlands (2,000-8,000 feet above sea level) in the Cordillera mountain ranges, Mt. Apo and Mt. Kitanglad, grow semi-temperate vegetables (cabbage, carrot, potato and other crucifers) and highland fruits including banana. Midland crops such as tomato, crucifers, cucurbits, banana, coconut, coffee, citrus, and various fruit trees are cultivated in elevations below 2000 feet above sea level. Lowland crops both in the irrigated and rainfed areas are mostly rice, corn, sugarcane, tobacco, eggplant, onion, garlic, okra and many other tropical crops.

Vegetables make up 3.6 % of the total agricultural production with the largest production areas for vegetables dedicated to eggplant (166,104 mt), tomato (132,984 mt), squash (87,666 mt), cabbage (85.5 mt) and garlic (19, 314 mt).

The national IPM programme (KASAKALIKASAN) was implemented in 1993 with BC forming the foundation of ToT and FFS activities. BCA such as *Trichogramma* species for lepidopterous pests (e.g. *Heliothis* sp., corn borer, stem borer and sugar cane borer) have been introduced and mass produced in different regional crop protection centers for mass releases. *Diadegma semiclausum* and *C. plutellae* were also released for DBM in crucifers. NPV was applied by some vegetable farmers for cutworm and earworm management.

Beauveria bassiana and *M. anisopliae* were evaluated and used for leafhoppers, rhinoceros beetle, and rice black bug. *Trichoderma* has been tested for damping-off control in vegetable seedlings. Studies and field releases of earwigs, *Orius* sp. (predatory bug) and predatory mites have also been conducted.

The challenges for BC of insect pests and diseases in the Philippines include:

- Need for commercialization of potential BCA for various pests to make these agents always available for farmers or growers.
- Farm level production of various BCA such as NPV. Training farmers to produce their own BCA will make the agents always available and reduce their cost of production.
- Although continuous research for potential BCA, their biology, efficiency, ecology, mass production, conservation and field establishment are being conducted, the government has however provided only minimal support to the researchers.
- Advocacy and training of IPM and BC for farmers through FFS and participatory action research should be continued.

4.8 Thailand

Thailand has a total land area of 51.3 million ha; 41 % of this is used for agricultural production while another 30 % is forested. The country is divided into 6 regions made up of 76 provinces. Approximately 40% of the population (65 million) are farmers. The main agricultural crops are rice, rubber, oil palm, sugarcane, vegetables and fruit trees and the key pests for these are: BPH, leaf folder, blast and dirty pinnacle for rice; stemborer, stem boring grub and white grub for sugarcane; thrips, whitefly, wilt, anthracnose and mosaic virus for chilli; DBM, armyworm, aphid, rootrot and softrot for crucifer vegetables; and root and stem rot, fruitfly, thrips, mite, mealybug, and stemborer for fruit trees.

Farmers have historically relied on chemical pesticides to control pests. In order to reduce this dependence and promote BC, nine Pest Management Centers were established in different regions in Thailand in 1995, namely: Chiangmai and Phitsanulok in the northern region; Khon Kaen and Nakhon Ratchasima in the north-eastern region; Chonburi in the eastern region; Suphanburi in the western region; Chainat in the central region; and Songkha and Suratthani in the southern region. Each of these centers is responsible for 7-10 provinces and has the following responsibilities:

- Mass rearing of BCA, such as:
  - *Trichogramma* sp. and *Cotesia* sp. to manage sugarcane stemborer
  - *M. anisopliae to manage* sugarcane stem boring grub
- Preliminary field trials to develop skills and confirm the results and benefits of the BCA
- Transfer this knowledge to farmers using the FFS approach.

4.9 Vietnam

In Vietnam, rice is the most important staple food crop. Vegetables, fruits and other miscellaneous crops are also grown to provide the nutritional needs. The major insect pests include stemborer, BPH, rice bug and leaf folder on rice and DBM, whitefly, aphid, webworm, armyworm, and cutworm on vegetables.

For vegetables, to improve their quality and to protect the environment, IPM was implemented since 1993. BC began with investigations of the egg parasitoid *Trichogramma* sp. by the Plant Protection Research Institute (PPRI) in 1976. This was followed by the introductions of *D. semiclausum* and *Diadromus collaris* in 1998 by the National Vegetable IPM Programme to control DBM. Both the parasitoids were mass reared and released in several regions and have now become established only in the cooler highlands of Dalat. Through training in FFS, farmers now know how to work alongside the parasitoids to manage DBM.

Efforts on BC with other pests have included the introductions of insect natural enemies for weed control and the CHB. For the former, several Coleopteran and Lepidopteran species were introduced for the control of water hayacinth and *Mimosa pigra*. For CHB, the parasitoid *Asecodes hispinarum* has been introduced in recent years and is being being evaluated in South Vietnam.

The Plant Protection Department (PPD) is promoting agricultural practices to reduce reliance on chemical pesticides through adoption of BC and other IPM practices to improve the quality of agricultural produce and the environment. To achieve this, PPD together with the National IPM Programme are promoting the identification, mass production and field use of BCA (e.g. field releases of natural enemies and applications of entomopathogens) in activities of Training-of-Master Trainers (ToMT), ToT and FFS, as well as strengthening regional networking with other BC/IPM specialists in the region.

5. Technical Presentations by Resource Persons and Participants

Many technical presentations were delivered by specialist resource persons and some of the country participants. Besides well-illustrated power point presentations, in some cases handouts were also provided (see *Annex 3, where additional BC information sources such as website, manual and journals are also given*). For several presentations, they were also supplemented with practical hands-on exercises. Overall, a wide range of topics and experiences were covered. Taken together, they provide full coverage of the crucial aspects of BC, i.e. concepts, principles and related theories, illustrated case studies, practical constraints and issues relating to field implementation, and the envisaged future prospects. For most of the technical presentations (as well as all the country presentations), they were captured in a CD and given to all the participants for use as reference materials after returning to their homes. A few, however, were given as printed hand-outs. Because the original technical presentations were too voluminous, only the summary versions are provided below.

5.1 Concepts, principles and the basics of BC (*by Lim, G.S.)*

Pest organisms (vertebrates, insects, nematodes, plant diseases and weeds) are major constraints to crop production, destroying about 30% of potential food, feed and fibre production worldwide. Over the last 50 years, farmers have increasingly become dependent on pesticides to assure the yields they expect. Their over-reliance and excessive use have resulted in many undesirable concerns, such as health hazards to farmers and consumers, ecological disruption and environmental pollution, and escalating production costs. Applying the IPM strategy is presently the most promising option to minimize/overcome these problems. This approach combines several control methods and is sustainable, ecologically sound and economically viable. Possible control tactics involve BCA, cultural practices, interference methods, sterile insect techniques, and use of ‘softest’ chemical pesticide as last resort.

Biological control involves using and manipulating pests' natural enemies - predators, parasites, pathogens and nematodes. Parasites may live *in* (endoparasites) or *on* (ectoparasites) their hosts, from which they get their nutrients. In contrast, predators tend to kill, then consume their prey, such as: birds, spiders and lacewings.

In general, BC involves three basic approaches, i.e. conservation (making most of natural enemies already there), augmentation (adding more of them), and introduction (introducing new ones). Conservation is achieved through minimizing pesticide impact and through environmental improvement to encourage natural enemies. Augmentation consists of inoculative releases (early in the season in situation where natural enemies cannot persist over the crop season owing to unfavourable climate or absence of pest) and inundative releases (of natural enemies to control a problem at a particular time). Natural enemy introductions (or classical biological control) involve importing exotic natural enemies for pest control.

Parasitoids are parasitic insects whose larvae feed on the living tissues of an arthropod host. Most are wasps (Hymenoptera), but a few are flies (Diptera). Parasitoids with only one larva feeding on each host are solitary parasitoids. Many gregarious parasitoids feed in groups (from 2 to over 1000) on a single host. Majority of parasitoids are endoparasitoids while some are ectoparasitoids.

Although parasitoids are a diverse group, they have a similar pattern in their lifestyles. The adults are active flying insects, seeking hosts to lay eggs in, on, or nearby. After hatching, the larva feeds on the host, often killing it. Pupation occurs in or near host remains. After emergence, the adult mates, disperses, and lays eggs in more hosts. Some adults feed on host remains, but most on flower nectar and honeydew.

Parasitoids may be parasitized by hyperparasitoids. These may be obligate hyperparasitoids (developing only on the parasitoid larva) or facultative hyperparasitoids that develop either on the hosts or on the parasitoids inside them.

Insect pathogens may enter an insect through host feeding (passive entry) or through body openings or penetrate through the cuticle (active entry). The pathogen multiplies inside, eventually killing the host by toxin produced, or by depleting its nutrient supply. The most important groups are viruses, bacteria, fungi and protozoa, all of which are microscopic and highly host specific.

Nematodes are small thread-like worms with tough outer cuticle. Many live on or in the soil and attack plants, animals and humans. When attacking insects, they can be useful for BC. Though highly diverse, they have similar life cycle pattern, i.e. four larval stages, with one/more stages living outside host as 'free-living stage'. During the free living (infective) stage, larvae 'swim' in free water in the soil, seeking and infecting hosts. Within the host, the nematode passes through several stages of development.

It must be recognized that not all BCA can give full control of pest by themselves, even though they play a key role in any well-developed IPM system and form the core of successful IPM programmes. As such, BCA should be viewed as only one of the IPM components. Other IPM tactics must align and harmonize with it. Understanding the concept and principles of IPM as well as how certain BCA are to be utilized within a particular IPM programme is crucial.

5.2 Regional experiences in BC – case of the diamondback moth (*by Lim, G.S.*)

In the tropics, the life cycle of DBM is short (2-4 weeks) and there are many generations, hence its population often increases rapidly. The larvae are voracious feeders and difficult to control. In many countries, DBM has become the most serious pest of crucifers, with farmers resorting to all kinds of insecticides to control it, often spraying 1-2 times each week. Insecticide resistance development is common and most farmers are trapped in the 'pesticide treadmill'. Because of the unilateral use and excessive reliance on pesticides many undesirable problems are experienced.

To combat the problem, BC within the IPM context has received priority because DBM has many useful parasitoids. For example, in most parts of Europe, DBM is not a problem because it is naturally suppressed by large number of parasitoids. Where parasitoids have been introduced into cool tropical highlands, they (especially *D. semiclausum*) have provided successful DBM control (e.g. in Taiwan and the mainland of China, India, Indonesia, Malaysia, Philippines and Vietnam).

In recent years, efforts to introduce *D. semiclausum* into Thailand and *Diadegma insulare* into Vietnam were attempted. In Thailand, an initial survey for DBM parasitoids in the Chiangmai and Phetchabun highlands revealed the presence of four common parasitoids (*C. plutellae, Macromalon orientale, D. collaris and Brachymeria excarinata*). Because they provided only partial control, by itself, or in combination (averaging 40%), *D. semiclausum* was introduced in 2005 from Malaysia. Following appropriate staff training, the parasitoids were introduced, quarantined and released into organic farms in Doi Angkhang (Chiangmai) and FFS fields in Phetchabun. This was done in accordance to ISPM requirements. The parasitoids are now established and have spread naturally into many farms in both the highlands.

In Vietnam, both *D. semiclausum* and *D. collaris* were introduced in 1996 and have become established and widespread in the Dalat highlands. However, in the warm lowlands of South Vietnam where they cannot survive, *D. insulare* collected from the warmer region of Florida (USA) was introduced in 2002 and 2004. Unfortunately, until today, it has yet to become established, mainly because the lowland temperatures of southern Vietnam are still too high for the parasitoids to survive.

5.3 Microbial control of insects (*by Attatham, T.*)

Insects are major constraints to crop production. To achieve effective control, it is necessary to know the target insect, species, the damage caused and its behavior and ecology. Chemical pesticides are widely used against them and these have resulted in many adverse side effects on human health, animals, beneficial insects, natural ecosystem and the environment. Strategies that can minimize or avoid these are necessary, such as using beneficial insects, entomopathogens, botanical pesticides, hormonal control, pheromones, sterile male technique and plants that are tolerant/resistant to the pest.

Among the entomopathogens that are registered as biopesticides, there are presently about 104 bacteria, 44 nematodes, 12 fungi, 8 viruses and 6 protozoa. For insect pest control, the common entomopathogenic viruses are NPV, Granulosis virus (GV) and the *Oryctes* virus. The common NPV pathology on infected insects are loss of appetite, cease of feeding, sluggishness, no response to stimuli, swollen segments, shortening and robust body, and white to creamy coloration. Dying larvae usually move to the top of trees and hang by prolegs with the internal tissues becoming liquidfied and the cuticle dark. After death, the cuticle ruptures and liberates masses of polyhedral occlusion bodies to infect other hosts. For pest control, both wild and genetically modified strains may be used. The advantages are its specificity, safety to people, no residual effect, induce no or slow resistance, and ease and low dosage in application. Disadvantages include narrow host range, non-persistence in the field, environment dependent, short shelf-life, and high production cost. NPV is presently used against common caterpillar pests such as DBM, cotton bollworm, beet armyworm, cutworm and cabbage looper. Its mass production may be on whole insect, artificial medium or avian embryo. For commercial production, the following are necessary: product standardization, quality control, formulation as bioinsecticide, and field trial on its efficacy.

Concerning entomothogenic bacteria, *Bt* is most common. It is a spore forming bacterium and produces delta-endotoxin as crystal protein within the cell. Bt can be applied onto a plant or transgenetically incorporated into a plant. The latter approach is particularly effective against borers.

The common entopathogenic fungi for pest control are *B. bassiana, M. anisopliae, Hirsutella thompsonii, Verticillium lecani, P. fomosoroseus, Ashersonia samoensis*, *Zoophthora radicans, Entomorphthora grylli, Coelomomyces stegomyiae, Lagenidium giganteum* and *Cordyceps brongniartii*. The pathological processes usually follow the following general pattern: spore drops on the insect cuticle, germ tube penetrates through the cuticle, fungus grows inside the insect body and invading cells and tissues, insect cells and tissues disintegrate, insect dies and fungus penetrates out to the surface of insect body, produces mycelia which cover the whole body, spore formation, and insect cadaver becomes mummified.

In the case of entomogenic nematodes, the common species together with their specific bacterium are *Steinernema carpocapsae* (bacterium: *Xenorhabdus nematophilus*) and *Heterorhabditis bacteriophora* (bacterium: *Xenorhabdus luminescens*).

In general, the advantages of microbial control of insects are that they are safe to other organisms, highly specific, no environmental pollution, induce no or slow resistance, ease in application, can be integrated with other control measures, and the dosage used is small. However, the disadvantages are that they are of narrow host range, non persistent, slow to kill, environment dependent, short shelf-life and production technology requires precision and can be expensive.

5.4 Microbial control for plant diseases, with special focus on *Trichoderma harzianum* (*by Chamswarng, C.*)

Diseases may be caused by biotic factors (e.g. fungi, bacterial, viroid, phytoplasma, nematode) or abiotic factors (e.g. moisture, temperature, lightning, acidity, alkalinity, salinity, mineral deficiency and toxicity). Expression of diseases due to biotic factors is largely governed by the pathogen, host, environment and time. Disease symptoms may occur on any part of a plant (e.g. leaf, stem, root, seed and fruit). Some common diseases are bacterial wilt, leaf spot, damping off, etc.

To date, chemical fungicides are used against most crop diseases and this approach has resulted in loss of biological balance, increase of fungicide resistant strains and toxicity problems from residues. To overcome or minimize these, the approach of using microbial control of diseases is receiving increasing focus. The antagonistic mechanisms of the microbial agents may involve parasitism, predation, competition, toxicosis, antibiosis, and induced resistance. Several registered biofungicides of powder and liquid formulations are now available in Thailand. To date, many common diseases are found capable of being controlled by microbial agents that are commerically available in the Thai market. Examples of these diseases have included *Phytophthora* root rot of durian and tangerine, damping-off of soybean, tomato, yard long bean and cotton, stem rot of soybean, lettuce, chilli and tomato, seedling blight of barley, stem blight of asparagus, root and stem rot of chilli, yard long bean and durian, root rot of celery and lettuce, anthracnose of chilli and mango (on leaves), tomato wilt, black leaf mold of tomato, leaf blight and tuber rot of taro, dirty panicle, brown spot and sheath blight of rice, shoot rot and yellow patch of orchid, and rusty spot of *Dendrobium* orchid.

Among the many known species of *Trichoderma* microbial agents, *T. harzianum* is one of the most effective BCA used for controlling plant pathogenic fungi. It is parasitic to most soil borne plant pathogenic fungi, often killing through coiling/penetration/lysing, or as a stong competitor for substrate, or produces antibiotics (pyrone/oxazole) and induces resistance (e.g. against *Pythium*). *Trichoderma harzianum* is known to be capable of controlling root and foliar pathogens through the process of changing the microbial composition on roots, enhancing nutrient uptake, solubilization of soil, and promoting roots, root hair formation, and deeper rooting. It may be applied as broadcast, spray, seed treatment, mix into the soil or compost and other planting media, or appled around the basal stem, in planting hole, with irrigation, and in hydroponic planting system.

Concerning its use with other chemical pesticides, caution should be taken to ensure it is not mixed with benomyl, carbendazim and propiconazole. Like other microbial agents, the use of *T. harzianum* must be used in an integrated manner with other planting practices.

To date, the processes for mass production of *T. harzianum* are well worked out and described, including procedures that farmers can easily follow and prepare the BCA itself. Training programmes to educate farmers to utilize *T. harzianum* against diseases on their crops are now being intensified in order to help them reduce their reliance on chemical fungicides.

5.5 Biofumigation for soil-borne disease management in small-scale vegetable production in Asia (*by Justo, V.P., et. al.*)

A major soil-borne disease of vegetables in the Philippines is the bacterial wilt caused by *Ralstonia solanacearum*. It causes 15-40% yield losses, is difficult to control, highly versatile and survives for a long time. Current control measures with sanitation, crop rotation, solarization, use of resistant varieties have some limitations. Other important soil-borne organisms are plant parasitic root-knot nematodes, or RKN, (*Meloidogyne* sp). which attack more than 170 plant species and often causing 25-50% yield losses, as well as club root (caused by *Plasmadiophora brassicae*) which is especially widespread in the Cordilleras highlands.

The primary objective of biofumigation is using it as a component of integrated disease management for soil-borne pathogens in solanaceous vegetables. Biofumigation here refers to the suppression of soil pests by glucosinolate hydrolysis products, primarily isothiocyanates (ITCs) released when the glucosinolates (GSLs) in *Brassica* tissues are hydrolyzed during and following soil incorporation. Glucosinolates found in crucifers are acted upon by the enzyme myrosinase to give off a natural gas called ITCs. Brassicas with high concentrations of toxic ITCs are radish, Chinese mustard, cauliflower and broccoli. Cauliflower and broccoli farm wastes and radish when used as green manure reduce bacterial wilt and RKN by 50-60%, doubling the yield of potatoes in Mindanao, Philippines. Soil incorporation of broccoli, cauliflower, Chinese mustard or radish suppresses *R. solanacearum* and RKN. Soil texture, *Ralstonia* strain, and soil moisture caused variability in bacterial wilt suppression. Biofumigants are more effective in sandy loam soil than clay soil. Shredding, crushing and maceration of *Brassica* tissues for soil incorporation and follow-up watering were found to improve the efficiency of biofumigants. Studies also showed no harmful effects of biofumigants on beneficial soil microorganisms such as *Trichoderma and Bacillus.*

Participatory action research on biofumigation has been carried out with farmers to extend the technology to them, as well as through field days and farmer congress. Also, a regional workshop was conducted to share the technique with IPM trainers and extension workers in Asia.

A major constraint encountered in the application of biofumigation is the need for large amount of brassica materials (5 kg/m^2). This may be overcome by utilizing waste materials from the market and post-harvest crop residues (60-70% waste left over from broccoli and cauliflower, and 20-40% from cabbage). It is also possible to use green manuring with radish, though not with Indian mustard. Other constraints are that manually chopping and incorporation of the materials into the soil is too laborious, while shredder and farm machineries for such a purpose are not available because suitable mulcher and cultivator are yet too be designed and fabricated. More studies are thus desirable, not only to overcome these constraints but also to explore other benefits of biofumingation. Efforts toward these should receive attention because biofumigation is found to have numerous benefits, such as suppression of *R. solanacearum* and RKN in solanaceous crops, reducing dependency on chemical pesticides, improving soil fertility and soil condition through incorporation of organic matter from the decomposed plant tissues, help reduce waste disposal problem by the local government, ensuring better quality of produce and higher crop yields, as well as enhances forest conservation.

5.6 Field survey and insect classification (*by Jamjanya, T., et. al.*)

The basic structure of a typical insect is described, i.e. body divided into three distinct parts (head, thorax and abdomen), thorax with three pairs of legs and often two pairs of wings, and body with a system for breathing composed of air tubes. Insect behaviour, physiology, development and life cycle were also briefly described. A simple insect identification set of keys to the Orders and Groups of common insects and other related pests was included for use to identify specimens specially prepared for the training course and other arthropods collected in the field survey. The keys covered both the adults and immature stages.

A large part of this session was devoted to practicals on identification of specimens by the course participants.

5.7 Biology and ecology of insect pests of some economic crops (*by Jamjanya, T., et. al.*)

This covered the life cycle stages (egg, larva, pupa and adult) of the common pest groups, e.g. grasshopper, moth, weevil and fruitfly. Insects injurious to plants, stored products, human and animals were discussed. The detailed biology of the following pests were described: *P. xylostella, S. litura, B. dorsalis, Ostrinia furnacalis, Mythimna separta, Rhopalosiphum maidis, H. armigera, Nezara viridula*, thrips, sugarcane stemborer and stem boring grub. Other aspects covered included the nature of damage caused to the crop(s) attacked as well as their field abundance and ecology. With respect to their BC, their common beneficial insects and their roles were also highlighted, in particular ladybird beetle, brown earwig *Proreus simulans, Eocanthecona furcellata, Sycanus* sp., *Cotesia flavipes*, and *Trichogramms* sp. For sugarcane in particular, the concept of IPM was presented, including the control recommendations and economic return/benefits of sugarcane IPM.

5.8 Biological control and biology and ecology of insect natural enemies (by Nutcharee Siri)

Within a crop agro-ecosystem, pests may include the categories of insects, diseases and weeds. The BC of insect pests usually involves the use of parasitoids, predators or insect pathogens. In the case of classical biological control, this would involve the introduction of exotic natural enemies into areas in attempts to control pests which themselves are often introduced, generally unintentional. Conservation of natural enemies would focus mainly on the protection and maintenance of existing populations of natural enemies while the augmentation approach has to perform regular actions to increase populations of the BCA, either by periodic releases or by environmental manipulation.

To get BC started or when integrating it in an IPM context, some important ecological factors needing consideration would include what natural enemies are available, knowledge of the surrounding crops and vegetation, whether the crop in production is also an 'organic crop', are there 'soft' chemical options, if the environment is suitable for the natural enemies, determine when is the best time for natural enemy introductions (if this is necessary), replace any broad spectrum pesticides in use with either bio-pesticides or more selective chemicals, and ensure chemical residues have time to dissipate before introducing any BCA.

In general, parasitoids can be monophagous, oligophagous or polyphagous, as well as endo- or exoparsitoids. They may occur individually (soliditary) or in groups (greagarious). Depending on their nature of development in the host stage(s), a parasitoid can be classified as an egg, larval or pupal parasitoid, or even egg-larval or larval-pupal parasitoid. There can be superparasitism (when more eggs are deposited by a single species in a host than can survive) or multiparasitism (when two or more species attack the same host). Also, oviposition can be in, on, or apart from the host.

Predators, unlike parasitoids whose immature stage can complete its life cycle on a single host, require more than one prey individual to reach maturity. In general, they have chewing mouthpart or sucking mouthpart. The common groups of predators are the Phytoseiid mites, spiders, Coleoptera (Coccinellidae, Carabidae, Cocindellidae, Staphylinidae), Hemiptera (Anthocoridae, Pentatomidae, Reduviidae, Miridae, Nabidae), Diptera (Asilidae, Surphidae), Hymenoptera (Formicidae, Sphaecidae, Vespidae), Orthoptera (Mantidae), Neuroptera (Chrysopidae), and predatory thrips. Examples of some predators that were described in details included the ladybird beetle, spider, brown earwig *P. simulans, E. furcellata, Sycanus* sp., and predatory mite.

5.9 Mass rearing of some common parasitoids and predators (by Nutcharee Siri et al)

For field releases and augmentation of parasitoids and predators, laboratory mass rearing of these natural enemies are necessary. Although parasitoids and predators have some different requirements (e.g. parasitoid completing its life cycle on a single host and the predator needing more than one prey), the method to rearing them has a similar approach. Basically, three levels of production are needed; the first level is production of food host plants (or substrates) needed to produce the pests (or hosts for the parasitoids or prey as food for predators). The third level is the production of the parastoids and predators themselves. The case of mass rearing of *C. plutellae* and the ladybird beetles may be used to illustrate the procedures for the production of parastioids and predators, respectively.

Cotesia plutellae is a parasitoid of DBM. To mass rear it, a system to rear large number of DBM is necessary and this is achieved using potted brassica plants as food for the DBM. Larvae of DBM are then exposed for oviposition by *C. plutellae* and the parasitized larvae reared on brassica plants until the parasitoids emerge. Through repeated cycle of this process, large numbers of *C. plutellae* can be mass produced for field releases. In the case of ladybird predator, whitefly is used as the prey. Large numbers of whitefly nymphs are first produced on host plants, upon which ladybird beetle adults lay their eggs which hatch out to young nymphs that feed and grow on the whitefly nymphs.

To achieve success in mass rearing of parasitoids and predators, it is critical that the three levels of producing the plant hosts (substrates), food hosts (pests or prey) and the parasitoids/predators are well synchronized, i.e. all these stages (food plants/substrate, pest host/prey, and parasitoids/predators) are available all the time. Should any be not adequately available when needed, production of the parasitoids/predators will be adversely affected.

During the training, the steps and other requirement for producing the common natural enemies (both parasitoids and predators) were described for the DBM parasitoid *C. plutellae* and cutworm parasitoids *Apanteles* sp. and *Trichogramma* sp., as well as for the predatory earwigs (*P. simulans* and *Euborellia* sp.), predatory mites (*Amblyseius* sp. and *Stethorus* sp.), coccinellid beetle *Serangium* sp., and predatory bugs (*E. furcellata* and *Sycanus* sp.).

5.10 Bioproducts (of parasitoids and predators) and their applications (*by Siri, N.*)

A good parasitoid/predator bioproduct should have high parasitism/predation rate as well as high fertility, can adapt well to the environment and is easily mass reared. In the case of parasitoids, they should preferably have high host specificity. Concerning their handling during field assessments, collections and shipments, a number of methods can be used, depending on the species concerned and their life habits and behaviour. For example, collections in the fields can be made with simple manual methods using sweep nets, vials, brushes, suction aspirators or with light traps, and assessments undertaken based on visual counts or volumetric measurements.

The applications of the BCA may be as follows: Inoculative release(s) (one or two releases early in pest infestation), regular or dribble releases (regular small releases during likely problem periods), inundative releases (repeated high rate releases during periods of pressure for quick knock-down of hot spots), or a combination of all these methods (e.g. initial high release rate for quick knock-down followed by regular smaller releases). The effectiveness of all these means of applications is well illustrated by the use of *Trichogramma* spp. for a range of insect pests, such as *Agrotis ypsilon, Argyroploce schistaceana, Chilo infuscatellas, C. sacchariphagous, C. suppressalis, Heliothis armigera, Ostrinia furnacalis* and *S. exigua*. In the conservation approach of using parasitoid and predator bioproducts, these would often include limiting the use of pesticides and using only selective ones, adopting crop residue management, strip harvesting and landscape crop patterning, or direct provision of shelters and food sources to the BCA.

Ideally, a bioproduct should be easy to use, easy to buy, can remain viable in storage for a long time, and its supply available all year round. Presently, many products are already available commercially; some common examples would include *Trichogramma* parasitoids, aphid parasitoids, whitefly parasitoids, scale insect parasitoids, ladybird beetles, predatory mites, etc.

Government support is crucial to promote the use of bioproducts, particularly in the current initial stages of development. This may be providing incentives to develop environment friendly crop protection through greenhouse crop production, organic agriculture and better market share and price of ‘safe’ or pesticide-free produce. Such support is necessary since the present share of organic agriculture in the Asian region is still relatively limited, as illustrated in the following figures: Australia/Oceania (39%), Europe (21%), Latin America (20%), Asia (13%), North America (4%) and Africa (3%).

5.11 Getting to know ISPMs in Relation to IPPC and WTO SPS Agreement (by Napompeth, B.)

An expected output of the RTBC is for participants to become aware of the International Standards for Phytosanitary Measures (ISPMs), in particular ISPM No. 3 which is the "Guidelines for the export, shipment, import and release of BCA and other beneficial organisms (2005)", previously known as the "Code of conduct for the export, shipment, import and release of BCA and other beneficial organisms". The latter, developed in late 1970s and endorsed in November 1997, was revised and approved in April 2005 to be ISPM No. 3.

Altogether there are 27 Related Multilateral Environmental Agreements (MEAs) in force globally. Those pertinent to conservation of biological diversity, bio-safety and agriculture are: (i) Convention on Biological Diversity (CBD) 1992: dealing with the development and conservation and use of biological diversity; (ii) Cartagena Protocol on Bio-safety to the CBD 2003: dealing with the safe use and transfer of genetically modified organisms (GMOs) or living modified organisms (LMOs) and LMO-FFPs (LMOs for food, feed or for processing), and (iii) International Plant Protection Convention (IPPC) 1951, 1997, 2006: dealing with plant protection, plant quarantine, Sanitary and Phytosanitary agreement (SPS agreement) under WTO and 29 ISPMs as of March 2007.

The objectives of ISPM No. 3 are (i) To facilitate the safe export, shipment, import and release of BCA and beneficial organisms, (ii) Help develop national legislation, where it does not exist, and (iii) Describe the need for cooperation between importing and exporting countries. Some requirements include the National Plant Protection Organizations (NPPOs) as authorities designated for export certification, import or release regulations, NPPOs carrying out pest risk analysis (PRA) prior to import or release, and in the case of sterile insect technique (SIT), the sterile insects may be marked to differentiate them from the wild insects.

Specifically, ISPM No.3 recommends that NPPOs should conduct a PRA either before import or before release of BCA and other beneficial organisms. The scope includes "Guidelines for risk management related to export, shipment, import and release of BCA and other beneficial organisms", of which BCA are parasitoids, predators, parasites, nematodes, phytophagous organisms, pathogens (fungi, bacteria, viruses), sterile insects, beneficial organisms (mycorrhiza, pollinators), and those packaged or formulated as commercial products. The BCA however do not include LMOs, registration of biopesticides, or microbial agents intended for vertebrate pest control.

Agencies that are responsible and need to comply with ISPM No. 3 would include contracting parties, NPPOs, national competent authorities, importers, and exporters. Closely related are also ISPM No.2 which is "Framework for PRA. (2007)." and ISPM No. 11 which is "PRA for quarantine pests, including LMOs. (2004)".

5.12 Thailand experiences in BC (*by Napompeth, B.*)

Pests are undesirable organisms which include insects, mites, plant diseases, weeds, vertebrates, animal diseases etc. They may be controlled naturally (by environmental factors) or using methods applied (by man), such as cultural, physical, mechanical, biological, chemical, genetic, regulatory and IPM. The latter has arisen to minimize the over-reliance on chemical pesticides, and one definition is "IPM is a decision support system for the selection and use of pest control tactics, singly or harmoniously coordinated into a management strategy, based on cost/benefit analyses that take into account the interests of and impacts on producers, society, and the environment". For example, if using the natural enemies (BC) is providing effective control in the natural system, the IPM decision would be "*doing nothing*". However, if it is insufficiently effective, other control tactics are also applied (aligned/harmonized to the best possible) with the BC method.

Like IPM, there are many definitions of BC, which has evolved from "The action of *parasitoids*, *predators*, or *pathogens* in maintaining a pest population density at level lower than the average level in their absence" to the modern definition "The use of *natural* or *modified* organisms, *genes*, or *gene products* to reduce the effects of undesirable organisms (pests), and to favor desirable organisms such as crops, trees, animals, and beneficial insects and microorganisms". BC may be categorized into natural, augmentative, conservative, classical, parabiological and modern BC, and they could target a wide range of insect pests and weeds in agriculture, forestry and fisheries, and insect pests and vectors of medical importance. Also, how BC is best applied has been widely theorized (e.g. ecological island concept, refuge theory, multiple efforts, etc). Evaluation of its success is often difficult, not time-bound (or endless), and can be ambiguous because once completely successful, *the end result is invisible*.

The historical milestones of entomology and BC in Thailand which began in 1770 and 1929, respectively, revealed that much effort had been expended over four decades to build BC as the core of pest management in Thailand and to achieve its present global recognition. A major milestone in 1975 was the approval by the Government for National Biological Control Research Center (NBCRC) to become functional at Kasetsart University under the National Research Council Thailand (NRCT) as a joint networking venture with Chiang Mai University, Khon Kaen University, Prince of Songkla University, Mahidol University, Department of Agriculture, Royal Forest Department, Department of Fisheries, Thailand Institute of Scientific and Technological Research, and the Ministry of Public Health. By 2001, NBCRC (with the Headquarters at KU, Bangkhen Campus in Bangkok) has six Regional Centers spread out over the different major regions in the country (at Nakhon Pathom, Chiang Mai, Phitsanulok, Khon Kaen, Ubon Ratchathani, and Hat Yai, Songkhla). Since 1929, many BC activities have been carried out in Thailand and the major achievements included: (i) Survey and evaluation of natural enemies of insect pests and weeds, (ii) Natural enemies reference depository (NERD) initiated and established at NBCRC Headquarters in KU (Bangkok), (iii) Augmentative BC of insect pests and weeds, (iv) Classical biological control of insect pests and weeds, and (v) Export of natural enemies from Thailand to other countries.

With respect to classical biological control, the key points of the 2005 guidelines for the export, shipment, import and release of BCA and other beneficial organisms in accordance to ISPM No. 3 were highlighted. Also considered was the code of conduct for the import and release of exotic BC agents.

5.13 Community based IPM in Bangladesh, with special focus on fruitflies (*by Alam, S.N.*)

Fruitflies, particularly *B. cucurbitae* and *B. dorsalis*, are important pests in Bangladesh. For instance, *B. cucurbitae* is widespread in Bangladesh and damages 50-70% of cucurbit fruits. Farmers cannot effectively control the pest with insecticides. Even after 3-4 times of weekly sprays, infestations are still well above 30%. Its lifc cycle is generally short, about 3 weeks on average. Many kinds of fruit vegetables are attacked, such as cucumber and various types of gourds (ribbed, snake, bitter, ash, sweet and teasel). Effective control is usually achieved through a community approach of IPM involving clean cultivation (weekly removal of infested fruits from the field) and the combined use of bait traps with synthetic pheromone and mashed sweet gourd (MSG). The latter consists of 100 gm of MSG plus 5-6 drops of Dipterex 80 SP or 0.5 gm Mipcin 75 WP maintained at one trap per 12-16 m^2. The pheromone trap consists of cuelure (1 ml/trap in locally-made water trap) maintained at one trap per 10-15 m^2.

In general, only male fruitflies are attracted to cuelure bait traps, whereas MSG bait traps would catch both males and females; the latter normally outnumbering the males. Overall, the cuelure bait traps would capture 5-18 times more fruitflies than the MSG traps. In field trials comparing plots (with pheromone plus MSG traps) and the untreated control plots (with no traps), it was found that the higher the number of fruitflies captured, the lower was the fruitfly infestation (60-70% less) on the crop and the higher the crop yield (50-80% more), illustrating that the combined treatment of cuelure and MSG has greater promise as a technique for fruitfly control in cucurbit crops. Because of its high success in trapping fruitflies, the pheromone trap has been coined the 'magic trap' by farmers.

Since other pests, such as *B. dorsalis* and armyworms (*S. litura and S. exigua*), are also important on cucurbits, additional control measures are incorporated into the IPM programme being implemented. For *B. dorsalis*, methyl eugenol traps are used, and for the armyworms, weekly releases of the egg parasitoid *T. chilonis* (at rate of 1gm parasitized eggs/ha/week) and larval parasitoid *B. hebetor* (at rate of 1 bunker /ha/week) are carried out.

Because of the beneficial impacts of the community based IPM programme (significant reduction in fruitfly and fruit borer infestations and higher crop yields and return in revenue), the programme has now been implemented throughout Bangladesh in the vegetable regions of Jessore, Norsingdi, Chittagong, Comilla, Pabna, and Bogra.

6. Practicals and Demonstrations on Mass Production of BCA

Several of the lectures were supplemented with demonstrations of BC activities or with practicals to allow hands-on discovery learning by the participants. These demonstrations mainly involved procedures for mass production of BCA (particularly entomopathogenic fungi, predators and parasitoids). Outlines of these are as given below and more details of the protocols for some are as given in *Annex 4*.

6.1 Culturing methods for the entomopathogenic fungi *M. anisopliae, B. bassiana* and *P. fumosoroseus* (Thursday 12/07/2007).

Staff at the Khon Kaen Pest Management Center conducted the practicals on culturing these species of entomopathogenic fungi that are being used in the local IPM programmes. In general, the isolate of each entomopathogen is produced in what is known as 'bag cultures'. A suitable growth medium (e.g. par boiled rice) is placed in a clear plastic bag before being inoculated with the isolate. The bag is then sealed and incubated in controlled temperature room for up to 14 days before the conidia are dried and harvested from the medium. No supplement of peptones or other nutrients is added to the growth medium.

For application, an aqueous suspension of the fungal agent is prepared. Efficient transfer of the conidia to the target insect is facilitated by adding a detergent-like additive. Usually, a thorough application to plant parts where pest insects inhabit will increase the number of infected insects. Also, applying entomopathogenic fungus in cooler periods of the day will increase the longevity of the conidia which must come in contact with the insect cuticle to germinate and penetrate to kill the host.

6.2 Culturing methods for *Trichoderma* spp. (Friday 13/07/2007).

Two methods can be used to produce bag cultures of *Trichoderma* spp. For example, sorghum can be soaked in water before being sterilized in an autoclave, then cooled and inoculated with a stock culture of the fungal agent. Alternatively, par boiled rice can be inoculated. The bag culture (inoculated with the *Trichoderma sp.*) is then incubated for 5-7 days before conidia are harvested from the grain. No addition of supplement with peptones or other nutrients is necessary.

The bagged *Trichoderma* is then supplied to farmers who can apply it in a number of ways, such as:

- Prepare a mixture of *Trichoderma*, compost and rice bran, then apply the mixture to seedbeds, open fields, planting holes, etc
- Apply as seed treatment
- Cover plants and soil with a suspension of the fungal agent
- Paint the suspended conidia lightly on fruit trees

6.3 Mass rearing of predators (Tuesday 17/07/2007).

Colonies of predatory bugs, beetles, earwigs and mites along with their food prey insect are maintained at the Khon Kaen Pest Management Center for research purposes and for releases in field crop protection. All insects were reared in simple containers or cages that can be constructed easily in FFS or small laboratories. The specific procedures on how to mass produce each of the predators were demonstrated and explained in detail to the participants. For example, predatory bugs feed mainly on Lepidopterous larvae, sucking out the contents of the body and leaving a shell of skin. This was illustrated using the rearing of the bugs *E. furcellata* (Pentatomidae) and *Syncanus* sp. (Reduvidae) which feed readily on the meal worm, a suitable prey for them in captivity.

Two species of ladybird beetles that predate on aphids and mites can be reared quite easily using simple techniques that can also be replicated in FFS. This is done by introducing the ladybird beetles onto either an aphid infested bean plant or mite infested mulberry leaves inside a cage. During the practical/demonstration session, participants were also shown how to distinguish between several species of predatory ladybird beetles and the phytophagus species.

The methods used to rear the black earwig *Euborellia* sp. and the brown earwig *P. simulans* were explained to the participants while viewing the mass rearing cultures. Participants learnt that the earwigs are able to produce 500–1,000 individuals in only a few months using small plastic containers filled with either corn husk or soil and corn husk. A mixture of honey, sugar and brewers yeast is normally provided to the adults as food.

Facilities and rearing techniques for the pest spider mite and the predatory mite *Amblyseius* sp. were demonstrated to participants. Spider mites can be reared on young bean plants which when infested, are transferred to predatory mite colony. This was demonstrated during a walk of the glasshouse facilities. The silver-leaf whitefly was also being reared on cotton plant as prey in the glasshouse.

6.4 Mass rearing of parasitoids (18/07/2007).

Participants visited the mass rearing unit of *Trichogramma* (an egg parasitoid) to observe how it is being mass produced on the eggs of the rice moth *Corcya cephalonica*. It was learnt that 'cards with parasitized eggs' can be stored for several weeks. When parasitoid releases are necessary, the cards are placed on selected plants in the field.

A larval parasitoid reared for the control of DBM is *C. plutellae*. The host insect is DBM itself. Participants have the opportunity to learn the rearing procedures and how to set up and maintain continuously a rearing culture of the parasitoids.

7. Field Visits

As part of the RTBC, visits were made to farms to enable participants to interact with farmers and to personally observe and learn the BC activities of institutions that are active in utilizing BCA as part of field level implementation of IPM programmes. These allowed opportunities for the participants to clearly understand the ground level operational constraints relating to implementing and managing actual field pest problems and how BC can play a useful role. A total of four visit activities were made as outlined below.

7.1 Biological control activities at Mitr Phol Sugar Company, Phukhiew District, Chaiyaphum (Tuesday 10/07/2007).

Mr. Pipat Weerathaworn introduced the activities of Mitr Phol Sugar Company and described the collaborations with associated companies that utilize the many byproducts of the sugar extraction process. He informed participants of the collaboration between the company and farmers and how this has helped to significantly reduce pesticide use by farmers and in overcoming problems of insecticide resistance development that was widely experienced previously. The technical staff then briefed on the BC activities implemented by the company, including the techniques used to culture the BCA *Trichograma*, *Cotesia* and *Metarhizium* that are used for controlling the sugarcane pests, e.g. stemborer, stem boring grub, etc. This was followed by visits to the laboratory and mass rearing facilities to learn how large numbers of the BCA are being produced. From the visit, participants learnt that the efforts of Mitr Phol Sugar Company clearly demonstrated the commercial viability of incorporating BC strategies into agricultural production, resulting in more environmentally-sound practices while maintaining quality of the product.

7.2 Good Agriculture Practice (GAP)/Safe vegetable production and marketing (Wednesday 11/07/2007).

Participants visited the "GAP safe vegetable production and marketing area" operated by a group of 30 farmers in Ban More village, Kho Khem Sub-district, Samsung District, Khon Kaen Province, and were informed that 3-4 years ago farmers there totally depended on pesticides for crop protection. However, with technical assistance and the introduction of nets from the DoA, farmers are now able to better protect their crops from insect pests and reduce the reliance on chemical insecticides. Currently each family in the group has four 'net houses' where they grow yard long bean, leafy vegetables and eggplant. With reduction in use of chemical insecticides, the farmers have gained recognition from consumers, thereby securing a more stable market price while at the same time have substantially reduced on-farm inputs.

Following the briefing, participants then worked in five separate groups by visiting fields of yard long bean, chilli, kale, Chinese kale and eggplant. They surveyed the fields for pests and natural enemies and interviewed the farmers on their agricultural practices. Below is a summary of the findings.

Crop	Insect pests	Diseases	Natural Enemies	Practices of farmer & related remarks
Yard long bean (YLB)	Thrips, leaf miner, green leafhopper, aphid, pod borer, armyworm	None	None	Crop rotation (YLB - kale - Chinese kale), remove and properly dispose of infected plant materials, apply organic fertilizers and effeictive micro-organisms (EM).
Chilli (at transplanting & harvesting stages)	Thrips, whitefly, aphid	Blight, leaf spot, wilt, mosaic	None	Mosaic disease was most widespread but no control done because it does cause significant yield loss
Kale	Flea beetle	None	None	Spray botanicals (neem, kalaka), apply biofertilizer.
Chinese kale (flowering) & at 2 weeks after transplanting.	Flea beetle, DBM, leaf miner		*Cotesia*, predatory bugs	Farmers can identify the main pests and natural enemies. They do not mind the damage to young seedlings because pest pressure is reduced over time and they are growing kale only for flower consumption (and not the leafy parts). For pest control, farmers use herb mixture (ginger + derris + others?) and handpicking of the pests. They sell the kale in the market themselves.
Egg plant	Aphid, thrips, leaf-feeding beetle (*Epilacna* sp.)	Fruit rot, wilt disease	Ladybird beetle, spider, dragonfly	Growth of the eggplant was poor because of poor soil conditions and the dry season. There was no organic fertilizer applied. Many suffered from virus infection. Suggestions made to farmers included practising crop rotation, use of organic fertilizer and application of *Trichoderma*.

7.3 Activities at Khon Kaen Pest Management Center (Thursday 12/07/2007).

At the Center, participants first reviewed the previous day activities. Then Mr. Faijaroenmongkol (Director of the Center) briefed and introduced the Center's activities. He explained that several predators, parasitoids and entomopathogens are mass-produced in the Center and distributed free to farmers. The main predators are earwigs, assassin bugs and green lacewing, while the parasitoids included *Trichogramma confusum* and *Cotesia flavipes* which are larval parasitoids of the fruitfly *B. dorsalis.* Microbial entomopathogens being produced at the Center included *Bt, M. anisopliae, B. bassiana, P. fumosoroseus* and three strains of NPV.

7.4 Field survey and insect classification (Monday 16/07/2007).

Led by Ms. Tasanee Jamjanya and Ms. Prakaijan Nimkingrat at the Khon Kaen NBCRC, participants first were introduced to the general terminology, life cycles and characteristic features used to identify insects of both adults and immature stages. Following this, in pairs, participants practised how to key through a collection of insects that represent a range of Orders and Groups. Participants then proceeded to the field and used different sampling techniques to survey and collect specimens from a neighbouring corn field and its surrounding areas. These were then sorted in the laboratory and participants repeated the identification process on their own with the insects they collected. Upon completion, they discussed their findings and what they have learnt.

8. Panel Discussions

The primary objective of the panel discussion was to identify the responsibilities concerning BC among the various stakeholders, namely researcher, extensionist, farmer, and the private sector. Chaired by Mr. Banpot Napompeth, the five panelists first presented the viewpoints of their respective constituencies, after which the session was open to questions and discussion. The panelists included Mr. Preecha Somboonprasert of DoAE (representing extension), Mr. Ruth Morakote of DoA (representing research), Ms. Apsorn Pliansinchai of Mitr Phol Sugar Company (representing private crop production company), Mr. Chairat Kitivarapol (a farmer of Nampong Sugarcane Farmer Association, Nampong District, Khon Kaen Province) and Mr. Vorachai Manomuth (representing private service sector). The following are summaries of the presentations made by the panelists.

8.1 Mr.Preecha Somboonprasert made a presentation on food safety policy of the Thai Government and the Q-label to certify GAP products. An important responsibility of DoAE is to educate farmers on GAP utilizing IPM strategies and FFS approach. Biological control is the main method in IPM and now forms the primary thrust of the Pest Management Division – Biological Control Group and Pest Management Center of DoAE. The goal is to reduce indiscriminate use of chemical pesticides and the many undesirable problems associated with their overuse and to promote the national food safety policy.

8.2 Mr. Ruth Morakote described the overall responsibilities of DoA, which in the past covered wide ranging aspects of research and transfer of research technologies to technical officials and farmers. The research focus included many pests of economic importance and the major aspects of plant protection, including BC and IPM. However, with the recent reorganization, the responsibilities of DoA have changed somewhat, with emphasis given to inspection and certification of crop production systems towards developing and suporting GAP and GMP. However, since the last 3 years following the incursion of CHB (a new invasive species to Thailand), most research efforts have been geared towards managing it through classical biological control with the introduced parasitoid *A. hispinarum*. He explained that large numbers of the parasitoids are being reared and released, and that plant recovery has been encouraging in some areas though not in all cases. Presently, it is still uncertain if the parasitoids have become established in Thailand and efforts are in process to determine this.

8.3 Ms. Apsorn Pliansinchai presented the sugarcane pest management programmes of Mitr Phol Sugar Company and the activities in support of sugarcane farmers, in particular BC measures to replace highly toxic pesticides which have in the past caused health concerns. In general, sugarcane pests are quite difficult to manage because of their biology and habitat (e.g. hidden nature of the pests such as borers within the stems or roots) as well as the tall older canes that are closely spaced, and hence, highly hazardous to do pesticide spraying. Consequently, adopting alternative BC measures have been given priority, in particular in the control of sugarcane stemborer and the white grub (also a borer). The BCA used included an egg parasitoid (*Trichogramma sp.*), a larval parasitoid *(Cotesia flavipes)* and predatory earwig to control sugarcane stemborer while the white grub is controlled by applying the green muscardine *M. anisopliae*. Although the use of BCA has many advantages (such as being safer to farmers when compared to using chemical pesticides, etc.), a disadvantage is that BC is usually more complex and time consuming.

8.4 Mr. Chairat Kitivarapol (a farmer) shared his experience on sugarcane growing. He recounted the serious sugarcane borer problem that he had to face in the past when none of the pesticides he used could control the borer. He was informed by DoAE about the beneficial role of the egg parasitoid *Trichogramma sp.* and the larval parasitoid *C. flavipes.* With support from the Sugarcane Association and Mitr Phol Sugar Company, he made releases of the parasitoids. Since then, Mr Chairat has never experienced any outbreak of the sugarcane borer in his field. However, last year he encountered a new problem of white grubs which attacked the sugarcane roots. Control with chemical insecticides is particularly difficult due to the subterranean nature of the grubs. Moreover, all effective chemicals are highly toxic. With help from Khon Kaen University, Mitr Phol Sugar Company and DoAE Pest Management Center, he was able to learn and to use the green muscardine (*M. anisopliae*) which has given him good grub control.

8.5 Mr. Vorachai Manomuth presented his viewpoint from the private sector based on his company business experience as an agricultural consultancy agent dealing with irrigation system, BC and IPM, as well as a supplier of BCA. In pest management, he regarded monitoring to be a critical element in helping good decision making on the correct management action to be taken. Without a good monitoring system to provide crucial information on the occurrence of a pest upsurge, the intervention undertaken against it could miss achieving the desired target, especially for area-wide pest infestations. He highlighted some key monitoring features, using the example of CHB in which his company is providing the service of mass producing and supplying the parasitoid *A. hispinarum* to DoA.

An open forum (questions, answers and discussions) was held following the formal presentations by the panelists. Many issues were raised, ranging from pest resistance development and resurgence to forecasting, economics of using BCA, constraints of field implementation, and national policy support for BC. Some major aspects highlighted have included the following:

- Monitoring is the key to IPM implementation. Without a monitoring system, there would be no basis on when and how to best deploy BCA. And as such, even the

most effective BCA may fail to exert its full potential. Thus, a proper scouting programme to gather relevant information for proper decision-making is crucial for IPM to be successful.
- A community approach to BC is necessary. This is because some BCA require area-wide application to be more effective. Moreover, cooperative efforts may be needed for the production of certain BCA because of economy of scale and sharing of common facilities.
- Farmer education on how best to apply BC is crucial because they are directly confronted by pest problems in the field. In addition, close cooperation and team effort among farmers in a village (or in an area) and others helping them to deal with the pests is necessary, as exemplified by the successful example of team work in sugarcane production in Khon Kaen.
- There is need to formulate strategies for the present (and the future) concerning GAP for every major food crop. Also, it is vital that extension workers work closely with the farmers in participatory action research (PAR) in FFS. Confidence in BC and IPM strategies need to be strengthened to overcome the reliance on chemical pesticides. The costs for BCA need to be reduced at the farmer level by educating them on how to produce the materials themselves, e.g. *B. bassiana*, *M. anisopliae* and *Trichoderma*.
- Bilateral and multilateral cooperation on BC in the region should be promoted, targeting at utilizing as many as possible the BC techniques that are economical and cost effective, sustainable, and readily available to the farmers.

In addition to the above suggestions, there were also many other specific questions and issues raised by participants. These, and the responses of the panelists, are given in *Annex* 6.

9. Curriculum/Session Guides, Formulation of National BC Activities and Evaluation of the RTBC

Having completed all the key aspects of BC in the training (technical sessions, practicals, field visits, panel discussions and many other miscellaneous exercises), participants then try to apply what they have learnt through developing training curriculum and session guides, as well as formulating local BC activities for implementation in each country. They also made an evaluation of the RTBC.

9.1 Curriculum and session guides

Working in 3 separate groups, the participants developed and presented training curricula and session guides which they may employ when they return to undertake FFS or ToT. The first group developed a 5-day "Training course for BC of pests using entomopathogens" and the second group a 7-day training on "Principles of BC". The third group prepared two curricula; a 3-day "ToT course on predators and parasitoids" for extension workers, and a 2-day "Training course on insect pests, predators and parasitoids" for farmers. Details of all these curricula and session guides are as given in *Annex 5*.

9.2 Formulation of national BC activities

Participants of each country were tasked to formulate a concept note outlining the BC activities that they consider are important and what BCA can be incorporated into country programmes after their return. The assignment was to encourage the participants to apply what they have learnt on BC in their home country. Guidance was given on the basic format for the proposal, which should include the background (explaining the issues and need for project), objectives (of the project), procedures (on how to carry out the project activities), materials (needed to carry out the activities), and the budget (to carry out the project, with indication of any external support where needed).

Each country draft proposal was presented and discussed, and suggestions were made on how to improve it where needed. Upon their return, participants are expected to revise their respective proposals and submit them for local or external funding support. The proposed topics are as follows:

Bangladesh: Investigating the use of pheromones, parasitoids, microbials and plant extracts for sustainable production of vegetables in IPM packages.
***Cambodia**:* Introduction of *C. plutellae* for the control of DBM.
China: Introductions and use of BCA in FFS.
Laos: Survey for predators and entomopathogens and their utilization as BCA in FFS.
Nepal: Production and pilot application of microbial pesticides, including the use of pheromones.
Philippines: Training farmers and extension workers on BCA of insect pests.
Thailand: Using parasitoids to manage fruitflies in IPM systems.
Vietnam: Introduction and training of farmers on the utilization of *Cotesia, Diadegma* and *Trichogramma* parasitoids in FFS.

9.3 Evaluation of the RTBC

In order to help improve future training courses on BC, an evaluation of the current RTBC was conducted by obtaining feedback from participants on its strength and weaknesses. The main findings as highlighted below are:

- Some country reports failed to provide adequate technical information on BC and did not follow the stipulated format. Strict adherence should be better enforced in the future.
- All the technical presentations were good and provided much useful information. The selected topics were relevant and would be helpful to participants in undertaking their work after their return.
- A few lectures could be better balanced with more hands-on practical and field work, e.g. those relating to microbial control and the biology and ecology of insect pests and natural enemies.
- In the case of mass production of BCA, although the guidance provided was excellent, the time allocated was insufficient for better interactions and hands-on activities.
- Because participants were from different countries and differed in English skills and understanding, difficulty in communication was sometimes experienced when working in groups. This also occurred between trainees and the facilitators helping with practical.
- Topics and practical on field survey and insect classification/identification were particularly valuable since most participants had only very limited skills and understanding of these prior to their training.
- Experience sharing by participants on practical aspects, such as bio-fumigation and field management of fruitflies, was especially useful for others to consider implementing upon their return.
- In the case of field visits, they were very informative and participants learned a lot on the practical implementation of BC. However, communication with farmers during interviews posed some difficulties, mainly because farmers often cannot provide accurate technical information.

- The time allocated to the open forum (for questioning and answering) in the panel discussion session was rather limited and many issues could not be discussed or clarified. Otherwise, the panel presentations were highly informative and useful.
- Concerning support facilities, one or two rooms/halls used for conducting the training were inadequately ventilated and too hot for comfort, and these were not conducive to learning.
- In general, the Khon Kaen NBCRC and the DoAE Pest Management Center have good facilities and staff for undertaking BC training courses.
- Transportation to training sites, fields and for other activities was excellent, punctual and reliable.
- The hotel accommodation was good and comfortable, but the breakfast menu was fixed and always the same daily.
- The organizing team had worked hard and was diligent to ensure that the RTBC progressed well and according to plans.
- In general, the RTBC was well organized and successful, and participants not only have learnt a lot about BC but also have enjoyed very much, including making many friends and contacts (both participants and resource persons) that would prove very useful for future consultations in BC. All the people involved have been very active, friendly and were an enjoyable group.

10. Closing Ceremony

An important event of the Closing Ceremony was the awarding of certificates to the participants for completing the RTBC. The certificates were officially handed over by both Mr. Udom Jirasawetkul (Director of Regional DoAE) and Mr. Jan Willem Ketelaar (CTA, FAO Vegetable IPM Programme). Mr. Jirasawetkul then delivered the closing address in which he urged a network be established to facilitate knowledge exchange among the participants and BC specialists in Thailand to help everyone improve BC technology to achieve the common goals of protecting the environment and producing clean food for consumption. *Annex 7* contains the full text of his speech. Finally, he welcomed everyone to enjoy the evening's dinner party before declaring the RTBC closed.

11. Acknowledgements

Sincere thanks are due to the collaborating institutions and many people (too many for individual mentioning) who have contributed to the success of the RTBC, in particular:

- Thailand DoAE and FAO Vegetable IPM Programme for co-organizing the RTBC and providing all the needed support (financially and otherwise) to make it possible;
- Senior officials of DoAE and Khon Kaen University and the CTA, FAO Vegetable IPM Programme, for gracing the occasions of the Opening Ceremony and Closing Ceremony of the RTBC;
- All country participants for their country presentations and active participation and cooperation in all the training activities carried out in the RTBC;
- All resource persons and panelists for freely sharing their knowledge and experiences;
- Khon Kaen NBCRC/University and Khon Kaen Pest Management Centre of DoAE for all local training facilities, materials and support staff needed to run the RTBC;
- Staff of Mitr Phol Sugar Company, officials/provincial field workers and farmers who willingly spent time with the participants to share their experiences during field visits by RTBC participants;

- The CTA, FAO Vegetable IPM Programme and his staff at FAO RAP (Bangkok) for all support necessary in making the RTBC feasible; and
- The organizing and management team for planning the RTBC, and together with other support helpers, for ensuring that all the RTBC expectations are met, including the smooth day-to-day operational execution of the training and related miscellaneous activities.

Annex 1: Concept Document for the Regional Training on Biological Control

1.1 Location: Khon Kaen, Thailand, 9-20 July 2007

1.2 Introduction/Background: Integrated Pest Management (IPM) is an approach that uses a combination of techniques to suppress pests effectively, economically, and in an environmentally sound manner. IPM is a decision-making process involving the identification and monitoring of pest populations, and using the monitoring information to decide the timing of treatments that integrate a variety of control measures, and finally, evaluating the results.

One of the most important elements of any robust IPM strategy is making optimal use of biological control (BC), which is the use of natural enemies to regulate pest populations to a level where these will not cause yield loss. The need for more optimal use of BC is recognized at national and international levels. However, in many places the technical knowledge and skills with regard to production and sustainable utilization of BC options are still inadequate to warrant its widespread adoption. A need has been identified by representatives of member countries participating in the FAO Regional Vegetable IPM Programme to review the principles and concepts of BC and to discuss regional collaboration on BC matters.

1.3 Rationale: The use of BCA is increasing worldwide and there are now many companies that mass produce and sell such organisms. However, lack of production quality control, limited knowledge and access to novel options for pest management have resulted in non-optimal utilization of BC options. There is also a need for R&D on novel BC options, including a bigger role to be played by the private sector in terms of production and marketing of good quality novel options for pest management. It is also important to note that farmers themselves can play a key role in local production of simple BC options.

To address the above concerns, a "Regional Training on Biological Control" (or RTBC) is planned and being organized by the Biological Control Group, Pesticide Management Division, DoAE-Thailand and FAO for participants from member countries of the FAO Regional Vegetable IPM Programme. Given Thailand long-standing expertise in the development, application and utilization of BC options in agriculture, Thailand has an important potential role to play in terms of strengthening BC programmes elsewhere in the Asia Region.

1.4 Training objectives: The overall objectives of the training is to provide participants with information, education and training on the principles and tools for BC in order to assist them in the development of national strategies for sustainable development of local BC programmes. In particular, the RTBC is planned to allow for review of concepts and principles of BC, to share experiences and discuss opportunities and challenges for quality production and sustainable utilization of BCA, and to identify best options for ensuring better access and utilization of BC options by IPM farmers. The specific objectives include:

- To review concepts and principles of BC, particularly within the context of the development and utilization of robust IPM strategies;
- To exchange experiences and knowledge on ongoing in-country BC programmes with neighbouring countries;
- To be able to identify BCA for potential production and learn how to produce and use them appropriately, including the techniques on mass rearing in the laboratory and releases under field conditions with follow-up field monitoring and evaluation of their effectiveness;
- To develop the capacity among IPM facilitators so as to be able to identify specific BCA (parasitoids, predators and microbials) for effective management of specific insect pests and diseases;
- To develop simple training models, curriculum, session guides, reference materials, and methodologies to train farmers on BC, preferably within the context of FFS and follow up training activities.

1.5 Expected outputs: The participants will:

- Master the concepts and principles of effective BC programmes;
- Be able to identify best bet options for development, production and utilization of BC options, particularly with regard to potential role that farmers themselves can play in this process;
- Understand the importance of support institutions in the field of quality control, marketing, extension education and certification, role of the private sector as well as producers' organizations for the development of BC;
- Understand the market conditions of BCA and preferred roles for the public and private sector;
- Become familiar with the available technical resources and develop a network of contacts at country and regional level of those interested and/or with expertise on BC matters;
- Become aware of the International Standards for Phytosanitary Measure/Code of Conduct for the import and release of BCA; and

- Plan for best bet options for further strengthening and expanding BC development projects in their home countries.

1.6 Training course contents: The following specific topics will be addressed during the programme:

- Concepts and principles of BC
- Potential of augmentation programme
- BC systems
- Present status of BC
- Microbial control
- Rearing techniques for predators, parasitoids and micro-organisms
- Responsibilities of public and private section partners in development and marketing of BC options
- Quality control and production of BCA
- Utilization of BC products, particularly within the context of GAP/Food Safety programmes
- M&E, assessment and management of BC
- ISPM guidelines/code of conduct for the import and release of exotic BCA
- Field visits to successful case studies of BC production and utilization in action

1.7 Training methodology: Active participation will be essential during the RTBC. Emphasis will be on lectures, discussions, workshops, practicum, and study visits to both public and private sector-led BC initiatives.

1.8 Organizing/ Management team:

- FAO Consultant - Mr. Lim Guan Soon (Course coordinator)
- FAO Consultant - Mr. Damien Cupitt (Course coordinator)
- IPM training expert to facilitate the course - Ms. Tattanakorn Moekchantuk (Course coordinator)
- DoAE Director of Biological Control Group - Mrs. Areepan Upanisakorn (Course coordinator)
- Director of Khon Kaen Pest Management Center - Mr. Sangar Faijaroenmongkol
- Staff of Khon Kaen Pest Management Center - Mrs. Bunchong Sirichumpan, Mr. Noppawit Kamkha, Mr. Chatchai Sittihakoat

1.9 Details of "Regional Training on Biological Control" 9-20 July 2007
Venue: Charoen Thani Princess Hotel, National Biological Control Research Center (NBCRC), Khon Kaen University, Pest Management Center, Khon Kaen , Thailand.

1.10 Work programme

Date		Training Activities	Venue
Sun 8 July, 07		Arrival at Khon Kaen and check-in: Mr. Sangar and his staff	Charoen Thani Princess Hotel
Mon 9 July	am	Opening Ceremonies - Mr. Preecha Somboonprasert, Director, Bureau of Agricultural Product Quality Development, DoAE), Ms. Lawan Jeerapong (DoAE), Mr.Jan Willem Ketelaar (CTA, FAO Regional Vegetable IPM, Ms. Tattanakorn Moekchantuk (FAO consultant) Course Introduction (Areepan Upanisakorn) Country Presentations: • Bangladesh • Cambodia • China	Charoen Thani Princess Hotel
	pm	• Indonesia • Lao PDR • Nepal • Philippines • Thailand • Vietnam Welcome party	Charoen Thani Princess Hotel
Tue 10 July	am	Concepts & principles of BC (Mr. Lim Guan Soon) Regional experiences in BC (Mr. Lim Guan Soon)	Charoen Thani Princess Hotel
	pm	Visit to private sector company BCA production (sugar factory)	Mittr Phol Sugar Company Ltd., Phukhiew District, Chiayaphum
Wed 11 July	am	Visit GAP/safe vegetable production and marketing by farmers	Ban Mor, T. Sumsung, Khonkaen
	pm	Laboratory tests/practical work on microbials at Khon Kaen Pest Management Center (Areepan and	Khon Kaen Pest Management Center

		Mr.Sangar & staff) Discussion on Country strategy concept paper.	
Thu 12 July, 07		Microbial control - lecture and practical. Entomopathogenic fungi and virus NPV, Bt by Dr.Tipvadee Attatham, Kasetsart University Practice at Khon Kaen Pest Management Center Group discussion &prepare session guides (participants)	Khon Kaen University, Khon Kaen Pest Management Center
Fri 13 July	am	Microbial control: for plant pathology by Mr. Chiradej Chamswarng, Kasetsart University	Khon Kaen University
	pm	Bio Fumigation (Vale Justo) Practical at Khon Kaen Pest Management Center Group discussions and preparation of session guides (participants)	Khon Kaen Pest Management Center
Sat 14 July		Optional: Visit local interesting places	
Sun 15 July	am	Cultural and historical site visit	Udon Thani, Nongkhai
	pm	Cultural and historical site visit	
Mon 16 July	am	Field survey and insect classification Practical: Ms.Tasanee Jamjanya, Ms. Prakaijan Nimkingrat	National Biological Control Research Center (NBCRC), Khon Kaen University
	pm	Biology and ecology of insect pests of some economic crops Lecture : Ms Tasanee Jamjanya Discussion on Curriculum, training models and session guides, work assignments	NBCRC, Khon Kaen University
Tue 17 July	am	Biology and ecology of insect natural enemies Production of insect natural enemies Lecture : Ms. Nutcharee Siri	NBCRC, Khon Kaen University
	pm	Mass rearing of some important predators Practical: Ms. Nutcharee Siri Mass rearing technique and quality control Release methods Lecture: Ms. Nutcharee Siri Presentation of curriculum, training models and session guides	NBCRC, Khon Kaen University
Wed 18 July	am	Mass rearing of some important insect parasitoids Practical: Ms. Nutcharee Siri, Ms. Prakaijan Nimkingrat	NBCRC, Khon Kaen University
	pm	Mass rearing of some important insect predators Practical: Ms. Nutcharee Siri, Ms Prakaijan Nimkingrat Discussion and evaluation: Ms.Tasanee Jamjanya, Ms. Nutcharee Siri Fruit Flies (Mr. Alam)	NBCRC, Khon Kaen University
Thu 19 July	am	Panel Discussion (Responsibilities among stakeholders: researcher and extensionist, farmer, and private sector) Mr. Banpot Napompeth (Chairperson) : Mr. Preecha , Mr. Ruth, Ms.Apsorn, Mr.Worachai , Mr. Chairat (Farmer)	Charoen Thani Princess Hotel
	pm	The Thailand experience in biological control (Mr. Banpot Napompeth) Award certificates, Closing ceremony, Farewell party	Charoen Thani Princess Hotel Khon Kaen Pest Management Center
Fri 20 July	am	Evaluation, course wrap up, presentation of country strategy paper	Charoen Thani Princess Hotel
	pm	Departure Khon Kaen - Bangkok - Home country	

1.11 Participants, resource persons, panelists and invited officials

Name	Nickname	Address	E-Mail	Tel
Ing Sina	Sina	House 54B, St. 656, Sangkat Teuk Laak, Khan Toul Kork, Phnom Penh, Cambodia	fao.ipmnatstaff@online.com.kh	855-12-974-494
In Sovanmony	Mony	Provincial Department of Agriculture, Battambang Province, Cambodia	monymariny@yahoo.com	855-12-672-822
Chhay Kry	Kry	# E07 St. 466 Sangkat Beung Trabek Khan Chamkamon, Phnom Penh, Cambodia.	mailto:danidaipm@online.com.khchhaykry@online.com.kh	023 726 723
Shan Xunan	Thomas	No.20 Building, Maizidian Street, Chao Yang District, Beijing City 100026, China	sxn@agri.gov.cn sxn0812@163.com	86-010-64194542 13810627921
Lu Jianping	Jiangping	No 19 Yongxing Road, Yunnan Plant Protection and quarantine Station, Kunming City, China 650034	mailto:Ljp4141005@163.com Ljp2000@km169.net	T: 86-8714141005 F: 86-8714141407
Phoukaothong Sykaisone	Air	Plant Protection Center, Vientiane Capital, Lao PDR	PkaothongIPM@yahoo.com	856-20-2202699
Phouvong Keomany	Noi	P.O. Box 19, Agriculture and Forestry, Campasak, Lao PDR	vongchane@yahoo.com	856-20-5942347
Vidavanh Yotsanga	Sanh	Plant Protection Center, Vientiane Capital, Lao PDR		856-20-5913432
Le Dinh Tham	Than	28 Tran Phu, Vinh City, Nghe An Province, Vietnam	thandung@vnn.vn	84-038-3843790
Nguyen Thi Hien	Hien	Trung Trac Village, Van Lam District, Leung Yen Province, Vietnam	ttlevtv@vnn.vn	84-0321-980027
Suwat Manimont	Mani	119/42 Moo2 Saimai, Khet Saimai, Bangkok 10220 Thailand		66-81-8695743
Wararut Luecha	Pong	103/1 Moo 7, Talook, Sapaya, Chainat 17150 Thailand	m.luecha@hotmail.com	66-81-2760861
Watchalee Sopin	Vok	35/9 Hoy Mook Rd., Hatyai, Songkhla 90110 Thailand	tongsopin@yahoo.com	66-81-2760861
Panupong Singkhum	Sing	9/4 Moo 10 Aranyik, Muang, Phitsanulok 65000 Thailand	Pong9_9@hotmail.com	66-81-5323770
Pasita Kaewlueamsai	Lee	Pest Management Center, Moo 5 Nonhkwai, Hangdong, Chiangmai 50230 Thailand	pmc08@doae.go.th	66-81-7160989
Huttaya Promto	A	186/1 Moo 12, Tambol Sila, Mueng District, Khon Kaen 40000 Thailand	huttaya@gmail.com	66-81-7690694
Narongchai Kaisai	Peak	Pest Management Center, 490 Moo 10, Tambol Khokgruad, Mouang District, Nakhon Ratchasima 30000 Thailand	narongchai@hotmail.com	66-81-8771920
Somkid Chalearmkiet	Kid	399/68 Yuttithum Rd., Mouang, Ratchaburi 70000 Thailand	somkid_bio2@yahoo.com	66-81-1983744
Sutee Shewhakarn	T	2/10 Tarathibbodee 12 Rd., Tambol Thakham, Phunpin, Suratthani 84130 Thailand		66-81-0775099
Kittisak Chantasang	Too	Bureau of Agricultural Product Quality Development, DoAE, Phaholyothin Rd., Jatujak, Bangkok 10900 Thailand	biological_doae@hotmail.com	66-81-8689497

Syaiful	Pul	Polonia No. 7, Air Tawar Timar Padang, Sumaters Barat, Indonesia		85263213481
Sharad Chandra Parasar Marahatta	Sharad	Bharatpur 7, Chitwan, Nepal	sharadparasar@yahoo.com	977-9841318631
Krishna Bhadra Adhikari	Krishna	Dhapasi VDC-5, Shree Tule Dhapasi, Kathmandu, Nepal	kbadhikari@yahoo.com	977-9841367380
Valeriana Justo	Vale	National Crop Protection Center, University of the Philippines Los Banos College, Laguna 4031 Philippines	vjusto@laguna.net	63-9198280384
Carlito Indencia	Lito	Office of the Provincial Agriculturist, Provincial Administration Center, Aguinaldo St. Bacolod City 6100, Negros Occidental, Philippines	carlitz2007@yahoo.com	63-9063427398
Damien Cupitt	Damo	House 54B, St. 656, Sangkat Teuk Laak, Khan Toul Kork, Phnom Penh, Cambodia	damiencupitt@gmail.com	855-92844330
Syed Nurul Alam	Alam	Entomology Division, Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh	entoipm@bdcom.com	88-0171190886
Tattanakorn Moekchantuk	Tim	14/7 Moo 2, T. Mittraphap, Sikhiu, Nakhon Ratchasima 30140, Thailand	tattanakorn@gmail.com	66-81-8052550
Lim Guan Soon	Guan Soon	CAB International, South East & East Asia Regional Centre, P.O. Box 210,UPM Post Office 43400 Serdang, Selangor, Malaysia.	cosmic-unity@psynex.net	(603)-89426489
Sangar Faijaroenmongkol	Sangar	Khon Kaen Pest Management Center Sila, Muang Khon Kaen, THAILAND	sangar97@gmail.com sangar@kknet.co.th	66-89-6176918 66-43-203512
Chai Sattha-anan	Chai	42 Sathorn 11 yak13, Yannawa, Sathorn, Bangkok, 10120 Thailand.	chaiphotography@gmail.com	66-86-9858261 66-02-286-4572
Areepan Upanisakorn	Tum	Bureau of Agricultural Product Quality Development, DoAE, Phaholyothin Rd., Jatujak, Bangkok 10900 Thailand	areepan03@yahoo.com	66-81-6752800

Name	Office	Date	Topic/Detail
Mr. Assanee Prachinburavan	Dean of Faculty of Agriculture, Khon Kaen University	9 July	Attend opening ceremony
Ms. Tipvadee Attatham	Kasetsart University	12 July	Microbial control lecture and practice : Entomopathogenic fungi and virus NPV, Bt : Biology, ecology, action, production and use.
Mr. Chiradej Chamswarng	Kasetsart University	13 July	Microbial control : for plant pathology: *Trichoderma* sp. : Biology, ecology, action, production and use.
Ms. Tasanee Jamjanya	Khon Kaen University	16-18July	General view of insects Field survey and insect classification Biology and ecology of insect pest in some economic crops
Ms. Nutcharee Siri	Khon Kaen University	16-18July	Biology and ecology of insect natural enemies Production of insect natural enemies Mass rearing technique and quality control
Ms. Prakaijan Nimkingrat	Khon Kaen University	16-18July	Mass rearing of some important insect parasites
Mr. Banpot	Kasetsart University	17-20 July	Biological control in Thailand : Education,

Napompeth			success story and trend to the future. Chair person: panel discussion on responsible and experience on biological control of each organization.
Mr. Chairat Kitivarapol	Farmer, Khon Kaen	19 July	Panel: Farmer experience on biological control
Ms. Apsorn	Mitrpol sugar Company, Chaiyapum	19 July	Panel: Private sector experience on biological control
Mr. Vorachai Manomuth	Biological control company, BKK	19 July	Panel: Biological control business
Mr. Ruth Morakot	DoA, Bangkok	19 July	Panel: DOA experience and responsible
Mr. Preecha Somboonprasert	DoAE, Bangkok	9,19 July	Panel: DOAE policy about food safety, IPM, GAP
Ms. Lawan Jeerapong	DoAE, BANGKOK	9 July	Panel: DOAE experience and responsibilities

Annex 2: Opening Remarks delivered at the Opening Ceremony

2.1 By Ms. Lawan Jeerapong, Director, Pest Management Division, DoAE

On behalf of the participants and organizers, I would like to express our gratitude to you for coming to this Opening Ceremony of the DoAE-FAO Regional Training on Biological Control.

As we all know, several pests and diseases having been causing great yield losses to farmers. In the last 15 years, farmers only used chemical pesticides as a major method to control their pests and diseases. With excessive reliance on the chemical pesticides, many more pest problems have emerged, mainly due to resistance development by the pests to the chemical pesticides. Also, other undesirable effects like increased health hazards to people and the environment have also emerged. And over time with more use of chemical pesticides the negative effects have become more obvious. To minimize their use, it is necessary to have better knowledge of other alternative control methods and their influencing factors, such as the impact on pest population dynamics, how they relate to the weather, etc. Implementation of these alternative methods could be promoted to increase profitability to farmers while minimizing the use of chemical pesticides and their negative effects in the environment.

In order to minimize losses caused by pests and diseases, it is necessary to use several methods that are favourable to the crop, but unfavourable to the pests or the diseases. Possible combination of control techniques in a particular cropping system may include cultural practices (e.g. crop rotation, use of resistant varieties, etc.), conserving natural enemies, and judicious use of chemical pesticides (which are only used when there is a real need). And when pesticides are used, they have to have a minimal impact on non target organisms and are acceptable by society. In principle, the farmers' crops must be protected to prevent unacceptably large yield losses and reduction in product quality

It has also increasingly obvious over the last decade that it is not possible to minimize the use of chemical pesticides in agriculture without alternative pest control methods that can effectively manage the pests and are cost effective. One potential alternative is biological control which uses living organism to keep pest populations below the economic threshold levels. Nowadays, there are many organizations already working on biological control, but more need to be done to advance the science of BC and to promote it, such that farmers can adopt and benefit from usng the biological control agents to help protect their crops from pests. Hopefully, through this Regional Training on Biological Control, participants will have the opportunity to share experiences and learn from one another on the wide ranging aspects of biological control, such as the concepts and principles, mass production of biological control agents, how to correctly deploy them, etc.

With this introductory remark, I would like to invite Mr. Preecha Somboonprasert, Director of Bureau of Agricultural Product Quality Development, DoAE, to now deliver his opening speech and to declare open the Regional Training on Biological Control.

Thank you.

2.2 By Mr. Preecha Somboonprasert, Director of Bureau of Agricultural Product Quality Development, DoAE.

Ladies and gentlemen, distinguish guests and participants,

First of all, I would like to say that it is my great honor to be here and to deliver the opening speech in this important Regional Training on Biological Control, and on behalf of the Thai Government, I would like to thank FAO for jointly conducting this training course with DoAE and to select Thailand as the host country.

As earlier mentioned by Director Lawan, the growing global concern on consumer's health and the need to protect the environment has triggered all stakeholders to develop an effective and efficient system to develop food safety measures and quality standards. The Ministry of Agriculture and Co-operatives in Thailand has responded with food safety policies of the Thai Government. All related agencies have already set about to develop the roadmap for improving and maintaining the quality of agricultural production from the "farm to table". Strategies and the mechanisms to achieve them have been identified and developed. Principally, IPM and biological control form the primary strategy in Thailand, with Q-GAP national standard certification of the farmer production when the requirements are fulfulled. The practice of biological control and IPM as part of GAP helps to ensure food safety and quality for consumers and exporters.

My Department concentrates particularly in this task. We have nine Pest Management Centers which have been producing and extending biological control agents for more than 12 years. Over time, many of the technologies have changed, and continue to change fast. As such, there is need to adapt the changes to our production system.

Currently, the most important goal is to promote as quickly as possible these activities to farmers for implementation at farm level. And this is done mostly through the Farmer Field School (FFS) since such a process is found to be the most effective tool to communicate with our farmers.

Because there are still many more technologies to be learnt and shared, I hope this Regional Training on Biological Control will enable all participants to achieve these goals, and I wish this training course every success in the endeavour. I also hope all participants will gain the shared experiences and new knowledge and would be able to implement them in their respective home country. With is remark, I would like now to declare open the Regional Training on Biological Control..

Thank you.

2.3 By Mr. Jan Willem Ketelaar, CTA, FAO Regional Vegetable IPM Programme.

Respected Director General of the DoAE, Respected Director of the Bureau of Agricultural Product Quality Development/DoAE, Director of the Regional Biocontrol Center in Khon Kaen, Resource persons, organizers and participants,

It is with pleasure that I welcome you all to the opening session of the Regional Training on Biocontrol here in Khon Kaen!

Pesticide abuse and overuse is still rampant in the Asia region. Farmers are overusing pesticides in desperate attempts to control pest and disease problems, often to no avail! Intensive use of extremely and highly hazardous chemicals by small-holder farmers is causing high incidence of farmer poisoning, causing serious disruptions in eco-system functioning and damaging the environment. Given the renewed attention and current prominent driving forces for pesticide risk reduction related to food safety, international trade facilitation and enduring environmental and health concerns, the need for strong Integrated Pest Management (IPM) and Good Agricultural Practices (GAP) farmer training programmes is greater than ever. Obviously, biological control is an important component in any well-developed IPM strategy.

FAO has been implementing IPM farmer training programmes in the Asia Region for the last 2 decades. The Farmer Field School has been a major training approach used for training farmers in IPM. As a result, farmers have been able to significantly reduce the use of pesticides, thereby increasing net returns, reducing pesticide risks to applicators, eliminating yield losses due to secondary pest outbreaks, improving the health of ecosystems, reducing negative impact of intensive agriculture on the environment and improving food safety due to reduced levels of residues on crop produce. IPM is GOOD for farmers and consumers alike and thus deserves full government support in terms of policy reform and resources to locally sustain such farmer education programmes.

Due to increased attention and investment of public and private sector resources, farmers increasingly have access to a range of newer options for pest and disease management. In their efforts to further reduce on farm use of pesticides, farmers should increasingly make use of biological control options to manage pest problems. It is therefore fitting that, within the context of the ongoing FAO support for the development of IPM in the Asia-region, this regional training is now organized to exchange successful biocontrol experience and to strengthen capacity building for strengthening biological control systems.

Thailand is recognized internationally for its wealth of experience in the field of novel options for pest management, most notably biological control. It is therefore fitting that FAO is co-organizing this international training with the Royal Thai Government and the Department of Agricultural Extension in particular. The diversity of biocontrol options available in the DoAE's 9 regional Pest Management Centers is truly mesmerizing. You will all have the opportunity to visit the DoAE's Biocontrol center here in Khon Kaen and study its work during the duration of this course. Also Khon Kaen University is internationally known for its expertise in sustainable agriculture and therefore the location of Khon Kaen for this training is even more fitting. I would like to thank the Royal Thai Government -and the DoAE Pest Management Center and the Khon Kaen University in particular- for co-hosting this training here in Khon Kaen!

This Training brings together a diverse group of IPM trainers from across Asia with a key interest and experience in biocontrol matters. Some of you are new to biocontrol, others will already have a wealth of experience to share during this training. May I encourage you all to share these experiences and learn from each other so that when you go back home you can make a real impact on strengthening biocontrol systems in your own country. May farmers benefit from increased knowledge and access on novel biocontrol options for pest management as a result!

Rest me to wish you all a fruitful and enjoyable training!

Annex 3: List of handouts and other useful information sources on biological control

3.1 Handouts

1. Chiradej Chamswarng. Microbial control for plant diseases.
2. Nutchareee Siri. Biological control, biology and ecology of insect natural enemies.
3. Nutcharee Siri, Viyawan Boontan & Saiphon Thodthasri. Rearing procedures of egg parasitoid *Trichogramma* sp.
4. Tasanee Jamjanya, Viyawan Boontan & Jirporn Sevana. Rearing procedures for earwigs: brown earwig *Proreus simulans* Stallen. and the black earwig *Euborellia* sp.
5. Nutcharee Siri & Jureet Rattanatip. Rearing procedures of predatory mite, *Amblyseius* sp, and coccinellid beetle, *Stethorus* sp.
6. Nutcharee Siri &Yuwatida Sripontan. Rearing procedures of coccinellid beetle *Serangium* sp.
7. Nutcharee Siri, Nuree Patthum & Saiphon Thodthasri. Rearing procedures of predatory bugs, predatory and phytophagous ladybird beetle (Coleoptera: Coccinellidae)
8. Tasanee Jamjanya, Prakaijan Nimkingrat & Viyawan Boontun. Field survey and insect classification.
9. Tasanee Jamjanya & Viyawan Boontun. Biology and ecology of insect pests from some important crops.
10. Nutcharee Siri. Rearing techniques and quality Control.
11. Nutcharee Siri & Ratree Phusri. Rearing procedures of diamond back moth parasitoid *Cotesia plutellae*.
12. Nutcharee Siri. Rearing of some parasitoids.
13. Banpot Napompeth. Thailand experiences in biological control.

3.2 Other information sources

3.2.1 Websites

CABI: http://www.cabi-bioscience.org
(This is managed by CAB International *and is great as a general resource, particularly for IPM and BC, including their applications by smallholder farmers)*
UC-Davis IPM: www.ipm.ucdavis.edu
CGIAR-SP-IPM: www.spipm.cgiar.org
For just one example of private sector involvement in commercialization of biocontrol agents, consult: www.koppert.nl

3.2.2 Reference Books and Manuals

Manual on biological control and biological control methods for insect pests in the tropics (1990). International Institute of Biological Control, UK.
(The manual is designed as a reference guide for the FAO-IRRI-IIBC Training Course on Biological Control in Rice Based Cropping Systems. It contains the basic concept of IPM and BC, biology of major natural enemy groups, advice on their collection, identification and rearing, methods for assessing natural enemy impact, general procedures for conservation, augmentation and introduction of natural enemies, ideas on showing BC to farmers, and sources of information on BC. Included are also specific examples from research on natural enemies, their assessment and use).
Handbook of Biological Control (1999) Thomas S. Bellows & T.W. Fisher (Eds), Academic Press, California, USA 1046 pp.
The Manual of Biocontrol Agents: A World Compendium (2004), Leonard G. Copping (Ed), British Crop Protection Council, UK 758 pp.
Biological Alternatives to Harmful Chemical Pesticides. IPM Research Brief # 4 (2006), The Systemwide CGIAR Program on Integrated Pest Management, IITA, Cotonou, Benin 24 pp.

3.2.3 Journals

1. Khon Kaen University Journal of Agriculture:
2. Kasetsart University Journal of Agriculture:
3. Cambodian Journal of Agriculture.

Annex 4: Protocols for mass production of BCA.

4.1 Entomopathogenic fungi:

4.1.1 Materials and general procedures

Collection: Fungal infected insects are collected from the field and placed in plastic bags. The cadavers need to be kept dry and cold. It is best to inoculate nutrient agar plates as soon as possible as the fungus can die or contaminants (from the soil or plant or other fungi on the insect) can grow if stored for long period.
(*Note** Aseptic techniques must be followed in every step).

Isolation and culturing:
Culturing medium: Potato Dextrose Agar (PDA)
Recipe:

- Boil 200g chopped potato in 1L water, remove the potato.
- Add 20g of Dextrose and 15g agar to the remaining water and stir to mix well.
- Gently heat the solution to melt the agar, remember *low* heat.
- Autoclave to sterilize the nutrient medium.

[*Note*: Now the nutrient solution is sterile you must keep it sterile (or contaminants will grow on the agar instead of your fungus). To keep the culture sterile you should do the next steps inside an inoculating chamber (fume hood or laminar flow cabinet)].

Warning: agar nutrient solution can get very hot, even when it is above 100^0C it may not be "boiling" and no bubbles will be present. It can peel skin off very quickly.

Once it is cool, pour nutrient medium into glass bottles and put in fridge until needed.
Gently reheat the nutrient agar (loosen the lid otherwise the bottle may explode spraying molten agar across the room) and pour into Petri dishes (20mL/plate) inside a fume hood.

Very carefully (not to collect contaminants) remove a very small amount of spores from these insect cadavers to inoculate the PDA agar. Fungal inoculated plates are then incubated at ~25^0C for 10-14 days until it sporulates.
Metarhizium has green coloured spores, *Beauveria* has white coloured spores and *Paecilomyces* has pinkish coloured spores.

Preparing stock solution from pre-cultured fungal isolate:

- Using a sterile spatula or loop, scrap spores from the PDA Petri dish and place in a small sterile glass beaker or bottle.
- Add 100mL of sterilized or distilled water and one drop of surfactant (detergent).
- Shake well to break up the spores.

Materials required for culturing entomopathogenic fungi:

- Whole rice, broken rice, maize or other grains
- Water,
- Plastic bag,
- Needle,
- Stapler,
- Autoclave,
- Electric rice cooker,

4.1.2 Culturing the entomopathogenic fungus *Metarhizium anisopliae.*

Mass producing inoculum for grain cultures:

- Prepare rice cooker, rice and sterilized inoculating equipment.
- Measure rice and water and place in rice cooker, 1:1 ratio.
- Cook the rice and allow to cool to about 40-50^0C
- Transfer 250g into plastic bags.
- Take bags and inoculum to inoculating chamber.
- Use 70% ethanol (alcohol) to clean the inside of the chamber, instruments and hands.
- Pippette 1mL of stock solution into each bag, fold the top of the bag and staple the bag closed quickly.
- Mix the bag well and make 10 pin holes at the top of each bag.
- Place the bags in the incubation room and lift the top of the bag to let air in.
- Incubate the bags for 10-14 days until green colour is seen; the green colour is the spores.

4.1.3 Culturing the entomopathogenic fungus *Beauveria bassiana.*

- Cook rice (3 rice:2 water) in a rice cooker for 15 minutes.

- Allow the rice to cool to 40-50^{0}C.
- Put 250 grams rice in one plastic bag.
- From your stock suspension inoculate the rice with 1mL *Beauveria suspension*.
- Using asceptic method, add 0.5 micro liter of *Beauveria* suspension to each plastic bag of rice.
- Seal the bag with staples.
- Prick the plastic bag with a needle making at least 15 holes.
- Mix by shaking gently the plastic bag for 1 minute.
- Set aside the plastic bag in the laboratory at 27-30^o C.
- Every 3 days, shake the plastic bag again for 1 minute.
- Repeat shaking the plastic bag at three days interval for 10-15 days.

4.1.4 Culturing the entomopathogenic fungus *Paecilomyces fumosoroseus.*
- Cook broken rice with water (1:2) in rice cooker.
- Allow the rice to cool to 40-50^{o}C, then place 250 g in a plastic bag.
- Make a small hole at the middle of the plastic bag with a scissors and cover the hole with plastic tape.
- Seal the open end of the plastic bag using staples.
- Using a pin to make 7-10 small holes at the upper portion of the plastic bag to ensure proper aeration.
- Put the plastic bag with cooked rice in an autoclave for sterilization at 121^{0}C and 15 lb/inch^2 pressure for 20 minutes.
- Open the hole at the middle of plastic bag and inoculate the rice with stock solution (1 ml $\simeq$ 10^9 spores).
- Cover the hole with plastic tape and shake gently. Then incubate at 25^{0}C for 10 days.
- Mix by shaking the culture every 3 days.

4.1.4 Harvesting the spores of entomopathogenic fungi.
- Cut the bag open and spread the rice and spores on a flat tray. Put this in a dry, cool room for 1-two days to remove any moisture (air conditioning helps but do not blow spores about every where).
- Place the grain in a sieve and shake, using a spatula to stir, to harvest the spores into a collection container. (Wear a face mask!)
- If you want to store the spores you need to dry them as much as possible (you can use silica gel or even kitty litter sealed in a small material bag) and put them into a sealed container and in the fridge. If the spores are very dry and very cool, this can be kept for up to 1 year.

4.2 Bacteria: *Trichoderma* sp.
- Soak sorghum in water for 12 hours.
- Pour out the water and let sit for 30 mins.
- Place 500 grams of sorghum in plastic bag and autoclave.
- Allow the sorghum to cool to 40-50^{0}C.
- Add 1 gram of *Trichoderma* stock culture.
- Incubate at room temperature for 5-7 days.
- When the culture turns green, apply in the field (broadcast, seedbed, planting hole, foliar spray)

4.3 Predators

The predatory bugs *Eucanthecona furcellata* (Pentatomideae) and *Syncanus* sp. (Reduvideae) are two common beneficial insects that contribute to IPM strategies by preying on pest insects such as Lepidoptera larvae. These predators use a proboscis to feed, sucking the fluid from the bodies of larvae.

The lifecycle of the predatory bug *E. furcellata* involves an egg stage lasting 5-8 days followed by five instar nymph stages lasting 16-23 days.
The life cycle of the assassin bug *Syncanus* sp. involves a 3-5 days egg stage followed by five instar nymph stages lasting up to 103 days.

Meal worms or other beetle larvae are suitable prey food for these predatory bugs. Plastic boxes (11cm x 11cm x 11cm) with a mesh covered window at the top are suitable containers for bug breeding. Wrap wet tissue or cotton wool around the cut end of a small leaf stem, then use foil wrap to attach the cotton to the stem. Place one stem in each container box along with adult bugs and larval prey at a 1:2 ratio. Replace the larval prey each day and replace the leaf stem every two days.

Allow the adults to lay eggs on the sides of the box, then transfer the adults to a new box so they can lay more eggs. As the nymphs hatch introduce small larvae as prey.

Field release of predatory bugs differs for each crop. Vegetable crops need to be monitored for pest larvae, when 1-2 third instar larvae are found per meter, release 100 bugs/1600m^2. In fruit crops release 100 bugs/m^2.

Annex 5: Curriculum, training models and session guides

Group 1: Training course on BC of pests using entomopathogens.

At the end of the course the participants shall be able to learn the different entomopathogens, their uses and their methods of mass production for BC of pests.		
Duration: 5 days	25 - 30 technicians and IPM trainers	Duration
Day 1	• Introduction to BC using entomopathogens (lecture). • Field application of entomopathogens for BC (field/lab work)	½ day ½ day
Day 2	• Fungal entomopathogens for BC of pests (*Metarhizium anisopliae, Beauveria bassiana,Paecilomyces fumosoroseus)* (Lecture) • Mass production of fungal entomopathogens (Laboratory)	½ day ½ day
Day 3	• *Bacillus thuringiensis* for BC of pests. Uses, application and production of NPV for BC. (Lecture) • Laboratory exercise on Bt application for DBM management. • Aplicaiton of NPV for control of cutworm, cornear worm and beet army worm.	½ day ½ day (for both)
Day 4	• Microbial agents for disease management (Lecture and laboratory exercise)	1 day
Day 5	• Presentation of plans for utilization and mass production of entomopathogens for BC (including field exercise and training exercise)	1 day
Budget	$2000 (food and accommodation $1600, materials $400)	
Comments: Participants must be able to: • Understand production, formulation and application of the BCA (lethal dose, concentration, stickers, surfactants) • Evaluate the course • Evaluate the entomopathogens with respect to health		

Group 2: Principles of BC:

Curriculum workshop 2 working days, 5 – 10 people.			
Training of Trainers (ToT) 7 days, 25 participants.			
Day 1	Introduction	Brain storming	½ day
Day 2	• Challenging pests of the country and basic problems. • Pest management approaches applied to date	• Discussion/presentation	½ day
Day 3	• Problems related to health and the environment	• Lecture and discussion	½ day
Day 4	Need of BC/basic approaches of BC (Lecture)	• Natural BC & applied BC • Mass rearing of predators, parasitoids, antagonists, NPV, Bt • Utilization of different traps	
Day 5	• Field survey and monitoring	• Group exercise	1 day
Day 6	Application strategy of BC in fields of farmers	• Individual exercise	1 day
Day 7	• Administration matters, evaluation		1 day
Comments: • Need evaluation of training, • To outline separately the detailed lesson plans, topics and objectives and how each will be achieved • To list materials (flip chart, video, handouts, lectures, field trip, etc.) • Prepare required budget			

Group 3: a. ToT course on predators and parasitoids

3 days	Dept. Agriculture and Extension, farmer trainers etc	
Day 1	• Introduction to insects and classification • Introduction to the predators and parasitoids	½ day
	• Field survey for the insect pests and natural enemies • Practical session on field survey, insect pests and natural enemy identification	½ day
Day 2	• Mass rearing techniques for predators • Practicals session - mass rearing of predators	½ day
	• Mass rearing procedures for parasitoids • Practical session on mass rearing of parasitoids	½ day
Day 3	• Technique on field release of natural enemies and quality control	½ day
	• Practical session on field release of natural enemies • Evaluation	½ day
Comments: • To outline separately the detailed lesson plans, topics and objectives and how each will be achieved • To list materials (flip chart, video, handouts, lectures, field trip, etc.) • Prepare required budget • See also comments of Group 3:b below.		

Group 3: b. Farmer training on insect pests, predators and parasitoids

Duration 2 days	25 – 30 farmers	
Day 1	• Introduction to insect pests, predators and parasitoids • Practical session on field survey	½ day
	• Practical session on mass rearing of predators • Practical session on field release of predators	½ day
Homework: How do the predators function?		
Day 2	• Practical session on mass rearing of egg parasitoids • Practical session on field release of egg parasitoids	½ day
	• Practical session on mass rearing of larval parasitoids • Practical session on mass release of larval parasitoids • Discussion • Evaluation	½ day
Comments: • IPM trainers should know more and therefore to provide more details and background • Need to include some development of exercises for trainers and farmers so they can see how the predators eat prey and parasitoids attack hosts • Revisit the field to see predators/ parasitoids after several days, e.g. return to look at presence/absence of *Cotesia* cocoons. • Possibly longer duration for training needed and to include a session on conservation • Time allocation: 30% for mass rearing; 70% for preparation of hosts on natural or artificial hosts/prey • Be aware that field release will depend on natural enemy availability, e.g. 10 today, 150 next week, etc. • Must monitor sex ratio because excessive of males is useless (Note: Crowding induces moer males and will affect the production quality and quantity. • See also comments of Group 3:a above.		

Annex 6: Questions, answers and comments in panel discussions.

Questions	Answers	Comments
How important are insect resistance and resurgence?	Many pesticides were used from 2000–2004. Then IPM was adopted and given attention. After this, the problems of insect resistance and resurgence subsided.	Presently, there are no good record keeping of the amount of pesticides that are stored and use by farmers. And this is still a major problem.
In Bangladesh, farmers use pesticides but found no control of BPH. What is the experience in Thailand?	The experiene here is that even with high pesticide use little BPH control is achieved, for example, in the central part of Thailand rice crops are sprayed many times with many chemicals but they are still not effective. In the future, use of chemical pesticides will be less because of the introduction of effective BCA to them.	
Metarhizium can work effectively in many ways. However, according to farmers I work with, the fungus is more costly than chemical pesticides. But your research shows that applying entomopathogenic fungus is cheaper. How can we manage to achieve the same low cost?	If you use the very virulent isolate you would use less and the cost will be reduced. If you use an avirulent/low virulent isolate the cost would increase because you have to apply more to reach an effective dose. I recommend you first conduct some research to identify a more virulent isolate before mass producing it..	The control will be economical if enough conidia can be produced on 7 kg of rice. Presently, we do not know exactly how many isolates we have. We are continuously looking for virulent isolates, studying them, especially their formulations and applications for furture use.
In China many farmers want to use BC. However, the government does not provide support to make BCA more affordable. The farmers felt the costs are too high and so BCA are less attractive. Is this the same in Thailand and what can be done?	In Thailand,the farmers in the sugarcane industry pay a levy towards the sugarcane fund which is used for R&D. Researchers therefore can investigate ways to minimize the costs of BCA as well as finding means to overcome other problems faced by farmers and the sugarcane industry. Athough the levies collected are sufficient, efforts are always made to source more funds elswhere wherever possible.	At 65 tonnes sugar x 3 baht, the fund generated is about 200 million baht/year which is fairly substantial. Previously centralized, this fund is now decentralized according to location. To access these funds each region needs to submit a project proposal. For example, if the proposel is approved, money will be provided to Khon Kaen University to conduct research on some local problems that can provide future protection of the sugarcane industry in Khon Kaen.
What are the constraints in the implementation of BC in Thailand?	The limited knowledge and low level of education of farmers make it very difficult to train farmers and to share their knowledge, sometimes even in FFS.	The nature of BC is more complex for farmers to learn. With chemicals pesticides, they only need to open the bottle, mix and spray. With BC, they need to have host plants, pests and the BCA, and need to understand each of the components. Thus, convincing farmers on BC is only one issue. A greater problem is how to convince politicians who formulate the pesticide regulations and policies and control the funds.
Is it better to use one or several BCA in an IPM strategy? For example, at	A range of BCA is always better. Cane plantations in Thailand are different from other countries. We have diversity in our fields, other	For *Trichoderma*, this is usually applied only once. In the case of parasitoids, the

Mitr Phol you use *Cotesia*, *Trichoderma* and *Metarhizium* in the field.	plants including rice, fruit trees, wheat, cassava and other crops. In other countries there is only cane (monoculture) This is why we promote BC in every crop; they all work together to protect the crops and maintain the parasitoids and predators.	availability of flowers and nectar food in the field is crucial.
Do you provide extra honey dew or nectar for parasitoids? And what is the release rate?	No, only natural flower source. In terms of release rate, we first survey the field. The data provide the release rate. In 2000-2001 we needed to release 10,000-60,000 each month. But now the pest population is reduced and we have surviving natural enemies in the field. So, we now release much less and currently we monitor and release when pest infestation reaches 5%.	
Can you tell us more about living mulches, please.	This is a new project and we needed to conduct many surveys, consider many designs, and crops. We considered IPM from the beginning, well before the surveys. Living mulch is any crop or plant that can live with your crop and beneficial insects can benefit from them. An example is a fast growing plant with compatible root system that protects soil erosion, suppress weeds does not compete for nutrients or water and provides food for beneficial insects. It is necessary to choose the right plant species that will best complement your main crop.	In living mulch, conservation BC is the main focus.
Before the importataion of the *Asecodes* parasitoid from Vietnam for the coconut hispine beetle, did DaA first survey for the presence of the said parasitoid in Thailand? In Cambodia, this parasitoid is not effective as many of the coconut trees have died from severe attack by the beetle..	A survey was first conducted but *Asecodes* was not found. But another species was found in the southern part of Thailand. For the importation, the ISPM #3 was followed. Host specificity was carried out and there was no problem found. Also, Vietnam provided good cooperation concerning the parasitoid importation. As we continued with the work on the parasitoids, not so many plants have died. Only a few seedlings or young plants died so far. Now we are trying to confirm the establishment of *Asecodes* in Thailand. We have made many releases augmentatively so far, though the parasitoids can disperse by themselves from the north to south. If releases are made on a small scale the population will last only 3 or 4 months. However, when applied widely at provincial level you can get better control. On a small scale the damage will still be present, but it will be much reduced when the community approach is adopted, which can be very successful. Remember that BC has to be implemented on a large scale. It is necessary for the BC community to work closely together. If only one person considers BC the odds are against the BCA and it would not be successful. Many people are now working on the hispine beetle and efforts are being made to develop a coordinated management programme against it.	When importing BCA, they should preferably be hand-carried.
The citrus greening disease is very important in Cambodia.	Practically all citrus cultivation in Southeast Asia suffers from the greening disease.	

What is the situation in Thailand and what can one do?	Community approach (and not individual approach) to dealing with the problem should be adopted. In general, profits remain high until after about 5-6 years. Then, when the disease shows up, losses will occur. Sometimes the whole crop may die out. It is important for the government to initiate an eradication programme which must take into consideration the plant, the disease and the vector. The eradication programme must also be implemented on a large area and not only in a localised area. Currently, citrus plantations are declining in the central area of Thailand. Most growes would do 'roaming cultivation' across the country about every six years	
How do you apply BCA with the help of a surveillance and forecasting system?	The key concept is to balance nature, with natural enemies as part of the whole system. Many researchers try to develop monitoring systems for this, but farmers often face difficulties in applying them because the systems are too high-tech and complicated. From a practical viewpoint, whatever systems to be developed for use by smallholder farmers must be within their knowledge. It is important that farmers are able to monitor and be responsible, even though monitoring can be expensive. This is because understanding pest-natural enemy population dynamics is important for successful pest management in an ecologically based IPM system. Based on my 25-year experience, BCA can succeed only as a community approach. A better option is therefore for all involved to collaborate.	Forecasting is an old concept. The most practical way is called 'scouting' where you move through the field and survey for 'good' and 'bad' insects. The field monitoring is done on a calendar basis, and based on the relative numbers of 'good' and 'bad' insects, an IPM decision is made about what action to take. When there is no problem, taking no action is still action and is a good way to protect the crop.

Annex 7: Closing remark delivered by Mr. Udom Jirasawetkul (Director of Regional DoAE) at the Closing Ceremony

Ladies and gentlemen, distinguished guests and participants,

First of all, the DG Mr Songsak is unable to attend today's closing ceremony, I would like to apologise on his behalf.

It is my great honor to be here and to deliver the closing speech on behalf of the Royal Thai Government. I would like to thank FAO for their support to conduct this training course and for selecting Thailand as the host country. From the report I noticed there are 26 participants from nine countries attended this training. This diverse group will bring together much experience and knowledge of biological control concepts and I hope after this workshop you will be able to take even more back to your home countries.

I hope the knowledge and experience from this training will help you to strengthen your work and help farmers successfully use biological control strategies to reduce pesticide use in the future. This will not only help farmers to reduce the costs associated with chemical pesticides but also avoid insecticide resistance, provide 'safe' products to the consumers and protect the environment.

As we are all aware, there are still many more biological control technologies to be learned and shared. The principles you've learned here are just the basics. They were provided to give you a clear understanding on biological control strategies employed here in Thailand. I hope that after you go back to work, you can learn more on your own and the good relations and networking established in this training will help to facilitate the knowledge exchange among participants, and with researchers back here in Thailand.

This will help everybody to improve biological control technology and reach the common goals of protecting our environment and producing clean food for our consumption.

Finally, I would like to again thank FAO for co-organizing this valuable training course. I hope that this training will promote strong and lasting collaboration. I wish you all a safe and enjoyable return journey to your home country and now, I would like to announce the closing of the training course. Please enjoy the party tonight!

22.8.2007