Microbial control in Southeast Asia

Ole Skovmand *

Intelligent Insect Control, 118 Chemin des Alouettes, 34170 Castelnau le Lez, Montpellier, France

Received 19 January 2007; accepted 12 March 2007
Available online 27 March 2007

Abstract

Beginning in the 1980s, concerns about the deleterious effects of synthetic pesticides have driven a significant Southeast Asian research and development effort directed towards alternative pest control strategies, including the use of microbial control agents. Despite this effort, use of microbial control agents has grown slowly in the region. This is the result of an interplay between internal factors such as economics, national research programs, farmer education, manufacturing capabilities and regulatory frameworks, and external factors such as the influence of neighboring countries (particularly China), the availability of competitive pest control products, import regulations on pesticide residues and the activities of donor agencies. The role of these factors in providing both incentives and barriers to the adoption of microbial control are explored, and examples of promising projects are examined as a means of pointing the way forward towards increased progress in the future.

© 2007 Elsevier Inc. All rights reserved.

Keywords: Microbial control; Southeast Asia; IPM; Integrated pest management; Biopesticide; Biological control

1. Introduction

Southeast Asia is a region characterized by rapid industrial development, but also by a strong agricultural sector that is increasingly focused on export. Over the past twenty years, there has been significant effort—at both a regional and national level—in biopesticide and integrated pest management (IPM) research, with universities, government agencies and donor groups all involved. Regulatory guidelines for microbial control agents are generally quite favorable as well. Despite this level of attention at the research and policy levels, it has not yet translated into dramatically increased usage patterns in the field. Although sales figures are difficult to obtain, it is likely that sales of biopesticides has been more limited in Southeast Asia than it has been on a worldwide scale, where it is currently estimated that biopesticides make up 1% of all global pesticide sales (Gelenter, 2005). Local production has been established on small scale in several of these countries with government or donor support, though mostly with limited success. Some of the main factors at play in this discrepancy between the desires of the research and policy community vs. the reality of the field experience are similar to those explored for other regions of the world, while others are unique to Southeast Asia, as will be described in more detail below.

2. Regional initiatives and institutes

The driving forces behind microbial control research, development and extension programs in Southeast Asia have come primarily from the top down, in the form of regional and national research and policy initiatives. These in turn have been driven by concerns about the negative role of conventional pesticides in human and environmental safety, as well as in the development of pest resistance.

2.1. The food and agriculture organization of the united nations (FAO)

In 1986, the FAO became the first high visibility international organization to draw attention to the need for

* Fax: +33 467605425.
E-mail address: ole.skovmand@insectcontrol.net
alternative approaches to pest control in Southeast Asia. This came about when a combination of pesticide poisoning incidents and resistance-related pest control failures (especially among brown plant hopper, *Nilaparvata lugens*) occurred in Indonesia during the 1980s. The Indonesian government responded by banning 57 pesticides and cutting insecticide subsidies, especially from rice, and as a result, saved 120 million (USD) per year in government subsidies and pesticide cost reductions for farmers. They partnered with FAO to introduce the concepts of IPM to farmers and agricultural research institutes. The model of using farmers field schools (FFS) for educating farmers in IPM and training them in more systematic observation and use of experience has become a model. A detailed description is given in the Indonesia country report on the program (Alimoeso et al., 2001).

Since then, FAO has introduced the model further into Southeast Asia and India. The general thrust is to work with national governments, donors and non-governmental organizations (NGOs) to encourage national research programs, create national IPM programs, and perhaps most importantly to introduce the concept of FFS. Since 1989, over one million farmers in Indonesia alone, and several million across Southeast Asia have been trained in these schools in the principles of IPM, including biological and microbial control (Alimoeso et al., 2001).

But while the importance of FAO programs in the adoption of IPM and the reduction of pesticide usage have been well documented, and while microbial pesticides have been a component of their training programs, there is unfortunately little quantitative information available on the part that microbial pesticides have played in this success. Several FAO websites and information booklets include information on microbial control, most notably Taborsky’s (1992) manual on “Small-scale processing of microbial pesticides”. This manual takes the reader through principles of production including formulation and quality control. It provides a broad range of information—from general principles and guidelines down to recommended additives for improved deposition of sprays on foliage—but it does not provide specific information on production of microbial control agents.

2.2. The international rice research institute

With its headquarters in the Philippines, IRRI conducts research and provides advice on rice growing, but also focuses on development of improved rice varieties. They have a heavy emphasis on development of new genetically engineered rice varieties, for which they hold several patents. Specifically, the institute works on transgenic hybrid rice strains that express a fusion gene of the lepidopteran-active *Bacillus thuringiensis* (*Bt*) toxins Cry1Ab/Cry1Ac for control of rice stem borers (*Scirpophaga, Chilo* and *Sesamia* spp.) and rice leafrollers (*Cnaphalocrocis* and *Marasmia patnalis* spp.) (Tu et al., 2000). These are some of the most destructive pests of rice in the region.

To reach IRRI’s worldwide client base, the institute provides extension services electronically, via a website known as “The Rice Doctor”. The information presented is philosophically in tune with the use of microbial control agents and other biological control strategies, but recommendations focus heavily on the use of resistant varieties and chemical pesticides. This is partly a function of the lack of available products, as well as the difficulty in controlling boring pests of rice with spray applications. It is for these reasons that the institute has intensified their research and development efforts on transgenic rice that delivers *Bt* toxins internally.

2.3. The food and fertilizer technology centre (FFTC)

FFTC in Taiwan is an international information center that provides educational and information services to farmers in the Asian and Pacific regions. The Center is supported by regular contributions from the governments of Japan, Korea, the Philippines and Taiwan. It also receives contributions on a project basis from national research and educational institutes in Indonesia, Malaysia, Thailand and Vietnam. Many of the courses and publications that it provides deal with biological and microbial control of pests.

2.4. BIOTEC

BIOTEC is a regional biotechnology research center in Bangkok, Thailand. It hosts a research park with high technology facilities where public and private institutes and companies work. They also organise regional courses in IPM and microbial control. Since 1996, the center has supported a culture collection of fungi, including 6000 strains of entomopathogenic fungi, which they say is the biggest collection in the world. The culture is kept in liquid nitrogen, at ultra-low temperature or in liquid paraffin, and is maintained at the Biotech Bangkok Herbarium in Pathumthani, Thailand.

2.5. Initiative on commercialization of biopesticides in Southeast Asia

The initiative, “Commercialization of Biopesticides in Southeast Asia” was implemented by the German government agency GTZ (German Technical Cooperation) in 2003. Based in Bangkok, Thailand, the goal is to bring biopesticides (microbial control products, pheromones, natural enemies) to the Southeast Asian marketplace by providing technical support to private companies and government institutions who share this goal. Technical expertise is available in areas such as mass production, formulation, product evaluation, regulatory strategies and business and marketing efforts.
3. National research programs and institutes

National IPM programs exist in all Southeast Asian countries, and local research institutes are becoming more and more involved. Most have at least some effort directed towards biopesticides. There is of course a big difference in national funding, so that very poor countries like Cambodia struggle, while richer countries such as Thailand have active and productive research programs. Programs are often co-ordinated with FAO, and in the poorer countries, with support from bilateral programs from Europe, the US and Japan. Non-governmental organizations are frequently participants and/or donors in national IPM programs as well. Research activities of some of the key national efforts are described below.

3.1. Thailand

In Thailand, there are several large and very competent groups conducting research, development and extension work on microbial control.

- At Mahidol University, a group is working on *Bt* subspp. *israelensis* for control of the *Aedes* mosquitoes that transmit dengue, a very important arbovirus disease in Thailand.
- At Kasetsart University the focus is on the three-dimensional structure, mode of action and insect specificity of *Bt* Cry toxins. There is also a smaller group working on *Bt* subspp. *israelensis*.

The Biocontrol section of the Thai Department of Agriculture conducts applied research on nuclear polyhedrosis viruses (NPVs), fungi and *Bt*. The extension service of the same ministry has a project to educate farmers on the use of microbial pesticides, and to help in the establishment of small-scale biopesticide production units. The production efforts are currently focusing on the fungi *Trichoderma harzianum*, *Beauveria bassiana* and, to a lesser extent, *Metarhizium* (Drs. A. Upanikorn and L. Jeerapong, personal communication, March, 2007).

3.2. Malaysia

The government stopped subsidizing synthetic pesticides in 1999 which by itself has led to some restriction in pesticide use. As the biggest palm oil producer in the world, Malaysia has a large effort, supported by government and private funds, on biological control of pests of palm oil and other crops.

- Nationally funded microbial control projects include use of *Metarhizium* against the coconut rhinoceros beetle, *Oryctes rhinoceros*, and lepidopteran-active strains of *Bt* and *Beauveria bassiana* against bagworms (*Metisa plana*), an oil palm pest that has developed resistance to many insecticides and where insecticide mis-use has resulted in government restrictions on conventional pesticides. In addition, there is ongoing work on control of nettle caterpillars, *Setora nitens* with *Bt* (Moslim et al., 2004).
- A major dengue outbreak in Malaysia in 2005 resulted in the first large scale applications of *Bt* subspp. *israelensis*, which were combined with fogging with conventional insecticides for a fast knock-down of mosquito populations. It is not known at this point whether this program has been further expanded.
- A U.S. Department of Agriculture-funded project (Vega and Posada, 2005) used *Beauveria* for a cocoa seedling treatment to control cocoa pod borer (*Conopomorpha cramerella*). In another project, a research group tested *Bt* Cry toxins against the cocoa pod borer with the intention to express these in cocoa plants, if regulations ever allow this (Santoso et al., 2004).
- At the Institute for Medical Research in Kuala Lumpur (Dr. Lee Han Lim, personal communication), there are several ongoing vector control projects. These include applied work with *Bt* subspp. *israelensis* and other microbials for control of the vectors of malaria, dengue, filariasis and Japanese encephalitis, as well as commercial production of local isolates of *Bt* subspp. *israelensis*. More basic work is also being carried out on isolation and characterization of mosquito-cidal bacteria such as *Clostridium bifermentans*, *Bt* varieties *jegathesan*, *pahangi*, and *malaysiensis*, and *Burkholderia pseudomallei*.
- Meanwhile, the government is working on guidelines for biotechnology and genetically modified microbes and plants. A national committee has suggested procedures and public information systems to this end (United Nations Development Programme for Malaysia, 2005).

3.3. Vietnam

Vietnam has several active research programs that focus on *Bt*, NPVs and entomopathogenic fungi for agriculture and mosquito control.

- There have been several initiatives to start local production of NPVs, *Bt* and *Beauveria* as “side businesses” in national research institutes, which is a standard way of trying to create extra income in these institutes. A review of many of these projects is given in a report by Khanh (2002). It is not clear, however, that these products are regularly used by farmers.
- Other biopesticide efforts are carried out at the Cuu Long Delta Rice Research Institute where it has been reported that *Beauveria* can be produced cheaply and is effective against brown plant hopper in the humid environment of paddy rice. *Beauveria* was also later found to be effective against rice earhead bug, *Leptocorisa acuta*, a pest that is important in the area (Nguyen and Vo, 2005).
Small-scale production of insect pathogens was investigated in a cooperative project funded by the Danish International Development Agency (DANIDA) and coordinated by Intelligent Insect Control, and included four Vietnamese institutions (Hanoi National University, Food and Industry Research Laboratory, National Institute of Plant Protection and the Plant Protection Department). The project resulted in production of small amounts of *Bt* subsp. *kurstaki* HD-1, a product registration for this strain and a feasibility study that showed that the locally produced product was price competitive with conventional insecticide applications.

Vietnam also has projects on the use of genetically engineered green algae that express the *Bt* subsp. *israelensis* gene (Vo Thi Thu, personal communication). The goal is production of a self replicating organism that can control mosquito larvae in puddles and containers. Vietnam has not yet developed a policy for genetically modified organisms, so the prospects for this approach are currently unclear.

### 4. Transfer of microbial control to the field

There are several biopesticide products that are registered and commercially available in Southeast Asia, with imported products based on lepidopteran-active strains of *Bt* the most widely available (Table 1). Despite the variety of products though, most workers in the area estimate that usage and sales are surprisingly low (Grzywacz, 2004; Jakel, 2004). Exact figures are not available, as comprehensive reports on microbial control usage and product sales in Southeast Asia are difficult, if not impossible to obtain. This is primarily because sales of these products are not tracked by any centralized organization, a task that would be extremely complex, since most microbial agents are imported, and then sold under many different names and labels by small agrichemical distributors. Localized production efforts, either by farmers, local governments or small private companies also exists (Grzywacz, 2003), but the volume of material produced and used has also not been quantified.

The discrepancy between the emphasis that biopesticides receive in research and policy institutions vs. their actual adoption in the field deserves attention, so that future efforts can address the deficiencies that have led to this state of affairs. The example of Thailand, where biopesticides have received strong support from international organizations as well as the national government, is illustrative of some of the barriers that are faced, as well as some potential solutions.

#### 4.1. The Thai experience

Starting in the late 1980s, the Thai government, in response to resistance-driven pesticide failures, invested in a national biocontrol program. Several imported commercial microbial control products were registered (Table 1), with government support (Grzywacz, 2004). But the government was also interested in supporting national production of biopesticides, based on the logical assumption that locally produced materials would be less expensive and also more aligned with the needs of local farmers. Projects funded at universities and within the Department of Agriculture led to isolation of local strains of insect pathogens (such as the NPVs of the cotton bollworm, *Heliothis armigera* and the beet armyworm, *Spodoptera exigua*) and construction of pilot production facilities for NPVs (at Kasetsart University in Bangkok) and *Bt*s (in Chiang Mai) (Grzywacz, 2004).

But the locally produced products have struggled. First, it has been difficult to generate enough profit to sustain production facilities that are wholly devoted to biopesticides, but that serve such a small market. And the variable quality of the products, most usually due to microbial contamination and/or low potency (Jenkins and Grzywacz, 2000), has made farmers wary of purchasing them.

<table>
<thead>
<tr>
<th>Country</th>
<th>Organism</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thailand</td>
<td><em>Bacillus subtilis</em></td>
<td>Plant diseases</td>
</tr>
<tr>
<td></td>
<td><em>Beauveria bassiana</em></td>
<td>Psyllids, mites, whiteflies, thrips</td>
</tr>
<tr>
<td></td>
<td><em>Bt</em> subsp. <em>aizawai</em></td>
<td>Caterpillar pests</td>
</tr>
<tr>
<td></td>
<td><em>Bt</em> subsp. <em>kurstaki</em></td>
<td>Caterpillar pests</td>
</tr>
<tr>
<td></td>
<td><em>Bt</em> subsp. <em>tenellus</em></td>
<td>Flea beetles</td>
</tr>
<tr>
<td></td>
<td><em>Heliotris armigera NPV</em></td>
<td><em>Heliotris armigera</em></td>
</tr>
<tr>
<td></td>
<td><em>Spodoptera exigua NPV</em></td>
<td><em>Spodoptera exigua</em></td>
</tr>
<tr>
<td></td>
<td><em>Spodoptera litura NPV</em></td>
<td><em>Spodoptera litura</em></td>
</tr>
<tr>
<td></td>
<td><em>Steinernema carpocapsae</em></td>
<td>Weevils, flea beetles</td>
</tr>
<tr>
<td></td>
<td><em>Steinernema thailandense</em></td>
<td>Weevils, flea beetles</td>
</tr>
<tr>
<td></td>
<td><em>Trichoderma harzianum</em></td>
<td>Plant diseases</td>
</tr>
<tr>
<td>Philippines</td>
<td><em>Bt</em> subsp. <em>kurstaki</em></td>
<td>Caterpillar pests</td>
</tr>
<tr>
<td></td>
<td><em>Bt</em> subsp. <em>aizawai</em></td>
<td>Caterpillar pests</td>
</tr>
<tr>
<td></td>
<td><em>Paecilomyces lilacinus</em> (strain 251)</td>
<td>Plant parasitic nematodes</td>
</tr>
<tr>
<td>Vietnam</td>
<td><em>Bt</em> subsp. <em>kurstaki</em></td>
<td>Caterpillar pests</td>
</tr>
<tr>
<td></td>
<td><em>Bt</em> subsp. <em>T 36</em></td>
<td>Caterpillar pests</td>
</tr>
<tr>
<td></td>
<td><em>Bt</em> subsp. <em>aizawai</em></td>
<td>Caterpillar pests</td>
</tr>
<tr>
<td></td>
<td><em>Beauveria bassiana</em></td>
<td>Broad pest spectrum</td>
</tr>
<tr>
<td></td>
<td><em>Metarhizium anisopliae</em></td>
<td>Broad pest spectrum</td>
</tr>
<tr>
<td></td>
<td><em>Heliotris armigera NPV</em></td>
<td>Cotton bollworm</td>
</tr>
<tr>
<td></td>
<td><em>Spodoptera litura NPV</em></td>
<td>Armyworm</td>
</tr>
<tr>
<td></td>
<td><em>Chaetomium cupreum</em></td>
<td>Plant diseases</td>
</tr>
<tr>
<td>Indonesia</td>
<td><em>Bt</em></td>
<td>Caterpillar pests</td>
</tr>
<tr>
<td></td>
<td><em>Beauveria bassiana</em></td>
<td>Broad pest spectrum</td>
</tr>
<tr>
<td></td>
<td><em>Gliocladium spp.</em></td>
<td>Soil-borne plant diseases</td>
</tr>
<tr>
<td></td>
<td><em>Trichoderma koningii</em></td>
<td>Plant diseases</td>
</tr>
</tbody>
</table>
starts with a good quality culture. The Thai universities have also created a consultant service for local private companies to improve their production procedures and quality control management. (Dr. L. Jeerapong, Thai Ministry of Agriculture, personal communication). The initiative is still very new and the outcome has not been evaluated, but the oversight and responsiveness of the Thai Ministry as well as their financial support and their focus on high quality local production bodes well for the future.

5. Incentives for adoption of microbial control in Southeast Asia

5.1. Motivation

Widespread problems with pesticide poisonings, pesticide resistance and food and environmental safety were the triggers that over 20 years ago motivated governments, researchers, NGOs and donors to explore alternatives to pest control with conventional pesticides. As described above, this has resulted in many active research and extension programs throughout Southeast Asia that have isolated and engineered new insect pathogenic microbes, investigated their basic biology and genetics, trained farmers in their use and devised improved methods for their production, formulation and application. This research is the necessary basis from which farmer education, local production and on-farm use flows.

5.2. Regulatory guidelines

National governments have also been supportive of biopesticides in terms of their user-friendly and streamlined regulatory systems. For example, Bt products have been registered in several Southeast Asian countries based on data that is publicly available in the scientific literature. In Vietnam, the registration of one Bt strain can be used to support product expansion to include strain variants, with only efficacy data required to complete the registration. Among Southeast Asian countries, the Philippines have the most detailed biopesticide regulatory guidelines, with procedures for semiochemicals, biochemical products, microbial products and macrobials (Jakel, 2004). If the use of biopesticides is to increase across the region, however, harmonization of regulatory procedures, across national boundaries will be critical.

In contrast to biopesticides based on naturally occurring microorganisms, guidelines for approval of the production and import of genetically engineered crops are more restrictive. In Southeast Asia, the Philippines is the only country that allows farmers to grow genetically engineered crops, though several nearby countries—most notably China—are heavily involved in biotech crop production (James, 2006). Experimental trials with genetically engineered organisms are permitted in certain countries, including Thailand, Indonesia and Vietnam, and several Southeast Asian countries permit the import of genetically engineered foods, including Cambodia, Laos, Indonesia, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam (Jakel, 2004).

6. Barriers to adoption of microbial control in Southeast Asia

Despite significant research effort, a need for safe pest control products and an inviting regulatory atmosphere, microbial insecticides are not widely used in Southeast Asia. The barriers to adoption are described below.

6.1. Economic assumptions

There is a generally accepted, but probably erroneous belief that high value (organic or residue-free) produce grown for export is a growing and viable market for use of biopesticides. On the basis of this assumption, the value of pest control alternatives, such as biopesticides, is set unrealistically high.

The reality is that most farms in the region are very small, and that impoverished farmers frequently cannot afford even the cheapest generic (off-patent) chemical pesticides. Pesticide products—both chemical and biological—that are sold through the traditional agrichemical chain of Western manufacturers and local distributors, are simply out of reach, financially, for most farmers. The percentage of vegetables that are produced for export (and whose value could hypothetically drive biopesticide development) is quite low. For example, Thailand exports many agricultural crops, but only 2.88% are high value vegetable crops (Nath, 1999, FAO, 2004a). This is not sufficient to drive development of biopesticides, though this situation may gradually change [for example, an FAO initiative to increase organic farming in Southeast Asia was recently initiated (FAO, 2004a)]. In the near term, though, if biopesticides are to become more widely used in Southeast Asia, they must cater—in terms of product price, availability and performance—to those small farmers who grow crops for subsistence and/or domestic use.

6.2. Competitive products

The IPM focus of governments and national programs are frequently at odds with the activities of the growing agrichemical industry, whose representatives far outnumber extension and university staff in Southeast Asia. Generic (off-patent) pesticides are now widely available, and are much less expensive than microbial-based products. Even less expensive are pesticides that are illegally imported from countries such as China and India. These products are formidable competitors for biopesticides.

6.3. Imported vs. locally produced products

To meet the demand for cheaper products that are tailored to fit local farmer’s needs, local production of biopesticides seems to be the answer. In fact, without some
success in decreasing the cost of biopesticides, adoption will remain extremely limited. This is because imported biopesticide products have heavy costs associated with them (shipping, distributor margins, etc), many have been re-packaged and stored over long time periods and thus their quality is compromised, and they do not always target the specific pests that Southeast Asian farmers deal with. In contrast, locally produced products would take advantage of relatively inexpensive labor costs and would likely be more responsive to farmer’s needs. Unfortunately, ensuring quality in small, local production facilities has proven to be a significant technical hurdle—sometimes more significant than the process of actually growing the microbes in the first place (Jenkins and Grzywacz, 2000). Although there are exceptions, many locally produced products have so far performed unacceptably, as a result of contamination or low product potency. This problem has been true of small production facilities not only in Southeast Asia, but around the world. A new approach to local production that emphasizes modified production schemes and strict quality control guidelines is needed.

6.4. Education

Although some strides have been made in educating local producers and farmers in the production and use of microbial control agents, lack of familiarity with the technology has been cited in several reports as a key barrier in adoption (FAO, 2004b).

6.5. Documentation

Although there is significant documentation in the scientific literature of research advances made with microbial control agents, there have been few projects that track the success (or failure) of research innovations in terms of farmer adoption, yield improvement, or reduction in conventional pesticide use. This is a problem not only in Southeast Asia, but also globally, where follow-through on research projects is typically limited. As a result, there is little feedback to researchers and policy-makers, and little real-life data available to guide them in decisions on research focus and funding opportunities.

7. The future

The agro-pesticide market in Southeast Asia is underexploited as seen in a global perspective, but should increase in the future. Some international organizations such as FAO and FFTC work hard to ensure that a good part of this growth is based on IPM principles, which include microbial control as an option. The registration situation is streamlined, and salaries are low, which means that labor-intensive technologies can be considered. As in other regions of the world, there is a need for more farmer education and producer education, though national IPM programs, farmer field schools and donor programs have made a good start.

On the other hand, cost-competitiveness and product quality/performance of biopesticides are the two major barriers standing in the way of their adoption. Inexpensive conventional pesticides and all of their associated problems will continue to dominate until these barriers are addressed. To do so will require more effort in technology transfer, so that research results are more readily translated into field use. And even more importantly, it will require additional funding for optimization of local production strategies, farmer education, continuing research and even subsidization of biopesticide retail costs so that their availability to farmers is ensured.

Acknowledgments

For editing assistance, thanks to Dr. Wendy Gelernter, and for information, thanks to Drs. L. Jeerapong and A. Upansakorn (Biocontrol Group, Ministry of Agriculture, Dept. Extension Service, Bangkok, Thailand), Dr. H.L. Lee (Medical Entomology Unit/Infectious Diseases Research Center, Institute for Medical Research, Kuala Lumpur, Malaysia), Dr. H. Warburton, (Schumacher Centre for Technology and Development, Rugby, United Kingdom), Dr. D. Grzywacz (Sustainable Agriculture Group, Natural Resources Institute, Chatham, Kent, England), Dr. Vo Thi Thu (Dept. Molecular Biology, Institute of Biotechnology, Vietnamese Academy of Science and Technology, Hanoi, Vietnam).

References


