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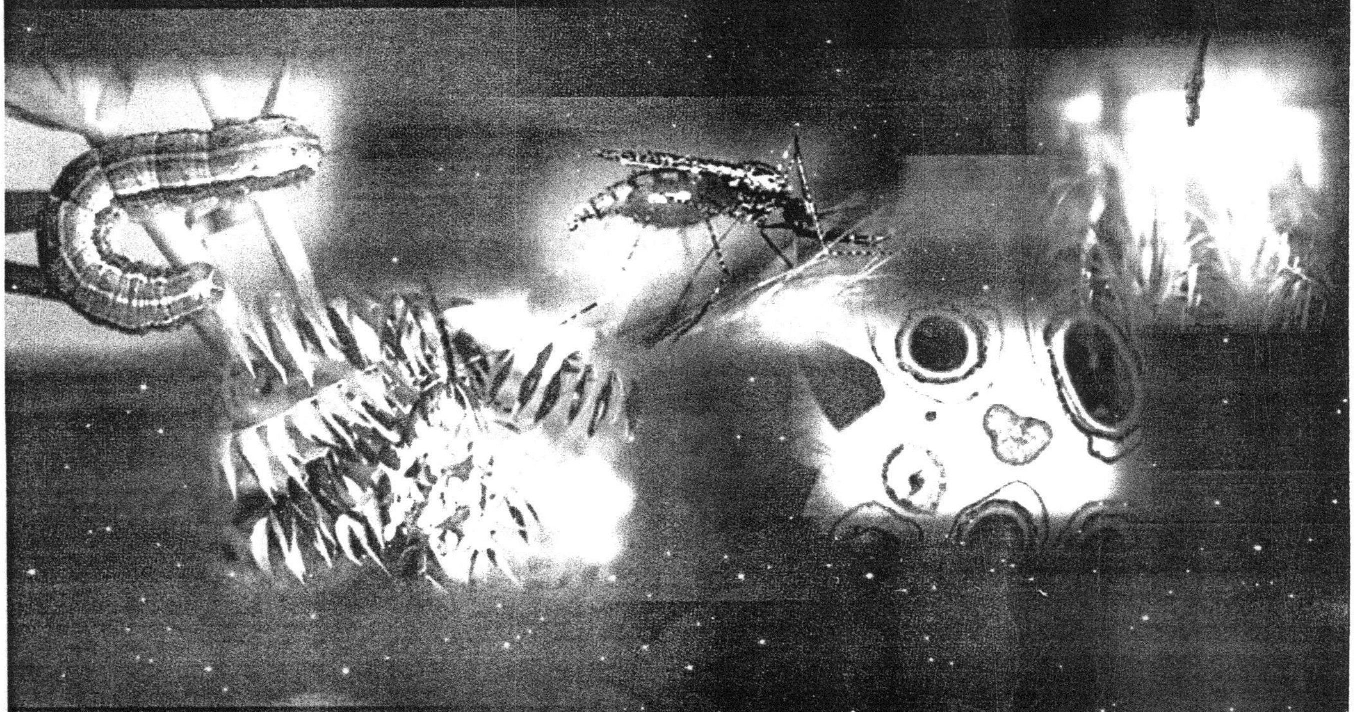

BIOPESTICIDES:

Phytochemicals and Natural Products for the Progress of Mankind

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Development, Uses and Application of Biopesticides in Indonesia: Current Research and Future Challenges

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ABSTRACT The Government of Indonesia has adopted integrated pest management (IPM) as a foundation of pest control system. Biopesticidess have been developed and applied as a part of control components against plant pests and animal parasites in line with the implementation of IPM in agriculture in Indonesia. Middle and large-scale industry of biopesticidess are dominated by *Bacillus thuringiensis* as active ingredient, mostly with strain *kurstaki* (13 trade products). Other biopesticidess officially registered at Pesticide Commission are *Trichoderma koningii* (3 products), *Beauveria bassiana* (2 products), *Gliocladium* (1mark). Insect pheromone has not been produced commercially, most probably due to the high cost production. One commercial product each for botanical nematicide based on azadirachtin, bioinsecticide based on rotenone and spinosad and attractant methyl eugenol are registered as well. However, the application of certain biopesticidess that can be prepared in simple method in the field is more extensive. Crude extract of various botanical materials, raw filtrate of nucleopolyhedrosis virus (NPV) of *Spodoptera* spp and baculovirus *Oryctes rhinoceros*, *B. bassiana* and *Metarrhizium anisopliae* cultured on rice media, antagonist agents *Gliocladium* and *Trichoderma* cultured on rice bran and sawdust are widely practiced by farmers. Researches on mostly applied aspects are being conducted by some universities and research centers in Indonesia.

KEY WORDS bioinsecticide, bionematicide, botanical, antagonist, Indonesia

INTRODUCTION

Pest control using biopesticidess in Indonesia has been attempted several years before the Second World War. The use of entomopathogenic insecticides albeit irregularly for controlling plant pests, has been practiced; however the results were reported unsatisfactory (Sosromartono 1989). An entomopathogenic fungus *Metarhizium* was reported in 1916 by Leefman as control agent against tea mosquito bug *Helopeltis antonii* (Dharmadi 1989). Unfortunately the information on the use of microbial agents was not well documented. The insecticidal properties of some plants have been known and farmers have used botanicals long before commercialization of synthetic pesticides. Tobacco and *Derris* spp. were among the popular plants used as insecticides for controlling plant pests and animal parasites.

The era of modern biopesticidess started in the beginning of 1960 when product with *Bacillus thuringiensis* as active ingredient was introduced. Until the following two decades, research on biopesticidess was limited on field trial of new products. At that time the sale of synthetic pesticides reached the peak. The integrated pest management (IPM) program officially launched by the Government of Indonesia in the middle late 1980s has lowered significantly the role of synthetic pesticides. Since then the government promoted the development of biological means of pest control, including the research on biopesticidess. The Directorate General of Estate Crops has established 19 field laboratories for mass production of entomopathogenic fungi *Metarrhizium anisopliae* and *Baculovirus*. Both pathogens are used to control *Oryctes rhinoceros*, a major pest of coconut. Subsequently, biopesticidess were also developed for food and horticulture crop.

Due mainly to the shortage of experts and availability of fund, research activity was limited to exploration and testing of potency of biopesticidess against important pests and parasites. Considering the diversity biological resources in the country, this type of research is always conducted until present. Many universities and research centers are actually involved in the research and development of biopestisides. However, basic aspects of biopesticidess receive only little attention.

Nowadays, the botanical pesticides, entomopathogenic fungi,viruses , nematodes are widely prepared and used in the field whereas attempts to propagate and apply bacteria as insecticides were not quite successful. On the other hand research and application of antagonistic agents for controlling plant diseases are progressing as well.

BOTANICAL PESTICIDES

In an attempt to alleviate the hazardous effect of synthetic pesticides, botanical insecticides are one of the potential alternatives (Prakash & Rao 1997). These groups of insecticides are relatively safe to pest natural enemies and biodegradable so that they can easily be used in a compatible manner with other IPM components and they will not pose any serious residue threats.

In the past 30 years, not less than 1500 species of plants were reported to have insect control properties (Arnason *et al.* 1989, Grainge & Ahmed 1988, Jacobson 1990, Hedin *et al.* 1997, Prakash & Rao 1997). However, there are still many plant species that have not been studied for their insecticidal activity. Opportunities are still wide open throughout the archipelago to find new sources of potent botanical insecticides.

In our laboratory, we collected plants from West Java and West Kalimantan. Plant materials were tested at concentrations of not more than 0.5 % for organic solvent extracts and not more than 5% for aqueous extracts. The extraction was done by infusion method with stirring, using organic solvents (acetone, ethanol or methanol). The crude extracts obtained were used directly or partitioned in a mixture of hexane and 95% aqueous methanol, and the methanol layer was taken and evaporated. The obtained methanol fraction was partitioned further in a mixture of chloroform and water or ethyl acetate and water. The organic solvent layer was taken, evaporated and used for bioassays. Aqueous extracts were prepared by grinding plant materials in water containing emulsifier alkylarylglycerolphthalate or household detergent at concentration of 0.025% or 0.1%. In some cases, small amounts of acetone and methanol (5% each) were added. Extract bioassays were done using leaf feeding method or contact method with extract residue on glass surface.

Extracts of the following plant parts had strong insecticidal activity against the cabbage head caterpillar *Crocidolomia pavonana* (mortality $\geq$ 90 % in the treatment with organic solvent extracts at concentrations of not more than 0.5 % or with aqueous extracts at concentrations of not more than 5%): seeds of *Annona glabra, A. montana, A. reticulata, A. squamosa*, and twigs of *Uvaria grandifolia* (Annonaceae), stem barks of *Calophyllum soulattri* (Clusiaceae), seeds of *Aglaia elliptica, A. harmsiana, A. odoratissima, Azadirachta indica, Dysoxylum mollissimum, Trichilia trijuga*, twigs of *Aglaia odorata, Chisocheton macrophylla, D. arborescens* , and leaves and twigs of *D. acutangulum* (Meliaceae), seeds of *Piper nigrum* and fruits of *P. retrofractum* (Piperaceae), stem barks of *Nephelium cuspidatum* (Sapindaceae) and roots of *Eurycoma longifolia* (Simaroubaceae).

LC_{50} of chloroform fraction of *C. macrophylla* twig extract, *D. acutangulum* leaf and twig extracts, and *U. grandifolia* twig extract on *C. pavonana* larvae were 664.7, 476.5, 107.7, and 436.9 ppm, respectively. LC_{50} of ethyl acetate fraction of *A. harmsiana* seed extract and *A. odorata* leaf and twig extracts were 150.3, 641.9, and 310.2 ppm, respectively. Under the same conditions, LC_{50}s of betacyfluthrin and spinosad were 76.9 and 0.896 ppm, respectively.

The potency of other plant materials as botanical pesticides were also studied in many research institutes (Table 1), as recorded during the national symposium of entomology in 2003. However, the list is not exhaustive and we can expect similar type of study from some other institutions. Martono (1998) from Gadjah Mada University studied the biological activity of kumchura (*Kaempferia galanga* L.) rhizome to melon fly. Atmaja *et al.* (2004) from Research Institute for Spice and Medicinal Crops for example conducted research on the potency of clove oil as insecticide against *Helopelthis antonii* and *H. theivora*, serious pests of tea; Manurung and Beriajaya (2002) from Research Institut for Veterinary Science investigated tobacco, sugar apple and neem extracts against a cattle tick *Boophilus microplus*.

The pesticidal properties of plants are not investigated merely against pests, but also for controlling plant pathogens. Arya et al. (2003) from Udayana University attempted the efficacy of a mixture of plant extracts (leaves of *Piper betle* and rhizome of *Alpinia galanga)* and *Bacillus* sp. for controlling *Ralstonia solanacearum*, a causal agent of tomato wilt disease; although they could not decrease the disease incidence, the synergism has been obtained. Other pathogens aimed as target of bioassays are usually *Fusarium, Phytophthora* and *Sclerotium.* On the other hand, the Pesticide Commission registered one rotenone-based biopesticides for use in aquaculture to control *Tilapia mossambica* in fishpond.

Despite the great enthusiasm of using plants as pesticides, Syahputra *et al.* (2004) questioned the importance *Aglaia* spp. since extracts of these plants could provoke unwanted effect such as phytotoxicity.

The efficacy of those extracts tested in the laboratory is so far promising although they did not use the pure extract. Many laboratories are not well equipped with sophisticated extraction apparatus.

Table 1. Research on the botanical pesticides reported in 2003 (Anonymous 2003)

Author	Institution	Plant studied	Target pests
Supriyatin & Marwoto	Res. Ins. For Legum. And Tuberous Plant	*Aglaia odorata*	Sybean pod suckers
Aminah, Lestari & Supriyono	R & D Ministry of Health	*Calotropis gigantean, Vitex trifolia*	Mosquito
Subiyakto, Sunarto & Aisyah	Res. Ins. For Tobacco and Fibrous Plant	*Nicotiana tabacum*	*Myzus persicae*
Dewi & Dadang	Bogor Agric. Univ.	Asteraceae	*Spodoptera litura*
Dadang & Undayasari	Bogor Agric. Univ.	*Aglaia calamus, Piper cablin, V. zizanioides*	*Callosobruchus chinensis*
Harnoto, Koswanudin & Nugraha	Res. Inst. Of Agric. Biotech. & Gene. Res.	*Lantana camara*	*Aphis glycine*
Sunari	Univ. Udayana	*Swietenia mahogani*	*Sitophilus oryzae*

So far the application of botanical pesticides in the field by farmers is based on the crude extract. Seeds of neem, annona or pepper, and twigs of *Dysoxylum acutangulum* are ground and mixed with water, left to stand for 0.5-2.0 hours. The mixtures then filtered through muslin cloth, and the filtrate can be directly sprayed to the plant. The concentrations about 25 - 50g/l water are generally effective against some leaf feeder pests (Prijono 2003). This last author published many research papers on botanical pesticides (Prijono 1997, 1998).

The development and production of botanical pesticides at industrial scale for commercial purpose is very limited. Only Nospoil 8 EC® (recommended for controlling root knot nematode on tomato) and Natural 9 WSC® (recommended for controlling cutworm *Spodoptera litura* on chili and rice bug *Leptocorisa* sp.) with azadirachtin as active ingredient are registered at Pesticide Commission.

BIOFUNGICIDES

Unlike the botanical pesticides which advantages have been known long enough ago, biofungicides were used belatedly. Even though some microorganisms like *Trichoderma* spp., *Gliocladium* spp., *Bacillus subtilis* and *Pseudomonas fluorescence* have been reported their effectiveness against plant pathogens, the research on biofungicides in Indonesia started intensively after 1980.

In the laboratory Hannan (1987) showed the inhibition of growth of *Rhizoctonia solani, Sclerotium rolfsii, Fusarium semitectum* and *Pythium* sp. (all are plant pathogens) by *T. koningii*. The potency of *T. harzianum* and *T. polysporum* as biofungicide against *Pseudomonas solanacearum*, a common pathogen of tomato, has been revealed by Paath (1988). Basuki (1989) studied the effect of sulphur on *Trichoderma koningii* in the control of *Rigidoporus microporus*, the causal agent of white rot disease of rubber. Since then the number of research on microorganism candidates for plant pathogen has been steadily increasing. Nawangsih *et al.* (1997) for example, found that *Pseudomonas fluorescens* B29 and B39 are effective to control *Xantomonas campestris* pv. *glycines*, the causal agent of bacterial pustule on soybean. However, most researches are still in the explorative phase, followed by testing the potency towards certain pathogens (Table 2).

There is a tendency to utilize soon as control agent once the potency of any microorganism is revealed. Many green house trials *ad planta* have been attempted to prove the efficacy after isolation and laboratory testing on the antagonistic potency. Almost all research institutes of agricultural and forest plants involved in the developing the antagonistic microbes for controlling plant disease. Interestingly, Beriajaya & Ahmad (2002) showed the potency of *Trichoderma* to control *Haemonchus contortus*, an important sheep parasitic cestode; field trial in West Java was planned.

Similar to other research on biopesticidess, basic aspects were poorly investigated. Haryono & Widyastuti (2001) found the increase of endochitinase production by *T. reesei*, the important lytic enzyme, when the medium was supplemented with 1% polyvinyl pyrrolidon.

Trichoderma sp.is the most widely studied among other antagonists up to now. Together with *Gliocladium* sp. these antagonists are intensively studied by the Laboratory of Plant Mycology at Bogor Agricultural University; the research is aimed mainly at controlling effectively various soil-borne diseases. Some plant diseases are actually hard to control even with chemical fungicides (Table 3), thus we are searching for the potency of the antagonistic agents.

The development stage of biofungicides is somewhat similar to that of other group of biopesticides. Four commercial products are actually registered by Pesticide Commission, three products with *Trichoderma koningii* (recommended for *Rigidophorus lignosus* and *Fusarium* spp.) and another one with *Gliocladium* sp. (recommended for *Sclerotium rolfsii*) as active agents.

Table 2. Number of research on beneficial microorganisms used as biocontrol agent against plant pathogens in Indonesia, 1995-2003

Microbial agents	Topic number*					
	a	b	c	d	e	f
Trichoderma	7	1	11	4	4	1
Gliocladium	2	1	5	0	0	0
Penicillium	4	0	3	1	0	0
Fusarium	3	0	0	0	0	0
Fluorescent Pseudomonads	3	4	14	0	2	1
Bacillus sp	0	0	2	1	0	0
Pasteuria	0	0	2	2	0	0
Others	2	0	2	0	0	0

Source: Indonesian Phytopathological Society
*a. Isolation & in vitro screening
b. Mode of action
c. Green house trial
d. Ecology
e. Field trial
f. Production and formulation

Since the technology of mass production of certain antagonist agents is relatively not complicated, the control by using these microorganisms becomes more frequent. Rice bran mixed with sawdust is packed in polyethylene bag, used as growing media for *Trichoderma* and *Gliocladium*. The frequent problem encountered during mass production was the contamination. Seedling of high economic value commodity such as chili and tomato, as well as oil palm are the common target for treatment with these biofungicides.

MICROBIAL INSECTICIDES

As stated earlier, the use of insect pathogenic fungi has been known before the World War II. The detail information was not well recorded. Apart from this, Sosromarsono (1989) did not mention the significant development of bioinsecticides until year 1976, when an entomopathogenic fungus *Metarrhizium anisopliae* and virus *Baculovirus oryctes* were attempted to control *Oryctes rhinoceros*, the main coconut pest in some regions. In the following 10 years, the control program was so successful that the healthy larvae were scarcely observed at breeding sites. The success was made possible by the improvement of the releasing technique and the knowledge of the susceptibility of various *Oryctes* population, the pathogenicity of *Baculovirus* strain (Zelasny 1988), and full support from the government.

Table 3. Examples of plant diseases that are not adequately controlled by currently available chemical pesticides

Disease	Pathogen	Crop
Fusarial wilt	*Fusarium oxysporum f.sp. cubense*	Banana & plantain
Fusarial disease	*F. oxysporum f.sp. cepae*	Shallot
Basal stem rot	*Ganoderma sp.*	Oil palm
White root	*Rigidoporus microporus*	Rubber tree
Pod rot	*Phytophthora palmivora*	Cacao
Club root	*Plasmodiophora brassicae*	Crucifers
Basal stem rot	*Sclerotium rolfsii*	Soybean & peanut
Bacterial wilt	*Ralstonia solanacearum*	Banana, Tomato, Potato & Ginger

M. anisopliae is prepared by using the parboiled rice as growing media. After drying at room temperature, media are ground and powdery formulation is obtained. For *O. rhinoceros* control, the powder that contain conidia are spread breeding site.

Insect infected by *Baculovirus* from the field are macerated in water and filtered. The filtrate is orally inoculated to the healthy beetles prior to the release in the field. Artificially infected beetles are expected to contaminate other individuals through feeding and copulation activity.

The use of *M. anisopliae* for insect control seems scarcer at present day as compared with *B. bassiana*. Investigation and research of this white muscardine fungus was done later than *M. anisopliae*. However, its application is much wider than *M. anisopliae* (Table 4). The mass production of *B. bassiana* follow the same procedures as for *M. anisopliae*, i.e. using the parboiled rice as media. In spite of the wide use of *B. bassiana* as a mycoinsecticide, the Pesticide Commission registered only two commercial products, while no product was registered for *M. anisopliae*. Actually, there is a high demand for *M. anisopliae* in sugarcane plantation. In certain areas, sugarcane plantation are threatened by a notorious borer of basal stem, the cerambycid *Dorysthenes* sp. The chemical control mean is not economical for large plantation area. In this case the researchers from formerly Bogor Research Institute for Estate Crops have formulated the fungi in powder and pellets (Purwantara 2001).

Growers of estate crops usually produce bioinsecticides in cooperation with the research institute of related commodity, whereas farmers of food crops receive the guidance from Department of Agriculture or even from the non-governmental organizations (NGO). Periodical training on the preparation, production and application of biocontrol agents has been implemented especially by Directorate of Food Crop Protection. The trainees were the provincial officers of plant protection; at their turn, they had to train farmer. In some areas, *B. bassiana* is frequently used by farmer for controlling rice bug (*Leptocorisa oratorius*) and soybean pod sucker (*Riptortus linearis*). For this purpose, the application is done by spraying conidial suspension.

Table 4. Bioinsecticides registered by the Pesticide Commission of Indonesia (2002)

Microbes	Number of products	Target pests	Crop
3.thuringiensis	13	*Plutella xylostella, Crocidolomia binotalis, Thosea asigna, Setora nitens*	Cabbage Oil palm
3. coagulans	1	*Liriomyza*	Potato
3. bassiana	2	*Helopeltis* sp., *Canopomorpha cramerella, Hypothenemus hampei*	Tea Cacao Coffee
. koningii	3	*Rigidoporus lignosus, Fusarium*	Rubber
Jliocladium	1	*Sclerotium rolfsii*	Soybean Peanut

On sweet potato and cabbage our investigation showed that *B. bassiana* is promising as a control agent against cabbage heart caterpillar *Croccidolomia pavonana* and potato weevil *Cylas formicarius*. However, the use on cabbage is not without risk since the fungus is also shown pathogenic to *Eriborus argenteopilosus*, an important parasitoid of *C. pavonana*.

The genetic variability of isolates of *B.bassiana* must be taken into consideration in selecting the most pathogenic fungus. Sometimes the failure of *B. bassiana* in controlling target pests is due to low pathogenicity of the fungus *vis à vis* the insect as host. Other entomopathogenic fungus that is more studied recently is *Verticillium lecanii*. Prayogo (2004) showed the excellent efficacy of this pathogen against soybean bug *R. linearis* in mini plot; moreover, *V. lecanii* was not pathogenic to spider *Oxyopes javanus,* an important predator in soybean ecosystem.

Beside the baculovirus *Oryctes rhinoceros* (belonging to sub-group C according to conventional nomenclature), the nucleopolyhedrosis virus (NPV, belonging to sub-group A) is also widely used. NPV based bioinsecticides are not yet registered at The Pesticide Commission, nevertheless some Institutes of Food and Horticulture Crop Protection produced and sold NPV powder in small batches. The most common product is NPV of cutworm, *Spodoptera litura*, a major leaf feeder of soybean. After grinding the cadaver, they added lactosum as additives to the formulation. Similarly, Research Institute for Tobacco and Fibrous Plant produces in limited quantity NPV of *Helicoverpa armigera*, the important cotton bollworm.

The practice of insect control by using other entomopathogenic viruses was carried out in North Sumatera (Sinuraya &de Chenon 1989). *Setothosea asigna*, an important nettle caterpillar pest of oil palm was successfully controlled by *Nudaurelia β* virus. The virus occurred naturally in plantation. Mass production of the virus was realized in vivo by inoculating virus to healthy caterpillars bred in cages.

A unique preparation is practiced by shallot farmers in Brebes, Central-Java. Traditionally they pick and kill *S. exigua* caterpillar as mechanical control measure. After introduction of NPV to the farmers about 10 years ago, the collected larvae are not killed, but inoculated with virus. The cadavers are then macerated, filtered and the filtrate is sprayed to the plant. The efficacy of such preparation is comparable to chemical insecticides (Israwan 1998, Effendi 1998).

As regard bacteria based bioinsecticides, we have 13 products of *B. thuringiensis*, all produced by multinational industry. Variety *kurstaki* and *aizawai* shares equal portion. The development at farmer level is hindered by the lack of technology for cheaper mass production. Attempt to culture on alternative media, for example that based on fermented shrimp, was not quite successful.

In order to extend the host spectrum, exploration of indigenous *B. thuringiensis* from various ecosystem, especially from agriculture and sericulture, has been reported by several authors (Prabowo 1990, Rusmana 1990, Suryawati 1993). Hundred of samples were collected and characterized morphologically. Suspected *B. thuringiensis* was tested against cabbage heart caterpillar *C. pavonana*. The result indicated that the pathogenicity of all isolates was relatively low. The prospective indigenous *B. thuringiensis* as biopesticides agent is so far not obtained.

Resistance of insect pests toward *B. thuringiensis* toxin was also investigated. Suharto *et al.* (2003) reported that population of *Plutella xylostella* in East-Java has developed resistance toward both *B. thuringiensis* var. *aizawai* and *kurstaki*.

Researchers from Forecasting Institute of Food Crop Pests in Jatisari, West Java, have collected the red bacteria highly infective against rice brown planthopper *Nilaparvata lugens*. Unfortunately, the identification remains unclear and the study was not further pursued. The existence of other bacterial species has never been reported to date.

The entomopathogenic nematode is the newest group of bioinsecticides being explored in Indonesia. The exploration was started at the beginning of the last decade. Only several laboratories from either universities and research institutes engaged in the research and development. The application of nematode as bioinsecticides has never been reported, however, some field trials at various scales have been conducted. During the last national symposium of entomology in 2003, three papers on entomopathogenic nematode have been presented, while during a conference on entomology held in Bogor recently in October 2004, five other papers have also been presented. The distribution of papers according the topic is as follows: mode of action (2 papers), bioassay (4 papers), field trial (1 paper) and storage (1paper). These eight papers deal with *Steinernema* (6 papers) and *Heterorhabditis* (2 papers).

Bunga (2004) explored soil from different type of vegetation in Kupang for the presence of entomopathogenic nematodes. *Steinernema* sp. has been found from non-irrigated rice field. This nematode is pathogenic for mealworm *Tenebrio mollitor* and sweet potato borer *Cylas formicarius*. For controlling leaf miner *Liriomyza huidobrensis,* Yulensri (2001) found that an indigenous species *Heterorhabditis indicus* was more pathogenic than an American isolat *Steinernema riobravis.* Purnomo (1998) showed that *S. carpocapsae* was effective against the cabbage caterpillar *C. binotalis*.

OTHER BIOPESTICIDES

We observed so far the use of bacteria, fungi, viruses and nematodes, but research on protozoa as a biocontrol agent is lacking. Hosang *et al.* (1988) isolated gregarines from natural population of *Sexava nubila*, a serious pest of coconut in Eastern Indonesia, inoculated to healthy cricket prior to release to the field. The result, as indicated by plant damage and pest population, was unexpectedly discouraging. Apart from this, no other study on protozoa was conducted.

Research on sex pheromone is also very scarce. Three papers were presented in the national symposium of entomology in 2003. The investigated insects are *Spodoptera exigua* (pest of shallot), *Phthorimaea operculella* (potato leaf miner) and *Etiella zinckenella* (soybean pod borer). Department of Biology, Institute of Technology Bandung, is the principle host laboratory, especially for the identification of the active substances.

Two spinosad-based biopesticidess are produced by Dow Agrochemical and has been registered at Pesticide Commission not long after its first release in USA. The pesticide are recommended for controlling cabbage heart caterpillar *C. binotalis* and diamond back moth *Plutella xylostella*, cutworm *S. litura* on chili, *S.exigua* on shallot, leaf miner *L. huidobrensis*, *Phthorimaea operculella* and *Thrips* on potato and *Helicoverpa armigera* on tomato.

The abamectin-based biopesticidess are also registered at Pesticide Commission. The recommended target pests are numerous: aphids *Aphis pomi, Thrips parvispinus, T. palmi,* leaf miner *L. huidobrensis, L. chrysanthemi, Phyllocnitis citrella,* and *P. operculella,* bean borer *Maruca testulalis,* acarina *Hemitarsonemus latus,* cabbage heart caterpillar and diamond back moth.

Up to now, there is no laboratory carrying out research on actinomycetes and streptomyces related to their use as biopesticidess in Indonesia.

DISCUSSION

The information described above gives general view on the development of biopesticides in Indonesia. The trend of using biopesticides in agricultural practices is
increasing albeit still limited for controlling plant pests and diseases and at lesser extent, animal parasites. The practical use of biopesticides for weed control is not yet initiated. As compared with entomologists or phytopathologists, the number of weed scientists in Indonesia is effectively lower, especially with interest in mycology. Thus, terms like mycoherbicide rarely mentioned in plant protection talks.

The development of biopesticides should have gained impetus since many governmental regulations apply strict requirements for the registration of new pesticides in general, particularly synthetic chemical pesticides (Deparaba 2000). However, such strict requirements are hard to fulfill by small producers of biopesticides. As stated above, some microbial pesticides are prepared in a simple manner and technology at small scale. For economic considerations, thorough analysis according to the formal regulation is rarely done. This is the reason for which many biopesticides products are not registered at The Pesticide Commission.

Applications of unregistered biopesticides are believed not to posing environmental hazard, provided the active organisms or substances are isolated from nature and cultured in such way without provoking any genetic change. In this regard, The Pesticide Commission at certain limit loosened the requirements of biopesticides from registration. So far all inocula for microbial pesticides and pesticidal plants are taken from indigenous resources.

The success of coconut pest control by using natural enemies including *M. anisopliae* and *Baculovirus* must be attributed to The Directorate of Estate Crop Protection. This directorate is again implementing integrated pest management for six small scale estate crops viz: coffee, cacao, pepper, cotton, coconut and cashew. The use of biocontrol agents of course is put in priority. For these commodities, *Verticillium* (for cacao pod borer), NPV (for cotton pest) and *B. bassiana* (for tea mosquito bug and coffee berry borer) certainly play significant role, next to *M. anisopliae* and *Baculovirus* for coconut pest. IPM Field School for estate crops could serve as extension for promoting those biopesticidess.

Biopesticides for food and horticulture crops are developed as well by related government agencies. IPM Field School was initially established for food crops. Technique of mass propagation of pest pathogens and extraction of pesticidal plants were delivered to users by regular training. Our Department was actively involved in such training and has strong collaboration with above mentioned government agencies.

Although pest control by biopesticides is widely practiced for food, horticulture and industrial crops, the amount applied is considered unbalanced when compared with chemical pesticides. Actually, we noted 813 commercial products of chemical pesticides consisted of 341 active ingredients and 22 biopesticides consisted of 6 microbial agents registered officially at The Pesticide Commission (Anonymous 2002). This opportunity is conducive to increase and broaden the production of biopesticides especially when the local biopesticides is exempted for registration.

Based on experience gained to date, a model of small-scale production (cottage industry) is generally suitable to food and horticulture commodities. This is true for certain microbial biopesticides such as viral insecticides, *B. bassiana, M. anisopliae* and nematode provided that the simple technology for mass production is available. The source or inocula for starter are supplied by government laboratories. The production must be planned in line with planting program, and considering as well the presence of endemic pest. In such way, the over-production of biopesticides could be avoided (Santoso 2004). The shelf time of biopesticides is in general short, that storing biopesticides for next planting season is considered wasteful. The preparation of botanical pesticides follows the same scheme. Larger scale production might be useful and economical for monoculture estate crop at wider acreage.

At present the fungus *B.bassiana* is the widest bioinsecticides produced. Various insect pests ranging from Coleoptera (coffee berry borer and sweet potato weevil), Hemiptera (soybean pod sucker, rice bug and tea mosquito bug), Homoptera (rice planthopper) and Lepidoptera (cabbage heart caterpillar) are frequently controlled by this bioinsecticide. Two significant problems during propagation by farmers are the contamination and the decrease of virulence. Culturing the fungi on media for long time without passing through natural host was the principal cause. Besides, the purity of culture was also hard to maintain. Therefore, the supervision by specialists and more training for farmers must be carried out periodically.

Seeing the biodiversity riches of the country, exploration of new agents for biopesticides must be conducted all the time. As a matter of fact, research and development are often impaired by limited fund and equipment. It is not surprising that most researches conducted in the country are still in explorative phase. From a practical standpoint, however, the result could be applied directly and give benefits to farmers. With the program "Go Organic 2010", explorations are expanded to obtain more candidates of biopesticides.

Cooperation with foreign laboratories from developed country could overcome financial and technical constraints. For instance our Department has a cooperation with Tokyo University of Agriculture in developing botanical pesticides and antagonistic agents. More cooperation are needed and welcomed.

CONCLUSION

1. Biopesticides have been produced and applied for controlling agricultural pests.
2. Biopesticides other than *Bacillus thuringiensis* are generally produced in small scale.
3. Biocontrol agents frequently used as biopesticides are: Fungi *Beauveria bassiana* , *Metarhizium anisopliae, Verticillium sp., Trichoderma koningii, Gliocladium sp.,* viruses *NPV of Spodoptera litura, S. exigua, Helicoverpa armigera, Baculovirus Oryctes rhinoceros,* Nematode *Steinernema sp.*
4. Biopesticides for controlling weed are not yet available and need more studies.
5. Basic researches on biopesticides were scarcely conducted.

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