Expert Consultation on Biopesticides and Biofertilizers for Sustainable Agriculture

Taiwan Agricultural Research Institute, Taichung, Chinese Taipei

27-29 October 2009

PROCEEDINGS AND RECOMMENDATIONS

Organized by

Asia-Pacific Association of Agricultural Research Institutions (APAARI)
Asia-Pacific Consortium on Agricultural Biotechnology (APCoAB)
Council of Agriculture (COA)

Cosponsored by

Global Forum on Agricultural Research (GFAR)
AVRDC - The World Vegetable Center

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FOREWORD

The past century has witnessed a slow but steady emergence of biopesticides and biofertilizers as potential supplementary and environment friendly inputs to their chemical counterparts. With the documentation of nearly 2,500 bioactive plant species, over 1,000 protozoa pathogenic to insects, 750 fungal species attacking terrestrial and aquatic arthropods, baculovirus infections in over 700 species of invertebrates and an array of other micro- and macro-bioagents; their role in future crop protection cannot be ignored. Likewise; bioinoculants or biofertilizers, primarily the nitrogen fixers and the phosphate solubilizers, hold vast potential in meeting plant nutrient requirements while minimising the use of chemical fertilizers. Furthermore, successful exploitation of genetic engineering technology to incorporate non-native pesticide producing genes into crop plants has added another dimension to the potential use of these inputs in agriculture.

Asia-Pacific countries are the leading advocates of biopesticides and biofertilizers for sustainable agriculture. Unfortunately, despite considerable research and development efforts, their use has remained limited to only 2.5% of the total chemical use. Several technological and policy constraints have been responsible for this limited adoption. The former are exemplified by: lack of knowledge intensive production and extension approach; poor availability of standard and stable products and situation specific packages; inconsistent establishment and performance in different crop and agro-climatic domains; inadequate information on safety; meagre set up for location, characterization, indexing, preservation, strain improvement, bioprospecting and chemical profiling; and reluctance on the part of big industry for promotion. The policy constraints comprise: inadequate government and media patronage; limited technology dissemination and promotion programs; lack of clarity on the role of these bio-inputs in the conventional production systems, and on regulatory and registration norms; and poor national and international linkages.

Keeping in view their potential, the Asia Pacific Association of Agricultural Research Institutions (APAARI) in collaboration with the Council of Agriculture, Taipei organized an expert consultation on "Biopesticides and Biofertilizers for Sustainable Agriculture" in Taichung, Chinese Taipei from 27 to 29 October 2009. The main aim was to review the current status of research, development and use of these bioinputs in agriculture, develop better understanding on their use in the conventional production systems and develop a strategy for addressing critical issues such as policy support, quality control, regulatory management and public-private participation. The meeting evoked excellent response with seventy-two participants from 23 countries representing NARS, CG centers, other academic institutions, private sector, CSOs and farmer organizations. APAARI is, indeed, grateful to Dr. Su-San Chang, Director General, Department of International Affairs, COA; Dr. Dah-Jiang Liu, Director General, Taiwan Agricultural Research Institute (TARI) and Dr. Hsin-Der Shih, Associate Researcher, TARI for hosting the expert consultation and providing excellent support for the participation of NARS leaders in the meeting. We also appreciate the funding support received from the Global Forum on Agricultural Research (GFAR) and AVRDC - The World Vegetable Centre. It is our

expectation that the recommendations of this consultation will stimulate researchers, development officials and concerned policy makers for increased adoption of bioagents in agriculture and to assist resource poor farmers in Asia-Pacific by reducing the cost of inputs and enable environmentally sustainable agriculture.

Raj Paroda,
Executive Secretary, APAARI

ACRONYMS AND ABBREVIATIONS

AAFC	Agriculture and Agri-Food Canada
ANGOC	Asian NGO Coalition for Agrarian Reform and Rural Development
APAARI	Asia-Pacific Association of Agricultural Institutions
APCoAB	Asia-Pacific Consortium on Agricultural Biotechnology
AREEO	Agricultural Research, Education and Extension Organization
AVRDC	AVRDC - The World Vegetable Center
BAR	Bureau of Agricultural Research
BRC	Bioproducts Research Consortium
CARP	Council for Agricultural Research Policy
COA	Council of Agriculture
DIA	Department of International Affairs
DOA	Department of Agriculture
DP	Dustable Powder
EFAP	Environment Friendly Agricultural Produce
FAO	Food and Agriculture Organization of the United Nations
FFF	Federation of Free Farmers
GV	Granulovirus
IANC	Institut Agronomique Néo-Calédonien
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research
ICARDA	International Center for Agricultural Research in the Dry Areas
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFAD	International Fund for Agricultural Development
IFAP	International Federation of Agricultural Producers
INM	Integrated Nutrient Management
IPM	Integrated Pest Management
IPNM	Integrated Pest and Nutrient Management

IRRI	International Rice Research Institute
ISAAA	International Service for the Acquisition of Agri-Biotech Applications
IPR	Intellectual Property Rights
JUST	Jordan University of Science and Technology
MARD	Ministry of Agriculture and Rural Development
MARDI	Malaysian Agricultural Research and Development Institute
MIU	Meiho Institute of Technology
MPI	Ministry of Primary Industries
NARC	Nepal Agricultural Research Council
NARI	National Agricultural Research Institute
NCANR	National College of Agriculture and Natural Resources
NCFNL	National Cooperative Federation of Nepal Ltd
NCHU	National Chung Hsing University
NGO	Non-government Organization
NPV	Nucleopolyhedrosis
NRDC	National Research Development Corporation
NTU	National Taiwan University
PCARRD	Philippine Council for Agriculture, Forestry and Natural Resources Research and Development
PGP	Plant Growth Promoting
PIP	Plant Incorporated Protectants
RAPD-PCR	Random Amplification of Polymorphic DNA Polymerase Chain Reaction
R&D	Research and Development
RDA	Rural Development Administration
SAC	SAARC Agriculture Centre
SKUASTK	Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir
SRRC	Strategic Resources Research Centre
TACTRI	Taiwan Agricultural Chemicals and Toxic Substances Research Institute
TARI	Taiwan Agricultural Research Institute
TFCL	Taiwan Fertilizers Co. Ltd.
VAAS	Vietnam Academy of Agricultural Sciences

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Background

Adverse effects of plant production and protection chemicals on the biotic and abiotic components of environment are well documented. The entry of these inputs and their transformation products into the human food chain and environment coupled with their bioaccumulation and biomagnification trigger toxicological effects of unforeseen consequences. Awareness on their harmful effects has resulted in public concern and debate on the wisdom of their indiscriminate use, leading to search for environment friendly options, biopesticides and biofertilizers. The vast reserves of available biodiversity provide abundant opportunities to harness the ability of plants and other organisms, and their chemical constituents, to sustainably minimize damage from pests or increase agricultural productivity and production. The potential of these bioinputs has been much discussed, though rarely fully exploited. Realizing their utility in sustainable agriculture, particularly on small farm holdings, Asia-Pacific Association of Agricultural Research Institutions (APAARI) in association with Council of Agriculture (COA), Taipei organized this expert consultation at Taiwan Agricultural Research Institute (TARI), Taichung, Chinese Taipei from 27 to 29 October, 2009. The following objectives were envisaged:

1. Review the current status of research, development and use of biopesticides and biofertilizers in agriculture at the regional and national levels.

2. Develop consensus on the place of biopesticides and biofertilizers in the conventional agricultural production systems and on issues of quality requirements, quality control, regulatory management, commercialization and marketing.

3. Identify the role of public and private sector organizations and public-private participation in promoting the use of bioagents in agriculture.

4. Promote stewardship, regional cooperation, public awareness and stakeholders' participation.

5. Policy framework and advocacy for promotion of their use in greater proportion.

Inaugural Session

Dr. Abd Shukor bin Rahman, Chairman, APAARI chaired the inaugural session with Dr. Dah-Jiang Liu, Director General, TARI as the Co-Chair.

In his welcome address, Dr. Rahman highlighted the role of APAARI in strengthening research partnerships to accelerate agricultural research and development (R&D) in the Asia-Pacific region. APAARI had organized several expert consultations and high level meetings on diverse themes relevant to agricultural development in the region including post-harvest management, climate change, biotechnology and biofuels. Biopesticides and biofertilizers provide substantial inputs for sustainable agriculture. However, their use has not picked to the expected level; hence, a critical appraisal of regional status, issues and options was necessary to promote their use for sustainable agriculture. He hoped that the expert consultation would stimulate adoption of biosafe products.

Dr. Liu in his welcome remarks stressed the need for using clean and energy saving agricultural materials and processes with least adverse impact on environment. He recounted the achievements of TARI in promoting the use of biopesticides and biofertilizers and the development of rapid bioassay methods for detection of pesticide residues.

The opening remarks of Dr. Wu-Hsiung Chen, Minister, COA were read on his behalf by Dr. Su-San Chung, Director General, International Cooperation, COA. The adverse impact of chemicals such as methyl bromide in depleting atmospheric ozone and the fertilizer crisis due to high energy costs were cited as examples to highlight the need for finding their environment friendly renewable alternatives. However, the use of biopesticides and biofertilizers is still very limited. Besides promoting their use, regulatory and registration norms are required to be developed. Dr. Chen appreciated the efforts of APAARI in addressing important agricultural R&D issues like biotechnology, biofuels, biopesticides and biofertilizers at the regional level.

Dr. Raj Paroda, Executive Secretary, APAARI gave a brief introduction about APAARI, its achievements and the current expert consultation. He expressed the hope that the outcome of this consultation will not only catalyze the national governments and policy makers but also draw a roadmap for an effective participation of the private sector and other stakeholders for promotion of bioinputs for agriculture in the region.

Dr. J. L. Karihaloo, Coordinator, Asia-Pacific Consortium on Agricultural Biotechnology (APCoAB) proposed a vote of thanks to the distinguished guests and participants.

Session I. Lead Papers

The session was chaired by Dr. Raghunath Ghodake, Director General, National Agricultural Research Institute (NARI), Papua New Guinea with Dr. Danilo C. Cardenas, Officer-in-Charge, Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD), Philippines as Co-Chair and Dr. Balraj S. Parmar, Technical Consultant, APAARI as Rapporteur.

Dr. Robert Zeigler, Director General, International Rice Research Institute (IRRI), Philippines made the presentation "Maintaining global food security in a dynamic physical and social environment".

While highlighting the Asian economic miracle, Dr. Zeigler elaborated on the concentration of poverty and hunger in Asia, population problem, rising prices of agricultural inputs, and malnutrition. The emerging issues of increasing agricultural demands and falling investments, primary lands moving out of staple crops, changing climate, rising sea levels at 3.1 mm per year, increasing frequency of tropical cyclones and floods, and increasing salinity add further to the challenges of planners and scientists. However, scientific and technological innovations in molecular biology, genetics and physiology, and data storage and analysis promise to lead to new breakthroughs in crop productivity and adaptability. The future roadmap should include priorities like improving nitrogen and water use

efficiency that could increase yields by 50%, identification and deployment of stress tolerance genes, converting C-3 into C-4 crops and reducing post-harvest losses.

Prof. Gary E. Harman, Cornell University made the presentation "Control of biotic, abiotic and physiological stresses with *Trichoderma* spp. and other beneficial plant microbes".

A need for change in the earlier approach that highlighted only the pathogen controlling effect of *Trichoderma* was stressed. It has now been established that *Trichoderma* communicates with plants, reprograms gene expression and induces systemic resistance. Besides, it reduces seedling diseases, enhances N use efficiency thereby reducing N requirement by 30%, overcomes biotic and more particularly abiotic stresses, saves around 40000m^3 of natural gas, restores seed viability, and increases photosynthetic activity. It was, however, opined that use of microbial consortia was a complicated issue and needed caution as there may be too many interactions which could produce unforeseen effects.

Prof. Yoav Bashan, University of Arizona in his presentation "Inoculants for sustainable agriculture - present status and future prospects" highlighted the constraints in formulating microbials with the conventional materials ex. peat. He elaborated on the scope of slow/controlled release formulations and advocated their future use. The use of products based on alginates was particularly emphasized, of which nearly 15 superior characteristics including simple and convenient production and use, biodegradability in about two weeks, cost effectiveness, easy quality control, better shelf life (at ~25°C), and convenient monitoring in field were cited. Both macro- and micro- products, the latter comprising bead-dust coated on seeds, could be obtained, the latter being superior. However, lack of an industrial process for large scale production of alginates is a serious limitation. Therefore, alternative carriers with similar characteristics need to be identified.

The salient points that emerged during discussion on the above three lead papers were as follows:

- About 40% of food losses occur during post-harvest period. Good on-farm storage could reduce this loss to a great extent.
- Genes to tolerate heat stress are being already incorporated in modern varieties of crops and flowering sensitivity to the stress is being analyzed.
- Seed treatment with microbial consortia may be an efficient delivery method. Even root inoculation during transplantation needs to be given a large scale trial.
- *Trichoderma* levels may sometimes go down to non-significant beneficial levels under unfavorable environmental conditions but can soon recover if the environment improves.

Session II. Country Reports

The session was chaired by Dr. Robert Zeigler, Director General, IRRI and co-chaired by Mr. Thierry Mennesson, Director General, Institut Agronomique Neo-Caledonien (IANC), New Caledonia. Dr. Andreas W. Ebert, Gene bank Manager and Global Theme Leader, AVRDC - The World Vegetable Center (AVRDC) served as Rapporteur.

Chinese Taipei – Dr. Suey-Sheng Kao, Taiwan Agricultural Chemicals and Toxic Substances Research Institute (TACTRI), Taichung.

The presentation highlighted the R&D achievements of the country in biopesticides and biofertilizers. Sex pheromones of *Cylas formicarius elegantulua*, *Cydia* (*Eucosma*) *notanthes*, *Cryptophelebia ombrodelta*, *Planococcus minor*, *Lymantria xylina*, *Conopomorpha sinensis*, *Spodoptera litura* and *S. exigua* have been isolated, identified and synthesized. Sex pheromones of sweet potato weevil, carambola fruit borer, tobacco cut worm and beet armyworm are being used in IPM programs. Cheap and efficient pheromone based insect traps have been developed. *Bacillus thuringiensis*, *B.subtilis*, *B.amyloliquefaciens*, *Trichoderma* spp. and several other microorganisms have been isolated from different biotypes around the island. Strain improvement through UV irradiation and transgenic manipulation was conducted to broaden the host spectrum and enhance bioactivity. Solid and liquid fermentation technologies have been established for mass production of several organisms, more particularly the serial plot-scale liquid fermenters for microbial fungicides. Separation and concentration of lipophilic fungal spores and their metabolites were invented. *Nomuraea raleyi* against beet armyworm in soybean and *Metarhizium anisopliae* against *Nilaparvata lugens* in rice provided a control comparable with synthetic insecticides. The use of rice cooker has been reported as very handy for the on-farm mass production of these entomopathogenic fungi. Microbes such as *Rhizobium*, associative and free living nitrogen fixing bacteria, phosphate solubilizing bacteria, arbuscular mycorrhiza fungi and organic materials degrading organisms are being isolated from different ecosystems as potential biofertilizers for the future. Most successful rhizobial inoculants were applied successfully to leguminous crops and muskmelons. Multifunctional biofertilizers were developed to reduce about ⅓ to ½ of fertilizer requirement.

Republic of Korea - Dr. Yong-Ki Kim, Rural Development Administration (RDA), Kyunggi-ku, Suwon.

Biofungicides have been targeted against 20 crop pests including sheath blight of rice, powdery mildew of red pepper, downy mildew of cucumber, shot hole of peach, brown patch, *Phytophthora* blight of red pepper, gray mold and bacterial wilt of tomato, *Alternaria* blight of Korean ginseng, *Septoria* leaf spot of fragrant edible wild aster, leaf mold of tomato, *Anthracnose* of wild grape and bacterial soft rot of leek. Bioinsecticides have been used on 26 crops; against *Cnaphalocrocis medinalis* of rice, *Pseudaletia separate* of grass, oriental tobacco budworm of red pepper, tobacco cutworm of *Pyrilla*, beet armyworm, common cabbage worm and diamond back moth of Chinese cabbage, *Allium* leafminer of leek, fabricus of beet, cotton caterpillar of cucumber and pumpkin, leaf miner of apple, persimmon fruit moth of persimmon, pine moth of pine tree, fall webworm of *Platanus*, spider mites of strawberry, green whitefly of cucumber and tomato, thrips of oriental melon and cucumber, cabbage armyworm of broccoli, pine pyralid moth of Korean white pine, onion maggot of garlic, *Lissorphoptrus oryzophilus* of rice and cutworms of spinach. The current researches aim to utilize systemic disease resistance, hyper-parasitism, nutrient competition, and volatile compounds for managing various diseases. The government policy supports environment friendly agricultural production, use of organic fertilizers, reduction of registration requirements, mass production of microbial agents and composts, improved certification system for the produce, and infrastructure for environment friendly agriculture. By 2013, it is proposed to reduce use of chemical pesticides by 30% and fertilizers by 40% as compared to 2003 levels. The production of environment friendly agricultural produce (EFAP) is encouraged and 3 EFAPs, namely organic, pesticide free and low input of chemicals, are recognized. During 2003-2009, 200% growth rate of biopesticides has been reported.

India- Dr. Balraj S. Parmar, Consultant, APAARI (Formerly Joint Director Research, and Emeritus Scientist, Indian Agricultural Research Institute (IARI), New Delhi).

Four botanical biopesticides are registered under the Insecticides Act, 1968 of which only neem, *Azadirachta indica* holds potential for a large scale use in agriculture. Over 450 azadirachtin based products are registered. During 2003-04, 2.7 million litres/1000 tons of Aza based pesticides were reportedly used. These control a wide range of pests on a number of crops including pulses, vegetables, turmeric, ginger, rice, cotton, jute, sorghum, fruits, coffee, tea, and flowers. The optimum Aza concentrations for best effect range between 20-50 ppm, depending upon the pest to be controlled, and use method and situation. Thirteen microbial pesticides including 3 bacterial, 8 fungal and 2 viral are registered under the Insecticides Act. Their most common use form is wettable powder, though aqueous solution, suspension concentrate and slurry for seed treatment are also used. Two larval parasitoids - *Bracon brevicornis* and *Goniozus nephantidis*, two egg parasitoids - *Trichogramma chilonilis* and *T. japonicum*, and two predators *Chrysoperla camea* and *Cryptolaemus montrouzieri* are available commercially. Biocontrol systems comprising crop/pest, the agent and dosage are available for a number of crops. Up to 2002, 16,260 thousand biocontrol agents were mass produced and released on an area of 523 thousand hectares against insect pests of rice, cotton, sugarcane, pulses, vegetables and oilseeds. However, the production capacity is underutilized and there is difficulty in selling the produced quantities. Fourteen sex pheromones are commercially available. These are sourced from *Earias vittella*, *E. insulana*, *Helicoverpa armigera*, *Pectinophora gossypiella*, *Spodoptera litura*, *Chilo auricilius*, *C. infuscatellus*, *C. sacchariphagus indicus*, *Scircophaga excerptalis*, *S. incertulus*, *Leucinodes orbonalis*, *Plutella xylostella*, *Oryctes rhinocerus*, and *Rhynochophorus ferrugineus*. About 2.5% of the total pesticide market is commanded by biopesticides. The significant recent research achievements include the development of stable technical azadirachtin and its formulations, a formulation of *Trichoderma virens* passing the accelerated storage test, a formulation of entomopathogenic nematode *Steinernema thermophilum* with a shelf life of over 9 months at 40°–45°C, and a formulation of growth promoting rhizobacteria with a shelf life of over one year at 40°C. As far as the biofertilizers or bioinoculants are concerned, efforts are underway to bring them under the ambit of Fertilizer Control Order, 1985. Their use has found better adoption in the southern and western regions as compared to the rest of India. During 2007-08, 20,111 metric tons of biofertilizers were produced as against an installed capacity of over 67,000 metric tons. The use intensity of chemical fertilizers (N+P+K) to biofertilizers was 90:0.04 kg per ha.

Sri Lanka - Prof. Rohan Rajapakse, Sri Lanka Council for Agricultural Research Policy (CARP), Colombo.

Bacillus thuringiensis is registered as a biopesticide. Its high cost coupled with rapid breakdown has been responsible for its rather poor adoption. Locally isolated *Beauveria bassiana* and *Metarhizium anisopliae* have shown potential for future use. Efforts are underway to use baculoviruses against *Oryctes rhinoceros* on coconut though high cost and slow rate of pest mortality in field are serious impediments. Botanicals namely, *Azadirachta indica*, *Allium sativum*, *Capsicum fruticens*, *Gliricidia sepium*, *Adathoda vesica*, *Pleurostylia opposite*, *Acronycha pedunculata*, and *Alseodaphne semicarpifolia* are used commonly for pest management. Studies have been conducted to identify the advantages of utilizing *Rhizobia*, *Azotobacter*, *Azospirillum*, blue green algae, *Azolla* and phosphate solubilizing bacteria and fungi as biofertilizers. The use of *Rhizobia* in mushroom cultivation and *Azolla* in paddy cultivation has shown promising results. Seventy-three strains of nitrogen fixing blue green algae belonging to 21 genera have been isolated from rice soils in central Sri Lanka. Fungal and bacterial biosolubilization of rock phosphate has also shown good results. A liquid formulation of biofilmed

biofertilizers together with 50% of recommended fertilizers for tea increased organic carbon by 30% as compared to the chemical fertilizer alone. Policy support is needed to promote the use of biofertilizers.

Philippines - Dr. Danilo C. Cardenas, PCARRD, Manila.

Organic movement has taken roots in the Philippines and many biopesticides, either microbial or ethanobotanical, are available. Rapid composting through *Trichoderma* based technology provides the added advantage of compost-fungus activator in the form of its biopesticidal property, such as against the club root disease of cabbage. Bio-N, a biofertilizer, produced by Biotech Company has two species of nitrogen fixing bacteria, one for rice and the other for corn. Besides promoting root and shoot growth, it is also known to induce resistance to drought and insect pests. There are 64 plants making Bio-N in the country. Government has adopted a number of strategies to promote the use of bioagents, and farmers are encouraged to produce own organic fertilizers and adopt IPM. National extension programs using farmer-scientist education and communication, and information communication technology are being adopted. However, mass production of bioagents is still at a small scale; quality control and improvement are in infancy and IPR issues are a concern since microbes are easily cultured and pirated.

Vietnam - Dr. Nguyen Van Viet, Vietnam Academy of Agricultural Sciences (VAAS).

Vietnam imported 105,999 tons of chemical and biopesticides in 2008 valued at US$ 352.65 million. A total of 902 insecticides/active ingredients were registered in 2009, out of which 150 were biopesticides. Only 12 active bioagents are widely used, abamectin being the most common one (56.28%) followed by validamycin (20.46%). Seven biopesticides (26.92% of the 18 active agents) were used on vegetables in the Red River Delta. Nearly 81.6% of the farmers applied these at the end and 35.7% in the middle of the crop season. Indigenous ViHa, ViSl, NPV, VBt, have been registered but find a limited application. Several Bt based products named *Bt1, Bt2, Bt3, BC1, BC2* have been developed, the first two in liquid form with a recommended dosage of 1L per ha. A formulation Boverit va Mat comprising *Beauveria bassiana* and *B.anisopliae*, and preparations based on *Trichoderma viride* are under preparation. Fifty-three toxic plants have been discovered and two highly toxic plant based products against yellow snails have been developed. In 2007, 1,717 fertilizers were registered of which 404 were biofertilizers. Over 400,000 tons biofertilizers are produced annually.

Iraq - Dr. Hamid Ali Hadwan, National Center for Organic Farming, Baghdad.

Prior to 2003, the locally produced biopesticides, *Trichoderma*, *Paecilomyces*, and *Beauveria* species and *Bacillus thuringiensis* were used on wheat, corn, tomato, faba bean, pea, groundnut, and mung bean. Biofertilizers, comprising nitrogen fixing bacteria, *Rhizobium*, *Azotobacter* and *Azospirillum* species were applied on tomato, broad bean, wheat, bean, corn and mung bean. Culture type collection was established for maintaining the related isolates. During the war of 2003, these facilities were destroyed. Recently, a center for organic farming was established; the infrastructure is being built through international cooperation. Several organizations including Food and Agriculture Organization of the United Nations (FAO), International Fund for Agricultural Development (IFAD), International Center for Agricultural Research in the Dry Areas (ICARDA), and countries like Italy, Australia and China are supporting related R&D programs.

During discussion on the presentations in this session, the following key points emerged:

- Regulations and quality control all along the value chain are important to ensure human safety

against opportunistic pathogens. Small producers who generally skip strict regulations need to be watchful, especially when human safety is at stake.

- Farmers are prime movers of technology. If they are convinced that the recommended technology is useful, they will adopt and adapt it.
- Involve farmers in technology assessment to build their confidence in the technology.
- Farmers have not only to be convinced about the utility of bioinputs but their interests also need to be duly protected, particularly since majority of them have limited loss bearing capacity. Insurance against poor performance of bioinputs may be enforced and producers of sub-substandard products penalized.
- Effective extension service is vital for the promotion of bioinputs.

Session III. Reports of Regional/International Institutions and other Stakeholders

Dr. Jacqueline Hughes, Deputy Director General Research, AVRDC, Dr. Rohan Rajapakse, Executive Director, CARP, Sri Lanka and Andreas W. Ebert, Gene bank Manager and Global Theme Leader, AVRDC were the Chairperson, Co-Chairperson and Rapporteur, respectively.

Biopesticides Research at ICRISAT: A Consortium Model, Dr. G. V. Ranga Rao and Dr. S. Gopalakrishnan, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India.

ICRISAT initiated a Bioproducts Research Consortium (BRC) in 2005, which is a public-private partnership aimed at delivering research outputs, capacity building and technologies for large scale production of quality bioproducts. BRC has a collection of about 2000 accessions that include important entomopathogens (*Bacillus subtilis* BCB 19, *B. thuringiensis* HiB67, in addition to 37 potential isolates), particularly against *Helicoverpa armigera* and *Spodoptera litura*, and antagonists of phytopathogens (*B. subtilis* BCB19, *Pseudomonas* sp. CDB35, in addition to 154 isolates), particularly against *Macrophomina phaseolina*, *Fusarium oxysporum* f. sp. *ciceri*, *F. solani*, and *Sclerotium rolfsi*. Various plant growth promoting traits have been characterized including phosphate solubilization, indole acetic acid and siderophore production, hydrolysis of chitin, cellulose degradation, and lipase and protease production. Twelve potential PGP bacterial and actinomycete isolates from 27 different herbal compost preparations have been identified. These induced up to 61% and 45% increase in shoot and root growth, respectively. Ninety-six village level nucleopolyhedrosis virus (NPV) production units have been set up in India and Nepal. By using biopesticides, reduction in pesticide application from 11 to 4 sprays in cotton, 2.1 to 1.6 in rice, 2.9 to 2.2 in pigeonpea and 2.9 to 2.3 in chickpea has been demonstrated in field.

Lack of effective regulation can, however, lead to poor product quality, performance and loss of user confidence. There is a need to prioritize research for better integration of bioagents into production systems, such as in rotation with chemical pesticides, and developing these into effective biomodels.

Biopesticides: A synergistic component in vegetable integrated pest management (IPM) strategies, Dr. R. Srinivasan, AVRDC, Chinese Taipei.

Chemical insecticides are used heavily in vegetable crops in Asia. Microbia like *Bacillus thuringiensis* sub sp. *kurstaki* and *aizawai* are effective against Lepidopteran pests and along with *Diadegma semiclausum*, an ichneumonid larval parasitoid, in controlling *Plutella xylostella* in tropical Asia and Africa. The parasitoid has established in several countries and effectively controls secondary lepidopterans on brassicas and vegetable legumes. The entomopathogenic NPV (exs. *Helicoverpa armigera* NPV, *Spodoptera litura* NPV, *S. exigua* NPV) nucleopolyhedrosis (NPV) are already commercialized and used against tomato fruit borer, common armyworm and beet armyworm. Mavi NPV, effective against legume pod borer, either alone or in combination with *B. thuringiensis* and neem, has been identified by AVRDC. Oil based formulations of entomopathogenic fungi- *Beauveria bassiana* and *Metarhizium anisopliae* reduce the population density of *Tetranychus* sp. significantly. Some of the isolates possess ovicidal effect against legume pod borer and larvicidal effect against diamond back moth on cabbage, and the web worms *Hymenia recurvalis* and *Psara vasalis* on amaranth. Among botanicals, neem is used in integrated management of early season sucking pests and defoliators on vegetable soybean. Sex pheromone traps to lure insects such as *H. armigera, S. litura*, *S. exigua*, *M. vitrata* and *Diaphania indica* are available. AVRDC has developed and promoted sex pheromone based IPM strategy to manage the eggplant fruit and shoot borer *Leucinodes orbonalis* in south Asia. An IPM strategy based on aggregation pheromones and host plant volatiles for controlling *Phyllotreta striolata* beetles on vegetable brassicas is being developed.

Biotech fertilizer development of Taiwan Fertilizer Co. Ltd., Mr. Joseph H.C. Lin, Taiwan Fertilizer Co. Ltd., Nanjing, Chinese Taipei.

A series of three in one biotech fertilizers developed by the company, combining beneficial microbes (such as organic matter decomposers, P-dissolving, N-fixers, stimulators of plant growth hormones, antibiotics secretors, etc.), organic materials and chemical fertilizers are important milestones in improving soil fertility for crop production. The process of product development involves: (1) screening microorganisms, (2) fermentation, (3) formulation, (4) field testing, and (5) development of end product. These bioagents raise fertilizer efficiency, prevent diseases, maintain soil vigor, and reduce soil degradation and acidification. Three key products are Taifer BioPowder (containing highly concentrated beneficial microorganisms, amino acids, humic acid, algae extracts, and fermented organic materials), Taifer BioOrganic (beneficial *Bacillus* sp. strains, enriched organic materials such as rice bran, humic acid, guano and tobacco leaf), and Taifer Effective (with beneficial *Bacillus* sp. strains, enriched organic materials and chemical fertilizers). Application on asparagus, strawberry, tea, rice, ornamental flowers and fruit trees has shown improved vegetative growth, profuse rooting, increased yields and quality, and lesser damage by pests and diseases.

Farmers' experiences in biofarming, Mr. Raul Montemayor, International Federation of Agricultural Producers (IFAP), Quezon City, Philippines.

IFAP is a world farmers' organization with 115 member organizations in 80 countries. Federation of Free Farmers (FFF), a national farmers' organization in the Philippines, undertakes education, advocacy, technical training and extension. The biofarming activities of FFF relate to training of farmers and technicians, organization of biofarming clusters and networks, development of knowledge centers, biofertilizer production and commercialization, farm exchanges and supplemental training, development of training materials and their dissemination, and marketing support. Two significant observations are that banana, squash and papaya induce flowering and water extracts of spinach and kangkong promote growth of plants.

Adoption of bioagents has been facilitated through farmer demonstrations showing significant and immediate impact, better prices for produce, and adaptable and affordable technology. Farmer organizations can be key actors in technology development and dissemination.

Asian Non-government Organizations' Coalition for Agrarian Reform and Rural Development (ANGOC), Fr. Antonio Francisco Lucas, ANGOC, Quezon City, Philippines.

ANGOC has members and partners in 12 Asian countries, comprising a network of about 3000 NGOs. It works with Asian rural communities through NGO members and partners focusing on food sovereignty and poverty reduction issues. Experiences shared by representatives from Japan, Chinese Taipei, Vietnam, Thailand, Korea, India, Philippines, Myanmar and Cambodia at a conference held in 2007 in the Philippines were presented. A case study on the sustainable rice production in the Philippines during 1998-2000 was presented in this meeting. It showed rice cultivation with organic inputs to be highest yielding with the lowest greenhouse gas emissions.

National Research Development Corporation (NRDC) activities on neem and other biopesticides, Dr. Arunabha Pradhan, NRDC, New Delhi, India.

NRDC is a premier Knowledge Transfer Organization in India established by Ministry of Science and Technology to promote, develop and commercialize indigenous technologies. The presentation listed the technologies on biopesticides available/licensed by NRDC. These include production of technical azadirachtin concentrates, formulations of neem pesticides, stable azadirachtin concentrates and formulations, plant based insecticide synergists, plant based and *Bacillus thuringiensis* based mosquito larvicidal compositions, a formulation with improved shelf life based on *Steinernema thermophilum*, a broad spectrum entomopathogenic nematode, technology of making shelf stable dustable powder (DP) based on *Trichoderma* sp., and the technology of making DP formulation based on *Bacillus cereus* for managing white grubs. The commercialization status along with the key features of each technology were presented.

The key points that emerged during the ensuing discussion in this session were as follows:

- Biofertilizer business in Chinese Taipei can yield profit in the range of 10-15%, while in traditional fertilizer business profit is below 5%.
- There is no hindrance in mass production of neem based products since the raw material is plentiful. Moreover, the tree grows in wastelands without much care.
- Farmers need to be involved more actively in use and promotion of biopesticides and biofertilizers.
- There is a need to provide factual information about the efficacy of bioagents. Avoid projecting overestimates or underestimates.
- The ability of *Trichoderma* to kill indiscriminately must be kept in mind before making recommendations based on its use.

Session IV. Biopesticide and Biofertilizer Innovations and Commercialization

The session was chaired by Dr. Mantana Milne, Director, Department of Agriculture, Thailand, with Mr. Raul Motemayor, Vice President, IFAP as Co-Chair and Dr. Andreas W. Ebert, AVRDC as Rapporteur.

Improvements in knowledge of mechanisms of beneficial microorganisms, Prof. Gary E. Harman, Department of Horticultural Sciences and Department of Plant Pathology, New York State Agricultural Experiment Station, Cornell University, U.S.A.

Most of the beneficial effects of *Trichoderma* spp., *Piriformaspora indica* (a Basidiomycete), and plant growth promoting rhizobacteria of the genera *Serratia* or *Rhizobium* spp., are due to their ability to control plant diseases and improve plant resistance to abiotic stresses such as water deficit, temperature, salt and intense light. They also often improve N use efficiency, by affecting plant physiology via reprogramming of the plant genome. Only a few general mechanisms seem to be involved. Systemic resistance is induced through jasmonate/ethylene signaling pathway. Resistance to both biotic and abiotic stresses is triggered by production of reactive oxygen species whose levels are modulated or alleviated via activation of the glutathione-ascorbate pathway. Even though the bioagents are phylogentically very distant, they seemingly induce similar responses in plants. Specific genes and biochemical pathways involved need to be better understood for their use in diverse applications.

Development and application of microbial pesticides in Taiwan, Prof. Shan-Da Liu, Meiho Institute of Technology, Chinese Taipei.

The application of a liquid formulation of *Trichoderma koningii* against the root rot disease of adzuki bean increased the bean yield by 24.7% against the untreated check. One of the several isolates (MA-1) of green muscardine fungus, *Metarhizium anisopliae* var. *anisopliase* isolated from naturally infected coconut leaf beetle, *Brontispa longissima* showed strong pathogenicity against Coleopteran and Lepidopteran insects. However, it was sensitive to benzimidazole carbamate fungicide. Through UV radiation and chemical mutation, a resistant isolate (MA-126) with the same efficacy has been obtained. This fungus also gave good control of *Plutella xylostella* on cruciferous vegetables. The virulence of MA-126 on *Myzus persicae* also matched with other entomopathogenic fungi such as *Beauveria bassiana* and *Verticillium lecanii*. Microencapsulated formulations of MA-126 have been prepared by using the biopolymers sodium alginate, hydroxypropyl methyl cellulose and chitosan. Genomic variability of MA-126 with other 12 isolates of *M. anisopliae* by random amplification of polymorphic DNA polymerase chain reaction (RAPD-PCR) revealed that OPI-18-1.0 kb fragment provided a useful and rapid tool for identifying species and strains of this fungus. Handicaps in mass production, standardization of formulations and storage, and patent issues are some of the problems in commercialization of bioagents.

Research, production and commercialization of biopesticides and biofertilizers, Chiu - Chung Young, National Chung Hsing University, Taichung, Chinese Taipei.

An overview of the diversity, classification, and strategies for exploration of biopesticides and biofertilizers was provided. Based on their risk, four groups were identified: (1) no or low individual or community risk, (2) moderate individual risk, low community risk, (3) high individual risk, low community risk, and (4) high individual and high community risk. To encourage adoption of bioagents, during 1987-2009, farmers have been given free products for evaluation covering an area of 111,000 ha. So far, farmers have benefited to the extent of 46.5 million US$. Key areas suggested for future work include, exploration, selection and identification of most effective organisms, shift of focus from monofunctional to multifunctional agents, complex rather than single biopesticides/biofertilizers, and development of controlled release products.

Biopesticides and biofertilizers in integrated pest and nutrient management, Dr. Hung-Chang Huang, Agriculture and Agri-Food Canada.

A need to develop biological pest control and nutrient management systems based on basic knowledge and fundamental understanding of pest and plant nutrition was stressed. Biological, environmentally sound integrated pest and nutrient management (IPNM) systems with emphasis on use and integration of diverse methods such as cultural (crop rotation), physical (organic amendments, chemicals, microorganisms) and resistant hosts would be desirable. Ideally, pest control and nutrient supply may be integrated in one system. Adequate research funding is crucial for successful integration of biopesticides and biofertilizers in IPNM.

Innovations in plant incorporated protectants, Dr. T.P. Rajendran, Indian Council of Agricultural Research (ICAR), New Delhi, India.

The last decade of twentieth century witnessed development of several crops such as cotton, tomato, brinjal, maize, rice, pigeonpea, and chickpea with plant incorporated protectants (PIP) against pests. Initially, very encouraging results were achieved. However, it is now emerging that there has been a shift in the nature of the biotic stress, the earlier minor pests emerging as major ones. Indispensability of plant protection measures necessitates a scientific application of IPM incorporating the biological tools in the pest and nutrient management schedules. Crop health needs to be managed with a holistic approach for enduring and long-standing metabolism-enabling process that enhances crop productivity. Intelligently integrated PIP with IPM and INM should enable ecologically sound management of pests and diseases.

Biopesticides status in the Middle East, Dr. Hail Shannag, Department of Plant Protection, Jordan University of Science and Technology, Irbid, Jordan.

The availability of biopesticides in the Middle Eastern markets is constrained by a number of factors such as small market size, lack of harmonized registration procedures and absence of registration system. Recently, screening of local bioagents possessing unique ecological traits has resulted in the discovery of numerous local species and strains of organisms effective against a wide range of plant pests. Promotional work for their practical application is being pursued. Farmers implementing IPM have experienced saving of about 70% in pesticides without reduction in yield or quality. Further, they find greater opportunities to market the produce. A number of steps were suggested to promote the use of bio-pesticides in the Middle East.

The following key points emerged during discussion in this session:

- The achievements of Chinese Taipei in developing plant production and protection bioproducts and their popularization among farmers are quite commendable. Other countries can benefit from their experience.
- Since the performance of bioagents varies across areas and environments, there is a need for their site-specific evaluation and package of practices.
- Efforts be made to utilize waste from sugar mills to be converted into nutrient supplying products.
- A network on biopesticides and biofertilizers in the Asia-Pacific region would go a long way in scientific promotion of these inputs.

- Efficacy, safety and quality of bioagents should be the keywords for their promotion. However, the areas of regulatory control need to be properly identified.

Session V. Breakout Group Discussions

Two groups facilitated by Dr. N. P. Adhikari, Nepal Agricultural Research Council (NARC), Nepal and Prof. Anwar Alam, Sher-e-Kashmir University of Agricultural Sciences and Technology Kashmir (SKUASTK), India deliberated on the key issues for promoting R&D, policy regulation and regional cooperation in biopesticides and biofertilizers.

Recommendations of Breakout Group I (Issues in Research and Development)

- There is a need to enhance and sharpen R&D efforts in biopesticides and biofertilizers to make them competitive with chemical inputs.
- Research on formulations with respects to active ingredients, auxiliary and other ingredients needs to be accelerated.
- Develop technologies to ensure precise dosage application and crop-pest and agroecology specific packages.
- Screening, cataloguing and indexing of bioagents and development of freely accessible data banks to be prioritized.
- Undertake research in safety of bioagents and develop protocols for their safe handling and field application.
- Develop linkages and regional partnerships to promote R&D and capacity building.

Recommendations of Breakout Group II (Issues in Commercialization, Policy Regulation and Regional Cooperation)

- Commercialization of biopesticides and biofertilizers will improve their availability and accessibility. However, viability of commercialization will depend upon the availability of appropriate technology and the targeted beneficiaries.
- There is scope for commercialization not only through organized sector but also by small farmer associations and self help groups.
- Products to be commercialized should be well tested at laboratory and field levels and production process should be well defined and proven.
- Every country should have policy on promotion of biofertilizers and biopesticides and their extension.
- Policy guidelines should provide enabling environment for development and use of bioagents and not be restrictive.
- For observance of quality assurance, adoption of quality certification is recommended.

- Shelf life of biofertilizers and biopesticides is a major issue. There should be regulatory mechanisms to ensure the prescribed shelf life.

- There should be a Regional Network on Biofertilizers and Biopesticides in APAARI Member countries/organizations for cooperation in: (i) knowledge sharing, (ii) partnership, and (iii) capacity building.

Plenary session: Presentation of Group Recommendations and General Recommendations

The session was chaired by Dr. Raj Paroda, Executive Secretary, APAARI, co-chaired by Prof. Chiu-Chung Young, National Chung Hsing University, Taichung, with Dr. J. L. Karihaloo, Coordinator, APCoAB as the Rapporteur. The facilitators of Session V presented the recommendations of Breakout Groups. The following additional recommendations were made by the participants:

- In view of the important place that bioagents have in sustainable agriculture and in meeting the Millennium Development Goals, the national governments should double their investment in R&D on biopesticides and biofertilizers.

- Promote adoption of bioagents in participatory mode with farmers, NGOs, farmer groups and public institutions through government aided programs.

- Refine technologies that will help farmers produce bioinputs on their own farms with on-farm ingredients.

- Research on increasing shelf-life of bioagents be given priority.

- Documentation of indigenous knowledge and its validation and integration with scientific knowledge be undertaken.

- Regulatory mechanisms of the member countries need to studied and documented.

- Public-private partnership in research, production and commercialization should be encouraged.

- Regional cooperation and capacity building should be targeted for all stakeholders including policy makers, scientists, NGOs and farmers.

- In view of the commendable achievements of Chinese Taipei in biopesticides and biofertilizers, the Council of Agriculture, Taipei is requested to support bilateral R&D and extension programs in the region.

General Recommendations

The delegates at the Expert Consultation on Biopesticides and Biofertilizers for Sustainable Agriculture, expressed consensus that biopesticides and biofertilizers have an important role in creating sustainable agriculture, reducing cost of inputs, and achieving Millennium Development Goals. In view of their ecofriendliness coupled with good efficacy, the Asia-Pacific countries should develop national strategies and implement them with a mission mode zeal to achieve an adoption level of at least 10 per cent of their total pesticide and fertilizer use. The national strategies must embrace the following:

- The countries to double their investment on promotion of biopesticides and biofertilizers in agriculture. This should comprise support and incentives in terms of policy, procedures, farmer compensation, risk insurance, R&D, capacity building, knowledge based extension and other efforts to promote biointensive pest and nutrient management systems.

- Intensify efforts to develop more efficient products and technologies, and enhanced capability and capacity for the production, availability, access, refinement, promotion, adoption and assessment of bioagents through participatory mode involving public and private sectors, self help groups, farmers and other stakeholders.

- Increased emphasis on formulation research and development, particularly on the active material/ organism-formulant/auxiliary/other ingredient(s), to yield standard and quality products with improved shelf and field life. Development of farmer friendly technologies be specifically focused and pursued.

- Promote indexing, cataloguing and documentation of products, technologies, indigenous folklore knowledge and other information, and have the data banks freely accessible for reference and use.

- Accelerate efforts towards outscaling of innovations through proper assessment, refinement and transfer of technologies and products to farmers and other stakeholders. Promote those technologies which help farmers produce bioinputs on their own farms using mostly the local ingredients.

- Devise and adopt simple and need-based regulatory systems for bioproducts, including improved species/strains, individual organisms and/or microbial consortia.

- Create jointly and support Regional Network on Biopesticides and Biofertilizers in the Asia-Pacific region in order to promote partnership, knowledge sharing, capacity building, and other activities for focused promotion of these bioinputs, including their need-based integrated use along with the chemical fertilizers and pesticides.

Closing Ceremony

Dr. Raj Paroda and Dr. Dah-Jiang Liu summed up the major recommendations and presented their closing remarks. Dr. J. L. Karihaloo offered a vote of thanks.

APAARI-APCoAB-COA
Expert Consultation on Biopesticides and Biofertilizers for Sustainable Agriculture

Venue: Taiwan Agricultural Research Institute, Taichung, Chinese Taipei

Dates: 27 – 29 October 2009

Program

27 October 2009

08:00-09:00	**Registration**
09:00-10:00	**Inaugural Session** *Chair: Dr. Abd Shukor bin Rahman, Chairman, APAARI* *Co-Chair: Dr. Dah-Jiang Liu, Director General, TARI, COA*
09:00-09:10	**Welcome Address:** Dr. Abd Shukor bin Rahman, Chairman, APAARI
09:10-09:20	**Welcome Address:** Dr. Dah-Jiang Liu, Director General, TARI, COA
09:20-09:30	**Opening Remarks:** Dr. Su-San Chang, Director General, International Cooperation, COA
09:30-09:45	**About the Expert Consultation:** Dr. Raj Paroda, Executive Secretary, APAARI
09:45-09:50	**Vote of Thanks:** Dr. J. L. Karihaloo, Coordinator, APCoAB
09:50-10:20	Group Photograph and Tea Break
10:20-12:05	**Session 1: Presentation of Lead Papers** *Chair: Dr. Raghunath Ghodake, Director General, NARI* *Co-Chair: Dr. Danilo C. Cardenas, Officer-in-Charge, PCARRD* *Rapporteur: Dr. B. S. Parmar, Technical Consultant, APAARI*
10:20-11:05	**Maintaining Global Food Security in a Dynamic Physical and Social Environment**- Dr. Robert Zeigler, IRRI
11:05-11:35	**Control of Biotic, Abiotic and Physiological Stresses with *Trichoderma* spp. and other Beneficial Plant Microbes** - Prof. Gary E. Harman, Cornell University
11:35-12:05	**Inoculants for Sustainable Agriculture-Present Status and Future Prospects** - Prof. Yoav Bashan, University of Arizona
12:05-13:00	Lunch

13:00-15:30 **Session 2: Country Status Reports**
Chair: *Dr. Robert Zeigler, Director General, IRRI*
Co-Chair: *Mr. Thierry Mennesson, Director General, IANC, New Caledonia*
Rapporteur: *Dr. Andreas W. Ebert, Genebank Manager and Global Theme Leader, AVRDC*

13:00-13:15 **Chinese Taipei** - Dr. Suey-Sheng Kao, TACTRI

13:15-13:30 **Korea** - Dr. Yong-Ki Kim, RDA

13:30-13:45 **India** - Dr. B. S. Parmar, New Delhi

13:45-14:00 **Sri Lanka** - Prof. Rohan Rajapakse, CARP

14:00-14:15 **Philippines** - Dr. Danilo C. Cardenas, Officer-in-Charge, PCARRD

14:15-14:30 **Vietnam** - Dr. Nguyen Van Viet, VAAS

14:30-14:45 **Iraq** - Dr. Hamid Ali Hadwan, Ministry of Agriculture, Iraq

14:45-15:10 **General Discussion**

15:10-15:30 **Tea Break**

15:30-17:35 **Session 3: Reports of Regional/International Institutions & other Stakeholders**
Chair : *Dr. Jacqueline Hughes, Deputy Director General - Research, AVRDC - The World Vegetable Center*
Co-Chair : *Dr. Rohan Rajapakse, Executive Director, CARP*
Rapporteur : *Dr. Andreas W. Ebert, Genebank Manager and Global Theme Leader, AVRDC*

15:30-15:50 **Biopesticides Research at ICRISAT: A Consortium Model**
- Dr. G. V. Ranga Rao and Dr. S. Gopalakrishnan, ICRISAT

15:50-16:10 **Biopesticides: A Synergetic Component in Vegetable Integrated Pest Management (IPM) Strategies**
- Dr. R. Srinivasan, AVRDC

16:10-16:30 **Taiwan Fertilizers Co. Ltd**
- Mr. Joseph Lin, TFCL

16:30-16:50 **IFAP Report on Farmers' Experience in Biofarming**
- Mr. Raul Montemayor, IFAP

16:50-17:10 **CSO Views and Actions on Biopesticides and Biofertilizers**
- Fr. Antonio Francisco Lucas, ANGOC

17:10-17:30 **NRDC Activities on Neem and other Biopesticides**
- Dr. Arunabha Pradhan, NRDC

17:30-17:45 **General discussion**

19:00 Dinner hosted by APAARI

28 October 2009

09:00-12:00 **Session 4: Biopesticide and Biofertilizer Innovations and Commercialization**
Chair : Dr. Mantana Milne, Department of Agriculture, Ministry of Agriculture and Cooperatives, Thailand
Co-Chair : Mr. Raul Montemayor, IFAP
Rapporteur : Dr. Andreas W. Ebert, Genebank Manager and Global Theme Leader, AVRDC

09:00-09:20 **Improvements in Knowledge of Mechanisms of Beneficial Microbes**
- Prof. Gary E. Harman, Cornell University

09:20-09:40 **Development and Application of Microbial Pesticides**
- Prof. Shan-Da Liu, MIT

09:40-10:00 **Research, Production and Commercialization of Biopesticides and Biofertilizers**
- Prof. Chiu-Chung Young, NCHU

10:00-10:30 **Tea break**

10:30-10:50 **Biopesticides and Biofertilizers in Integrated Pest and Nutrient Management**
- Dr. Hung-Chang Huang, AAFC

10:50-11:10 **Innovations in Plant Incorporated Protectants**
- Dr. T. P. Rajendran, ICAR

11:10-11:30 **Biopesticide Status in the Middle East**
- Dr. Hail Shannag, JUST

11:30-12:00 **General Discussion**

12:00-13:30 **Lunch**

13:30-15:00 **Session 5: Break-out Group Discussions**
Group I: Issues for Research and Development
Facilitator: Dr. N. P. Adhikari, Director (Crop and Horticultural Research), NARC
Group II: Commercialization, Policy Regulation and Regional Cooperation
Facilitator: Prof. Anwar Alam, Vice-Chancellor, SKUASTK

15:00-15:30 Tea break

15:30-16:30 **Plenary Session: Presentation of Group Recommendations and General Recommendations**
Chair : Dr. Raj Paroda, Executive Secretary, APAARI
Co-Chair : Prof. Chiu-Chung Young, NCHU
Rapporteur : Dr. J. L. Karihaloo, Coordinator, APCoAB

16:30-17:00 Concluding Session

18:00 Dinner: hosted by COA

29 October 2009

Visit to AVRDC

30 October 2009

Taipei local visit

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