Innovation network for food security and poverty reduction

Workshop on Biological Control of Agricultural Pests and Diseases

5-7 March 2014, Kathmandu, Nepal

Workshop Report

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The Network for Knowledge Transfer on Sustainable Agricultural Technologies and Improved Market Linkages in South and Southeast Asia (SATNET Asia) aims to support innovation by strengthening South–South dialogue and intraregional learning on sustainable agriculture technologies and trade facilitation. Funded by the European Union, SATNET facilitates knowledge transfer through the development of a portfolio of best practices on sustainable agriculture, trade facilitation and innovative knowledge sharing. Based on this documented knowledge, it delivers a range of capacity building programmes to network participants.

SATNET Asia is implemented by the Centre for Alleviation of Poverty through Sustainable Agriculture (CAPSA) in collaboration with the AVRDC – The World Vegetable Center, the Asian and Pacific Centre for Transfer of Technology (APCTT), the Food Security Centre of the University of Hohenheim and the Trade and Investment Division of UNESCAP.

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Executive Summary

The workshop on "**Biological Control of Agricultural Pests and Diseases**" was organized as one of the key objective of The Network for Knowledge Transfer on Sustainable Agricultural Technologies and Improved Market Linkages in South and Southeast Asia (SATNET) held from 5-7 March 2014 in Kathmandu, Nepal. The workshop was held in accordance with the objective of food security which is one of most important goals of 2015 for the United Nations. The workshop was organized in partnership with Asian and Pacific Centre for Transfer of Technology (APCTT), Nepal Agricultural Research Council (NARC), Nepal. The welcome address and introduction of the program was delivered by Mr. Michael Williamson, Head, APCTT-ESCAP, New Delhi. The main focus of the workshop was on explaining the importance of controlling agricultural pests and diseases using local and biological means. An extensive theoretical as well as practical introduction in the form of a field visit was given to the participants regarding the best practices in the utilization of natural enemies to control the frequently occurring pests in the field.

In the past few decades excessive use of chemical pesticides in agricultural crops has resulted into multiple undesirable effects such as environmental damages, ecological imbalance, pesticide residues in food, vegetables, soil and ground water as well as adverse impacts on, human, and animal health. Integrated pest management practices and in particular, biological control approaches targeting control of insect pests and diseases of agricultural crops is a very promising alternative to synthetic pesticides. The biological control approaches are environment-friendly, effective against a broad range of insect pests and are easy to adopt.

The workshop was attended by nearly 30 participants representing farmers, cooperatives, chairmen, scientists, project engineers, executive directors etc. Out of 30 participants 6 were females. The resource persons trained the participants on the relevant topics and discussed specific case studies. The participants were encouraged to interact with the resource persons during tea/lunch breaks. The concluding session chaired by APCTT summarized the way forward for application of the learnt techniques as well as the opportunities to apply the tools, techniques and skills learned from this training programme in real life situations.

SATNET Asia National Training Program on Biological Control of Agricultural Pests and Diseases

5-7 March 2014, Kathmandu, Nepal

Introduction

The Network for Knowledge Transfer on Sustainable Agricultural Technologies and Improved Market Linkages in South and Southeast Asia (SATNET) is working with institutions that share knowledge on sustainable agricultural technologies and improved market linkages in the region. SATNET facilitates knowledge transfer through the development of a portfolio of best practices on sustainable agriculture, trade facilitation and innovative knowledge sharing. Based on this documented knowledge, it delivers a range of capacity-building programmes to network participants. This will enable them to transfer this knowledge to those who need it most – smallholder farmers and small-scale entrepreneurs.

Sustainable development requires knowledge and capacity in government agencies, businesses and local communities to enable all stakeholders to participate in the decision making and to put in place appropriate strategies, thereby strengthening their communities to the desired change processes and their ability to identify with them. The work package 4 (WP4) of the SATNET Asia focuses on knowledge transfer as well as capacity development aspects of the project, with a particular emphasis on South-South collaboration.

APCTT organized the **SATNET Asia National Training Programme on Biological Control of Agricultural Pests and Diseases** during 5-7 March 2014 in partnership with the Nepal Agricultural Research Council (NARC). This training attracted the participation of representatives from smallholder farmer groups, research groups and agro-cooperatives. The focus of this training was to provide exposure to the participants on a wide range of practices related to pest and disease control. The training programme shared knowledge on technologies and best practices related to eradication of agricultural pests and diseases that have a significant impact on the livelihoods of farmers and to the national economy as a whole. The participants developed a clear understanding of biological pest control and to network with each other to learn best practices related to controlling of agricultural diseases.

Programme structure

Methods used to train participants included theoretical lectures, case studies, classroom interaction, audio/video presentations, and field visit for demonstration of studies carried out in the domain of organic control of agricultural pests and diseases. Below is the program summary of the stress tolerant technologies training program.

Day-1	Day-2	Day-3
• *IPM programmes in Nepal* • *CABI's Bio-Control programmes* • *Integrated Disease Management* • *Handling of Bio-control Agents* • *International Standards of Phytosanitary Measures (ISPM)*	• Bio-Control Agents in Asia Pacific region • Biological Control researches • Plant Diseases Management • Parthenium Status in Nepal • IPM Trails (theory and practical)	• Caribbean Experience on Classical Biological Control • Mass Production of bio-control agents • Establishment of Bio-control Laboratory • Preparation of semi synthetic diet for mass media production

Key learning outcomes:

1.0 Current Status of Biological Control/IPM Programmes in Nepal

Identification and agricultural use on natural enemies of crop pests commenced in Nepal from 1967-68 in Entomology Section (now Entomology Division), Department of Agricultural Research and Education at Jagadamba Krishi Bhavan, Pulchok, Lalitpur, Nepal. For the first time biological control laboratory was established in 1998 with minimum lab-facilities in entomology division. There upon mass productions of larval parasitoid, *Cotesia plutellae* (hymenoptera: braconidae) and its host insect, diamondback moth, *Plutella xylostella* (lepidoptera: plutellidae) commenced. The South Asian Vegetable Research Network (SAVERNET), a sub regional framework for cooperation composed of the South Asian countries of Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka, facilitated Entomology Division to reorganized prevailing laboratory into mass rearing chamber for parasitoids and predators for immediate use in crop field as bio-control agents. Rearing *Cotesia plutellae* and *Diadegma semiclausum* against diamondback moth in cabbage was the first target as recommended by AVRDC (Asian Vegetable Research and Development Center, 1996).

Biological control of weed initiation started in Nepal in 1972 while the Croton weed, *Ageratina adenophora* (sprengel) King and Robinson (*Eupatorium adenoforum*) (asterales: asteraceae), (locally called banmara, kalejar, cangresijar, salahajar) needed fare control management in the middle mountain region of Nepal. *Spenorala rutilans* (Coleoptera: Chrysomelidae) was discovered as a specialized natural enemy of skunk vine, *Paderia foetida* L. which was successfully reared in mass and delivered to Agriculture Research Service (ARS), United States Department of Agriculture, Florida to be used against an invasion of skunk vines. *Lilioceris impressa* (Coleoptera: Chrysomelidae) was discovered as a specialized natural enemy of air potato, *Dioscorea bulbifera* L. which was successfully reared in mass and delivered to Agriculture Research Service (ARS), United States Department of Agriculture (USDA), Florida to be used against an invasion of air potato vines. The USDA-ARS, Florida demonstrated the beetle's host range is exceptionally narrow. It could develop only on air potato.

Parthenium entered Nepal early in 1950s from India. There was rapid expansion of this weed in urban areas during 1990s. The weed invaded roadside vegetations, agriculture lands and community forest of tropical and sub-tropical regions throughout Nepal. It was a dominant weed in major urban areas such as Kathmandu, Hetauda, Narayangargh, Butwal, Dang, etc.

An exotic insect pest, *Leucaena psyllid*, (heteropsylla cubana crawford) (hemiptera: psyllidae) suddenly appeared in *Leucaena spp*. trees in the Kathmandu valley, Nepal during July 1989. Mexican origin lady beetles, *Curinus coeruleus* Mulsant (coleoptera: coccinellidae) (30 adults and 100 eggs of beetles) were imported from national biological control research centre, Kasetart University, Bangkok, Thailand to entomology division, Khumaltar, Lalitpur, Nepal on October 8, 1990. Successfully importing parasitoids, aphelinus mali (haldeman) from Europe (France) in 1978 against apple woolly aphids (*Eriosoma lanigenim* Hausmann) was the first initiation of classical biological control of key insect pests of agriculture in Nepal.

Potato tuber moth is considered an exotic potato insect pest in Nepal that is thought introduced from India along with imported improved varieties of seed tubers in the Kathmandu valley through the then Indian aid mission assisting horticulture development in the agriculture sector in Nepal. Entomology division, under the collaboration project between CIP and NARC entitled 'Development and application of ecological approaches in pest management to enhance sustainable potato production of resource poor farmers in the Hindukush-Himalaya (hkh) region of Bhutan, Nepal, Pakistan and India (Sikkim)' has imported in 2009 and 2010 three biological control agents.

1.1 Biological control of Plant Diseases using Trichoderma in Nepal

Holistic plant health care is defined as the management of the abiotic and biotic constraints to plant health through an integration of biological, physical and chemical manupulation or alteration. Some approaches in plant health care are to know the limits of the agro-ecosystem, maintain soil organic matter, rotate the crops, use clean seeds, plant well-adopted, pest resistant cultivars, minimize environment and nutritional stresses, conserve or enrich population of beneficial microorganisms and treat with chemicals.

The modes of action of *Trichoderma spp* are

- Mycoparasitism
- Antibiosis
- Competition
- Tolerance to stress through enhanced root and plant development
- Induced resistance
- Solubilization and sequestration of inorganic nutrients
- Inactivation of the pathogen's enzymes.

Rhizosphere competent organisms are those capable of colonizing the root surface or rhizosphere when applied as seed or other point source at the time of planting whereas Phyllosphere competent organisms are those capable of colonizing microniches and adaptive to the microclimate of aerial plant surfaces.

As a compost enhancer, Trichoderma shortens time for composting by 10-15 day, increases the quality of compost and lessens pathogen in the compost. It is compatible with other biocontrol and biofertilizer agents such as Mycorrhizal fungi, Rhizobium, Pseudomonas, Azotobacter, etc. In Nepal, Trichoderma can be used to increase N-efficiency, produce fortified compost, for mass production and wide range of applications. It provides tolerance to a variety of biological and edaphic stresses. If no stresses occur and plants are always growing at near-optimal condition, it can provide little visual or yield improvement. In Nepal, if not always, most of the time, crops are grown in one or more stress conditions.

2.0 Relevance of Integrated Disease Management (IDM)

Integrated Pest Management (IPM) is the simultaneous use of multiple pest management strategies to suppress the adverse effects caused by a pest which usually leads to a reduction in the pest population. Integrated Pest Management (IPM) is an umbrella term encompassing Integrated Disease Management, Integrated Weed Management, Integrated Rodent Management and Integrated Insect Management. These are used to control diseases which can be defined as an impairment of the normal physiological functioning of a plant or plant part. There is upto 40% crop loss due to disease and pests. In case of severe infection there is 100% crop failure. Development of any disease depends on a close interaction among three diverse factors: susceptible host, virulent pathogen and a conducive environment.

Plant disease management is the eminent process in crop production. Measures are taken to prevent incidence of a disease, reduce the amount of inoculum that initiates the spreads of disease and finally minimize the loss caused by the disease have traditionally being called as control measures. A disease can be managed by eliminating interaction among susceptible host, virulent pathogen and a suitable environmental condition or any two.

2.1 Principles of Plant Disease Management

Integrated Disease Management (IDM) is the simultaneous use of multiple disease management strategies to suppress the disease incidence or its severity and lead to a reduction in the pathogen population. It is based on the following principles –

1) Avoidance

2) Exclusion

3) Eradication

4) Protection

5) Resistant Varieties

6) Therapy

2.2 Avoidance

Avoiding disease can be done by altering planting time, location or environment. Avoidance can be carried out by proper choice of geographical areas, selection of field, selection of seed/ planting material, planning of time of showing, selection of disease escaping varieties and modification of cultural practices.

2.3 Exclusion

Exclusion is preventing the inoculum from entering or establishing in the field or area where it does not exist. Seed treatment, Inspection, Certification, Quarantine (National and Domestic) can be carried out to ensure exclusion.

2.4 Eradication

Elimination a pathogen after it is introduced into an area but before it has become well established or widely spread is carried out. It can be applied to individual plants, seed lots, fields or regions. It is generally not effective over large geographic areas. Eradiation can be done by destroying weeds that are reservoirs of various pathogens or insect vectors of disease, biological control of plant pathogen, crop rotation, soil treatment, heat and chemical treatment.

2.5 Protection

Protection is the prevention of infection by creating a chemical toxic barrier between the plant surface and pathogens. It can be done by chemical treatment, chemical control of insect vector, modification of environment or environment condition and modification of host nutrition.

2.6 Resistant Varieties

Resistant varieties prevent infection or reduce effect of infection by managing the host through improvement of resistance in it by genetic manipulation or by chemotherapy. Selection and hybridization of disease resistance is done by mutation for disease resistance.

2.7 Therapy

Therapy can be carried out by reducing severity of disease in an infected individual by chemicals. Chemotherapy, Tree Surgery and Heat Therapy are vital elements of therapy.

2.8 Managing Plant Diseases

i) Cultural - Improved growing conditions, Host removal, Inoculum reduction, Pruning, thinning, Crop rotation, etc

ii) Chemical – Fungicides, fumigants, control of insect vectors, resistant species and varieties

iii) Genetic - Breeding For Resistance/ Biotechnology

iv) Biological Control - antagonistic fungi and bacteria, mycorrhizae, antibiotics

v) Quarantine - Excluding diseased plants, seeds, bulbs or contaminated soil, machinery, etc.; introduced pathogens

vi) Doing Nothing

Successful disease management can be achieved if prevention is emphasized rather than cure. Monitoring of crops should be done daily (or at least two times per week) by walking through the crop(s) to achieve early detection. Growers should work closely with the agro-advisors. Correct diagnosis is crucial. Anticipation needs to be done when possible pathogen infection phases are likely to occur. Detailed records need to be kept that enable merging of cultural, environmental, and insect and disease data for review when a production problem arises or for doing post season crop summary reviews. The weather needs to be monitored to help anticipate potential disease problems.

3.0 Code of Conduct on Import and Release of Bio-Control Agents: ISPM #3

ISPM is a standard set by agencies to ensure food security. FAO defines a standard as a document established by consensus and approved by a recognized body that provides for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context. North American Plant Protection

Organization (NAPPO) is the regional organization of the IPPC and FAO that sets standards for food security. NAPPO provides a public and a private forum for countries to collaborate and set standards for the universal protection of agricultural, forest and other plant resources. It also sets guidelines for petition for release of exotic entomophagous agents for the biological control of pests.

3.1 The IPPC and Agricultural Trade - The IPPC seeks to achieve international harmonization of phytosanitary measures with the aim to facilitate trade and to avoid the use of unjustifiable measures as barriers to trade, while mitigating economic impact to agriculture and forestry and preserving natural plant and fungal biodiversity. The 177 countries currently contracting parties to the IPPC have adopted 38 ISPMs to date on topics like import regulations, export certification, compliance procedures, pest surveillance, exotic pest response, pest management and post-entry quarantine. The IPPC has set some universal definitions for phytosanitary import requirements, security, quarantine, regulated pest, invasive pest, quarantine pest which define the domain of these subjects and can be used universally.

3.2 ISPM #3 And Its Purpose – Few of the primary purposes of ISPM#3 are to facilitate safe export, shipment, import and release of regulated articles/BCAs and to provide guidelines to national governments in developing the national guidelines based on their capabilities and infrastructures. There have been several instances which have necessitated the application of certain codes for import and export of BCAs. For example introduction of mongoose in the Caribbean to control a certain species of snakes actually led to extinction of 7 species of reptiles. Moreover, introduction of *Coccinella septempunctata* in North America posed several environmental concerns.

3.3 Responsibilities of Importer and Exporter – The importer of biological control agents needs to carry out certain duties before he can successfully import agents. These responsibilities may include carrying out pest risk analysis on BCA, developing a dossier on the BCA to be imported and released, designating a person/authority to receive and destination/point of entry for safe delivery of the consignment, etc. Similarly the exporter on the other end needs to ensure that he has fulfilled his obligations. These include ensuring that consignment complies with import permit/requirements and international agreements, providing appropriate documentation on BCA, taking precautions during contamination of consignment etc.

3.4 Pest Risk Analysis (PRA) – PRA is the evaluation of the probability of the introduction and spread of a pest and of the associated potential economic consequences. The NPPO should determine whether an organism is required to be subjected to pest risk analysis. PRA has certain steps associated with it –

i) Preparation of a Dossier - A document containing information on the organism such as nature of pest problems, detailed control options, host specivity of BCA, multivoltinism is to be imported and warranted national or international guidance. The dossier must be submitted to GOI/PDBC with exporter source mentioned.

ii) Technical Committee on Import - Export of Biological Control Agents – These documents are then submitted to a committee that consists of members such as DDG (Crops), Joint Director (Plant Q.), ICAR, ICMR, National Bureau of Agriculturally Important Insects (PDBC) -Nodal Agency etc. This technical committee then takes decisions on the issuance of Import Permit & fixes the responsibility of BCA handling before, on and after import.

iii) Issue of Import Permit and Request Placement to the Exporter by the PPA – An Import Permit is an official document authorizing importation (of a biological control agent) in accordance with specified requirements. It must contain essential details such as number of BCA (specific name) to be exported, port of entry into the importing country, tentative date of shipment/ proper liaison etc.

iv) Post Import Handling – These include duties such as quarantine handling of imported BCA, staff training on mass production and release, laboratory evaluation of imported bio-agent.

4.0 History of Natural Enemies and Their Mass Production

Natural enemies of insect pests, also known as biological control agents, include predators, parasitoids and pathogens. The history of biological control dates back to the seventeenth century. Great deal of success has been achieved in biological methods of pest control. In India, organized and systematic biological control research began with the establishment of the Indian station of Commonwealth Institute of Biological Control (CIBC) at Bangalore in 1957. In India, so far 166 exotic biological control agents have been introduced of which 33 could not be released in the field, 71 recovered after release, 6 providing excellent control, 7 substantial control and 4 partial control.

Some selective examples have been taken and explained –

i) Biological Control of Prickly Pear - An insect, *Dactylopius ceylonicus* was introduced from Brazil in 1795 in the mistaken belief that it was the true carmine dye producing insect, D. coccus. Currently *D. ceylonicus* continues to successfully control. *Opuntia vulgaris*, reducing it from a state of widespread abundance to that of virtual extinction in southern India and northern Sri Lanka.

ii) Biological Control of Water Fern, *Salvinia molesta* - Water fern, a native of southeastern Brazil has invaded many water bodies of Asia, Africa and Australia. It was introduced into India through Botanical gardens. It was first observed in 1955 in Vole Lake (Kerala) has assumed pest status since 1964 and affects the lives of 5 million people. For the biological suppression of *S.molesta* , the weevil, *Cyrtobagous salviniae*, native to Brazil, was imported from Australia in 1982. More than 75 economically important plants belonging to 41 families were tested for host specificity. It was declared safe for field releases.

iii) Biological Control of Water Hyacinth, *Eichhornia crassipes* – It is a free floating aquatic weed of South American origin. It ranks among the top ten weeds worldwide. It is one of the most noxious weeds known to man and has spread to at least 50 countries around the globe. First introduced into Bengal around 1896 as an ornamental plant, it has spread throughout India over 200,000 ha of water surface. Under ideal conditions water hyacinth plants can double their number in 10 days.

iv) Biological Control of Cottony Cushion Scale, *Icerya purchase* - *Icerya purchasi* (Origin: Australia) was probably introduced on imported orchard stock or flowering plants from Sri Lanka. It spread to cultivated rose-bushes and citrus. The coccinellid beetle, *Rodolia cardinalis* (Origin: Australia) has an excellent track record for the suppression of cottony cushion scale. This predator has been effective against *Icerya spp* on some of the Pacific Islands indicating be easy to introduce it wherever *Icerya spp*. have spread and predator is absent.

v) Biological Control of Mealybugs - Eggs of the mealybugs, protected by waxy filamentous secretions of ovisacs are almost impossible to reach with insecticides. The first intentionally introduced beneficial was the coccinellid predator, *Cryptolaemus montrouzieri* which was introduced in June 1898.

vi) Biological Control of San Jose Scale, *Quadraspidiotus perniciosus* - It is a polyphagous pest of Oriental origin. It is a serious pest of apple in Northwestern India. It also attacks other deciduous trees, poplars and willows. About 50 hosts have been recorded in India. Aphelinid parasitoid *Encarsia perniciosi* (Origin: Far East) strain from California was introduced in 1958 and Illinois, Chinese and Russian strains were introduced in 1960 for the biological suppression of San Jose scale.

vi) Biological Control of Woolly Aphid, *Eriosoma lanigerum* - It is a native of Eastern United States. It was probably accidentally introduced to India from England as indicated from its record in Shimla district of Himachal Pradesh where nursery stocks were imported. The aphids feeding on the roots cause maximum direct injury, although large numbers may be found on the aerial parts of the tree. The aphid sucks sap from the bark of the trunk and the roots. It also infests fruit stalks and calyx end. The infested twigs shrivel and die. The nursery plants when attacked suffer the most. For the control of woolly aphid, exotic aphelinid parasitoid, *Aphelinus mali*, a native of North America, was introduced from UK at Saharanpur.

vii) Biological Control of Carrot Weed, *Parthenium hysterophorus* - *P. hysterophorus*, also known as white top and congress grass, is native to the area around Gulf of Mexico including the West Indies, and central South America. It has accidentally been introduced, over the past five decades, into many countries. In India, it was recorded from Pune in 1955. Parthenium grows in pure stands in almost all the states, suppressing local vegetation and threatening natural diversity.

The laboratory rearing of natural enemies is a stepwise process and is specific to the predator which is being reared. First a suitable laboratory prey is chosen which can be grown in large amounts given time and space constraints. Then the host-prey is collected from the market produce or from the field. At times misidentification may lead to some rearing constraints. The nucleus of natural enemies can also be collected from the field which can be at the Oviparous, Viviparous or Ovo-viviparous stages. A suitable host is chosen on which the predator is grown. Studies revealed that a specific variety of pumpkin (locally known as Disco) was suitable to all the mealybugs except *P. solenopsis*, which requires sprouted potato tubers. Such tubers are not available throughout the year, hence, studies are being continued to look for cheaper locally available material.

5.0 Advances in Biological Control Research of Insect Pests and Weeds

Biological control is a pest control strategy making use of living natural enemies , antagonists, competitors or other biological control agents, basically a natural enemy, antagonist or competitor, or other organism, used for pest control. There is a lot of awareness gap these days in terms of biotechnology due to lack of user awareness, weak pressure on authorities, retailers and growers and lack of planned demand. However, BCAs which are a genius of biotechnology have immense potential in terms that they can develop capabilities of NGO's and self-help groups, develop agro based cottage industries, potential for rural employment & women empowerment, develop research projects for financial support from GOI and conserve biodiversity.

Manipulation is a procedure which may be necessary to help BCA become established or to become more effective. It involves augmentation and conservation. Augmentation of BCA includes the mass production of biocontrol agents (In Lab, semi field/cage and field) or genetic improvement (Selective breeding, hybridization, irradiation). Conservation & habitat management can be done by following certain practices judiciously such as establishment of NE, Pest and NE balance.

Semiochemicals are chemicals that mediate interactions between organisms. It is sometimes useful to refer to Semiochemicals (allelochemicals and pheromones) as arrestants, attractants, repellents, deterrents, stimulants or other descriptive terms.

An understanding of parasitoid or predator foraging movements in field, in either agricultural or natural ecosystem, or about effects of movement on parasitoid/predator population ecology is important to develop more effective strategies for both the conservation of NE and their use as bioagents of insect pests in field crops.

Technological advancements are directed towards newer, more ecofriendly pesticide molecules, more efficient techniques of bioagent mass production and plant protection transgenic crops. Molecular Characterization of *C. blackburni* and *A. angaleti*, Semiochemical studies on *Trichogramma brasiliensis* and *T. chilonis* in relation to Bt cotton and its host insects, Hydrocarbon profile in vegetative phase of different bt cotton hybrids are carried out using complex equipment like Electroantennogram (EAG) and gas chromatography. Sterile Insect Technique (SIT) is done using Radiation Sterilization with the benefits that it is ecologically compatible (parabiological approach, no transgenic) and environmentally safe. Nuclear techniques are used for the colonization and production of natural enemies towards augmentation of biological control. Radiation hormesis (also called radiation homeostasis) is the hypothesis that low doses of ionizing radiation (within the region of and just above natural background levels) are beneficial, stimulating the activation of repair mechanisms that protect against disease, that are not activated in absence of ionizing radiation.

6.0 Advances in Plant Disease Management with a Focus on Biological Methods

Biological Control employs natural enemies of pests or pathogens to eradicate or control their population. This can involve the introduction of exotic species, harnessing whatever form of biological control exists naturally in the ecosystem in question. The induction of plant resistance using non-pathogenic or incompatible micro-organisms is also a form of biological control. Some diseases that can be successfully controlled using biological agents are pathogens of pruning wounds and other cut surfaces, crown gall, diseases of leaves and flowers, such as powdery mildew, diseases of fruits and vegetables, such as Botrytis, and fungal pathogens in the soil (disease suppressive soils). All biological communities are complex ecosystems in which the abundance of any organism is dependent on its food supply, its environment and other organisms. If a pathogen is kept in check by the microbial community around it, then biological control has been achieved. Biological control appears to take place on the plant surface by the activity of epiphytic microflora. This is then an important consideration when applying chemicals to plants, since there is a risk of killing natural antagonists of pathogens other than the one being treated.

Biological Control Procedures are often very specific and leave little or no residue after application. These are inexpensive to develop and the natural enemies are used in ecologically based IPM, but they have lower potency than synthetic pesticides. An important consideration to be made before using biopesticides is that they have a key and specific role to play in crop protection as part of IPM. Biopesticides should be regulated as something that is ‘natural’ does not mean that it is safe. Hence it is to be used and with care. Before biocontrol can become an important component of plant disease management, it must be effective, reliable, consistent, and economical. To meet these criteria superior strains must be developed.

The successful control of diseases by biological means are mainly Rusts, powdery mildews, diseases caused by *Alternaria, Epicoccum, Sclerotinia, Septoria, Drechslera, Venturia, Plasmopara* and *Erwinia*. Good soil biocontrol systems have been reported for species of *Fusarium, Sclerotinia, Phythium, Rhizoctonia.* Biocontrol agents may have several modes of action; therefore, it is important to know the proportion and timing of each mode of action that may occur.

6.1 Mechanisms of Biological Control of Plant Diseases – These are several modes by which biological control of plant diseases can be carried out –

i) Induced Resistance - Induced resistance is a plant response to challenge by microorganisms or abiotic agents. Induced resistance can be *localized*: when it can be detected only in the area immediately adjacent to the inducing factor; or *systemic*: when resistance occurs subsequently at sites throughout the plant. Localized resistance occurs in many plant species. Systemic resistance is limited to some plants.

ii) Hypovirulence – Hypovirulence is the reduced virulence found in some strains of pathogens. It was first observed in *Cryphonectria (Endothia) parasitica* (chestnut blight fungus) on European *Castanea sativa* in Italy, where naturally occurring hypovirulent strains were able to reduce the effect of virulent ones. Hypovirulence has also been reported in many other pathogens, including *Rhizoctonia solani* and Gaeumannomyces gramini var. tritici

iii) Competition - Competition occurs between microorganisms for space nutrients (i.e., carbon, nitrogen, and iron). Attribute of a successful rhizosphere biocontrol agent would be the ability to remain at high population density on the root surface providing protection of the whole root for the duration of its life. Mycorrhizal fungi can also be considered to act as a sophisticated form of competition, decreasing the incidence of root disease.

iv) Antibiosis – It is the production of antibiotics by bacteria and fungi. Species of Trichoderma are well-known biological control agents that produce a range of antibiotics that are active against pathogens. Within bacterial biocontrol agents Pseudomonas produce antibiotics involved in their ability to control plant pathogens.

v) Mycoparasitism - Mycoparasitism is a condition when one fungus exists in association with another. It derives some or all its nutrients while conferring no benefit in return. One of the characters of Trichoderma is its ability to parasitize other fungi. Weindling in 1932 for the first time described the biocontrol of *R. solani* (causing citrus seedling disease) by Trichoderma lignorum to mycoparasitism.

vi) Biocontrol of Airborne Diseases - Many naturally occurring microorganisms have been used to control diseases on the aerial surfaces of plants. The more common bacterial species that have been used for the control of diseases in the phyllosphere include *Pseudomonas syringae, P. fluorescens, P. cepacia, Erwinia herbicola*, and *Bacillus subtilis*. Fungal genera that have been used for the control of airborne diseases include *Ampelomyces*, and the yeasts *Tilletiopsis* and *Sporobolomyces*. The mechanisms of action proposed for these biocontrol agents, include competition for sites or nutrients antibiosis.

vii) Biocontrol of Soilborne Diseases - Biological control agents colonize the rhizosphere, the site requiring protection and leave no toxic residues, as opposed to chemicals. Fluorescent pseudomonas are the most frequently used bacteria for biological control and plant growth promotion. Bacillus and Streptomyces species have also been commonly used. Trichoderma species are the most frequently used fungal biocontrol agents. Perhaps the most successful biocontrol agent of a soilborne pathogen is *Agrobacterium radiobacter* strain K84, used against crown gall disease caused by *A. tumefaciens*. The phytopathogenic bacterium *Erwinia carotovora* subsp. *carotovora* secretes various extracellular enzymes, including pectinases, cellulases, and proteases. Pectinases are known to be a major pathogenicity determinant in soft rot disease of potato. Biological control of some soilborne fungal diseases has been correlated with chitinase production, bacteria producing chitnases or glucanases exhibit antagonism in vitro against fungi.

6.2 The Future of Pathogen Bio-control - Biocontrol may not completely replace the chemical mode of disease management. It can definitely help in some decline in the use of chemicals. Though most of the approaches have involved the single antagonist concept, in biological systems approach, the strategy is to suppress from multiple angles, might provide a better alternative. Similarly, the use of biological control agents could be used as one component of an integrated management program to achieve the best possible results.

7.0 Fortuitous Biological Control of Parthenium in Nepal

Parthenium allergy is widespread among countries of South Asia and South East Asia. Allergy means an altered reactivity of the body to harmless environmental substances. In other words, in allergic individuals the body starts producing increasing amounts of an antibody called 'Immunoglobulin E (I gE) in response to exposure to common harmless environmental substances that it recognizes as "allergens" (antigens).

After noticeable occurrence of Parthenium allergy in 1955 in Pune, Maharashtra, it was estimated to spread in about 5 million hectares in India by 1975 which expanded in an area of 35 million hectare across the country by 2007. Human allergy problems have been identified in Australia, Ethiopia and India. The allergy leads to contact dermatitis and non-contact asthma. 70% people are sensitive to weed in Australia where weed is primarily composed of Parthenium.

Parthenin, a sesquiterpene lactone, is the major antigen which produces contact dermatitis in sensitive human beings. It may cause allergy, dermatitis, eczema, black spots and blisters around eyes, burning, rings and blisters over skin, redness of skin and asthma etc. Cyclosporine has proved to be quite effective in controlling the Atopic Dermatitis (D2) caused due to Parthenium.

Parthenium allergy is fewer in cows; however it causes hypersensitivy in rabbits and ulcerations in buffaloes, horses, donkey, sheep and goat. It may cause clinical signs as salivation, diarrhea, anorexia, pruritus, alopecia and dermatitis. There is loss of hair and marked de-pigmentation of skin. The biodiversity is affected as it leads to encroachment of agricultural land, fodder scarcity and increased labour cost. Parthenium seed is spread by rain, water, seed lots, vehicles, animals. Parthenium can be managed by Cultural Utilization, Physical Burning, Mechanical Uprooting, Chemical Salt & herbicides and Biological Biocontrol agents. The Parthenium Beetle, *Zygogramma* reduces vigour of parthenium, reduces flower production and reduces seed bank in soil. Plants such as Amaranthus spinosus, Ipomoea species, Kochea indica can be used as physical suppressors. As Parthenium has been documented for its insecticidal, nematicidal and fungicidal properties and its antifeedant activity has also been reported against agricultural and forestry pests, it can also be used as a biopesticide. Parthenium biomass can also be used in composting.

8.0 Lab Visit trip to study the recovery and conservation methods of Mexican Beetle, Zygogramma bicolorata and IPM Trials

A lab visit was organized by NARC in the plant pathology as well as entomology divisions of NARC for participants to get expose to bio-control agents, water hyacinth and *Zygogramma biocolorata* for integrated pest management in Nepal.

9.0 Classical Biological Control of Pink Hibiscus Mealy bug in the Caribbean

During 1995, Trinidad and Tobago were hit by a widespread infestation by Pink Mealy Bug (PMB). Around 2,500 hectares of agricultural land was considered to be under infestation. Among the species attacked were hibiscus, wild okra, pigeon peas, citrus, dunks, mango, acacia, ixora, croton, palms, sorrel, white-top etc. As a result of the infestation and decrease in food supply the economy of the country was suffering both in terms of tourism and food security. The mode of transport of PMB was through birds, insects, crabs, rats and other animals. Even rain water, air and human beings helped in their transport. Transportation of agricultural produce especially fruits and berries, manures/ soil from infested areas led to the proliferation of the menace. The chemical sprays that were being used caused cuts and burns among human beings.

The best method to control this menace was to let nature take charge itself through classical biological control. It involves deliberate introduction and establishment of natural enemies into areas where they did not occur previously and employed largely against pests of exotic origin. Through the collaboration of various organizations as FAO, USDA, CABI etc. the natural enemy of the PMB was discovered to be the Indian Beetle. The Ladybird beetle was released in selective areas and its mode and means of attack on the PMB was studied. After 10 months of intensive action, the plan proved to be a success and the menace of PMB was brought under control.

10.0 Mass Production of Important Biocontrol Agents

Certain standard techniques are followed for the production of BCAs in mass quantities. The procedures for a few are discussed as follows.

10.1 Trichoderma spp. - Trichoderma spp. are present in nearly all agricultural soils. Antifungal abilities have been known since 1930s in the form of Mycoparasitism and nutrient competition. Agriculturally it is used as biocontrol agent and as a plant growth promoter. The mass production of Trichoderma spp. takes place in saline bottles under certain specific temperature. Soil temperatures above15℃ is the best condition for Trichoderma to be introduced into the soil. Trichoderma has a lifecycle of about 28 days. It is self-replicating. Like any lifecycle it becomes weak hence product needs to be re-applied to maintain strength.

Trichoderma fungi work well as soil inoculants. For disease control use of Trichoderma is preventative. Late application of Trichoderma does not produce encouraging results. 4gm per kg of seed is used for controlling soilborne plant diseases. The powder is mixed with sufficient quantity of water to make slurry for treating seed before sowing.

10.2 Beauveria – To prepare Beauveria culture in laboratory, first the infected insect-pest by Beauveria from the field are collected and brought to laboratory. Then the culture media is prepared and the spores of fungi are isolated from infected pest and inoculated on media. In this way we can prepare the culture of Beauveria in petridish and test tubes as slant which later on used for mass production.

10.3 *B.Bassiana* - *B. bassiana* is most successful used in controlling corn borer in USA and China. It is also used for controlling Colorado Potato Beetle in Russia. It can successfully control soil inhibiting cockchafer, melolontho in France. In China it is used for controlling Alfalfa weevil and green leaf hopper. In India it is most successfully utilized for controlling rice hispa beetle in rice field and to control Red Spider Moth and Mosquito bug in tea.

Among the major advantages *B. bassiana* can be used to control harmful insect-pest without affecting beneficial insect predators and non-harmful parasites. It avoids pollution and environment hazards. It has high potential for further development by biotechnological research as insects lack resistance against it. It has long term effects on pest suppression.

However there are a few constraints associated with it as more time (2-3 week) is required as compared to chemical insecticides (2-3 hrs). The application needs to match with high RH, low pest no. and fungicide free period. Due to high specificity, additional control agents are needed for other pests. Production is expensive and due to short shelf life spore, it requires cold storage.

10.4 Bacteria as Biopesticides – Among the 14 registered bacterial bio-control agents, 6 are based on Bacillus, 5 on Pseudomonas, 2 on Agrobacterium and 1 on Streptomyces. Bacteria that are used as biopesticides can be nonspore-forming or aspore-forming bacteria.

i) Pseudomonas – Pseudomonas occur commonly in the rhizosphere of plants and they are important for the control of soil borne plant pathogens. Numerous compounds have been shown to be important for biocontrol activity. Inhibitory compounds include degradative enzymes and antibiotics.

ii) Bacillus – Members of the Bacillus genus are often considered microbial factories for the production of a vast array of biologically active molecules potentially inhibitory for phytopathogen growth. Their spore-forming ability makes these bacteria some of the best candidates for developing efficient biopesticide.

iii) *Pseudomonas Fluorescens* – The *Pseudomonas migula* is a species of nonpathogenic fluorescent bacteria found in sewage, soil and water and which liquefy gelatin. It has the ability of plant growth promotion and effective disease management. It produces a soluble, greenish fluorescent pigment, particularly under conditions of low iron availability. The mechanism of its operation is via Competitive root colonization, Antibiosis and Induced systemic resistance. Antagonistic activity was also observed for Pseudomonas spp. in the rhizosphere has been recognizes as major factor in the suppression of many phytopathogens.

11.0 Release and Conservation of a Natural Enemy - The term release is defined as “Intentional liberation of an organism into the environment “(FAO, 1996). It can be done in the following forms –

i) Accretive Release: The periodic colonization of small numbers of natural enemies against low populations of pests (Flanders, 1930).

ii) Inundative Release: The natural enemies when used in an inundative manner, are termed as “biotic insecticides” (Stern et al; 1959).

iii) Inoculative Release: It consists of relatively small numbers of natural enemies, intended to propagate in the target habitat so that their progeny would effect control for several subsequent generations. (De Bach, 1964).

iv) Prophylactic Release: Release of *C. montrouzieri* in absence of pink mealybug to suppress local mealy bug and scale insects in threatened countries (Gautam, et al, 2000b). This provides opportunity to introduce duly Quarantined predator (Gautam,1996d) along with biocontrol technology in advance on alternate local hosts in anticipation/ containment of accidental occurrence of quarantine pest.

The enemy release hypothesis states that an exotic pest in a new area will increase to pest numbers due to the lack of natural enemies in the new area. In their native places the insects that are pests in the new area are not pests because they are controlled by a suit of natural enemies that have coevolved with them in their places of origin throughout their evolutionary history keeping their population numbers under control.

Conservation is a process which involves manipulation of the environment to favour natural enemy either by removing or mitigating adverse factors or by providing the lacking requisites. The purpose of natural enemy conservation is to evolve pest control strategies based on host plant resistance, cultural practices, mechanical methods, to discourage indiscriminate use of chemical pesticides, to ensure pest suppression and safety to the environment so as to enrich biodiversity and to encourage recovery and establishment of NE.

Establishment is the permanent occurrence of an imported natural enemy in a new environment. There can be three types of control –

i) Complete control: When no other control method is required or used, at least where the agent is established.

ii) Substantial Control: Other control methods are needed but the efforts required from these other methods have been reduced due to the activity of the natural enemies released.

iii) Partial control: The case in which even though released natural enemies have some controlling effects, other means of control are still necessary (also called “negligible” control).

12.0 Preparation of Semisynthetic diet for Insects

A balanced diet contains all different types of food groups and nutrients (proteins, carbohydrates, minerals, vitamins, fats & roughage including water) in such quantities and proportions that the need for calories is adequately met and small provision is made for extra nutrients to with stand short duration of leanness. Eating a well-balanced diet on a regular basis along with regular exercise helps maintain one’s general well-being. On closer observation, the same holds true for all living beings, including insects. Manipulation is a procedure which may be necessary to help BCA become established or to become more effective. It involves augmentation and conservation. One of the components of manipulation is to feed the right kind of nutritious food to the BCA so that it may proliferate quickly.

Typically for cutworms there is a trusted composition of artificial diet which includes, chickpea flour, dried yeast powder, agar-agar powder etc. in specific percentages. Six commercial salt mixtures as USP-XIV, HMW, BTM, No.-2, McCollum and Wesson’s at 100mg per 52.3 g of diet are used for the growth and development of fruit fly, *Bactrocera dorsalis*. Larval Diet is implemented for gregarious feeders like Drosophila. 10-20% honey solution is provided to the adult Trichogrammatids/chalcidoids. Similarly, effect of Solasodine hydrochloride on growth and development of brinjal fruit borer, *Leucinodes orbonalis* has been studied and comparative performance of different diets in the rearing of *Sesamia inferens* has been done thoroughly.

Way forward

Feedback from the workshop shows that participants have learnt and gained knowledge from the workshop. Participants expressed the usefulness of learning IPM, IDM, and biocontrol techniques, especially in Nepal, and the benefits of implementing IPM and biocontrol in their respective areas in Nepal. All participants will be integrating IPM concepts and techniques learned in the workshop in their work, as well as further spreading knowledge to extension workers and agencies in Nepal. Further, participants want to increase their capacities to implement biological control techniques at the farm, landscape, ad nationwide level by obtaining advance level training on the subject.

Annexes

Annex 1: Workshop Evaluations

The evaluation of the workshop was conducted based on two different approaches including (i) general feedback and (ii) Knowledge, Attitude and Practice (KAP) Survey. The criteria of evaluation were completed on the scale of excellent, good, fair and poor. Further, the general feedback part was divided into two segments (content and process). Hence, this part was evaluated based on the delivery of technical sessions by the resource persons. The second part of the evaluation was prepared using the perception based approach known as Knowledge, Attitude and Practice. This segment of the evaluation mainly discusses individual knowledge gained from the workshop as well as the implementation of specific knowledge in the participants' own areas of research.

On the final day of each workshop, 27 evaluation forms were received from the participants to assess the workshops according to their usefulness in dissemination of knowledge, quality and innovation of biological control techniques. Overall the workshop was rated as good by more than 55% of the participants, followed by the excellent category.

Participants were given evaluation forms to rate the usefulness of the workshop content and quality of processes on the scale of "excellent to poor". Averaging both workshops, statistics in the table show that the workshops were rated as good, since around 70% of the

responses were observed under the categories "good" and "excellent" in terms of the workshop content and processes. 51% of the participants rated the processes as good while over 39% rated them as excellent.

Usefulness of the content and quality of processes and logistics

In addition, topics 1, 4, 5 and 14 were rated 66, 69, 70 and 65% respectively in the "good" category because of the innovative knowledge on these topics offered in terms of choices of sustainable agricultural technologies and their presence in Nepal. The other topics were rated either excellent or good by the participants because of their valuable addition to the participants' existing knowledge base.

Expectations

About 52% of the participants indicated that this workshop met their overall expectations on a large scale, while 45% of the participants felt that the workshop met its objectives beyond their expectations. However, 25% of participants indicated that the workshop met just their minimum requirements.

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Table 1: feedback Statistic of SATNET National Training on Biological Control of Agricultural Pests and Diseases in Nepal

	TOPICS	Excellent	Good	Fair	Poor
Content	Topic 1: Current status of Biological Control/IPM programmes in Nepal	31	66	3	
	Topic 2: CABI and Bio-control programmes	38	52	10	
	Topic 3: Relevance of Integrated Disease Management	33	48	5	14
	Topic 4: Visit to Lab/field for exposing the participants for collection and handling of bio-control agents (especially Parasitoid and predators), and IPM Kit	24	69	7	
	Topic 5: Code of Conduct on import and release of Biocontrol Agents: International Standards of Phytosanitary Measures (ISPM # 3) of FAO	26	70	4	
	Topic 6: Natural Enemy introductions in Asia-Pacific region for Biological control of insect pest, diseases and weeds-An update	38	41	21	
	Topic 7: Advances in Biological Control research of insect pests and weeds	29	50	18	3
	Topic 8: Advances in Plant Disease management with a focus on biological methods	39	50	7	4
	Topic 9: Fortuitous biological control *Parthenium hysterophorus* in Nepal	16	36	24	24
	Topic 10: Field trip to study the recovery and conservation methods of Mexican Beetle, *Zygogramma bicolorata* and IPM Trials (THEORY)	13	35	17	35
	Topic 11: Classical Biological Control: A Caribbean experience on the success management of Mealy bug, *Maconellicoccus hirsutus*	52	48		
	Topic 12: Mass production of important bio-control agents of plant diseases	45	45	7	3
	Topic 13: Mass production of important factitious host insects and their natural enemies of important insect pests	38	55	7	
	Topic 14: Establishment of ideal Biocontrol Laboratory	30	65		5
	Topic 15: Preparation of semisynthetic diet and media for mass production and handling of biocontrol agents in the laboratory	32	53	10	5
Process	Agenda and flow	17	50	33	
	Facilitation, feedback and discussion	22	44	34	

Aspects to be improved in the future

Participants felt that the training like this should have been included with substantial practical exercises by focussing on particular plant diseases of Nepal as well as more practical demonstration is required in Integrated Pest Management in Nepal. Few participants also mentioned that SATNET Asia project also help Nepal Agriculture Department to establish biological control laboratory.

Content

- Practical demonstration is needed to learn this subject with respect to any particular plant diseases and weed management.

- Include some sessions on practical exercise
- Detail demo should have been given on mass rearing of bio-control agents
- Several participants indicated that the training programme on bio control should also focus on different aspects of Integrated Pest Management in Nepal to cover crops and fruits

Process

- Presentations slide should be legible and voice audible.
- Demonstration should be given in the field and not in lab
- It should be organized more than 3 days to learn in detail.

Logistics

- The presentation slides should have been shared prior to workshop for better understanding of the subject as well as preparation.
- Extra time period should be assigned to each presentation along with interactive session with participants.

Way Forward

- Most of the participants indicated that they will apply this knowledge in their research work and will also provide training to the relevant scientists of biological control and entomology in Nepal.
- Few of them expressed they will train farmers horticulturist in their farm in the form of practical demonstration as well as more emphasis will also be given in mass rearing of bio-control agents in Nepal.

Additional Comments:

- It was very good and informative training but side by side practical exercise (T R Risal)
- Guided theory should be decided by the practical (Ram Chandra Gouli)
- "Fish from the river is more delicious than Fish in Book". Role of BCA is relatively new and hot topic for the agricultural stakeholders (Subash Sabedi).
- I liked both the content and presentation of the training. Identification of natural enemy in the field condition would have give more clear vision on this topic (Resona Simkhada)

Annex 2: Programme Agenda

SATNET Training Programme on Biological Control of Agricultural Pests and Diseases,

5-7 March 2014, Kathmandu, Nepal

Day 1: 5 March 201

Time	Programme	Speakers
09.00-9.10	**Introduction of the Training**	Dr.Devendra Gauchan/ Director NARC
09.10-09.20	**Opening address**	Mr. Michael Williamson, Head APCTT-ESCAP
09:20-10.30	Current status of Biological Control/IPM programmes in Nepal	Resource Person from NARC
10.30-10.45	**Tea/Coffee Break**	
10.45-11.30	CABI and Bio-control programmes	Dr.Kavya Dashora CABI
11.30-13.00	Relevance of Integrated Disease Management	Dr.Kavya Dashora CABI
13.00-14.00	**Lunch Break**	
14.00-16.00	Visit to Lab/field for exposing the participants for collection and handling of bio-control agents (especially Parasitoid and predators), and IPM Kit	Dr.R.D.Gautam & Dr.Kavya Dashora
16.00-16.45	Code of Conduct on import and release of Biocontrol Agents: International Standards of Phytosanitary Measures (ISPM # 3) of FAO	Dr. R.D.Gautam

Day 2: 6 March 2014

Time	Programme	Speakers
09.00-10.00	Natural Enemy introductions in Asia-Pacific region for Biological control of insect pest, diseases and weeds-An update	Dr.Kavya Dashora CABI
10.00-11.00	Advances in Biological Control research of insect pests and weeds	Dr. R.D.Gautam
11.00-11.15	**Tea/Coffee Break**	
11.15-12.00	Advances in Plant Disease management with a focus on biological methods	Dr.Kavya Dashora CABI

12.00-13.00	Fortuitous biological control of *Parthenium hysterophorus* in the Nepal	Dr.R D.Gautam
13.00-14.00	Lunch Break	
14.00-15.00	Field trip to study the recovery and conservation methods of Mexican Beetle, *Zygogramma bicolorata* and IPM Trials (THEORY)	Dr.R.D.Gautam & Dr.Kavya Dashora CABI
15.00-15.15	**Tea/Coffee Break**	
15.00-16.00	Field trip to study the recovery and conservation methods of Mexican Beetle, *Zygogramma bicolorata* and IPM Trials (PRACTICAL)	Dr.Kavya Dashora CABI

Day 3: 7 March 2014

Time	**Programme**	**Speakers**
9.00-10.00	Classical Biological Control: A Caribbean experience on the success management of Mealy bug, *Maconellicoccus hirsutus*	Dr.R.D.Gautam
10.00-10.30	**Tea/Coffee Break**	
10.30-11.30	Mass production of important bio-control agents of plant diseases	Dr.Kavya Dashora CABI
11.30-13.00	Mass production of important factitious host insects and their natural enemies of important insect pests	Dr.R.D. Gautam
13.00-14.00	**Lunch Break**	
14.00-15.00	Establishment of ideal Biocontrol Laboratory	Dr.Kavya Dashora CABI
15.00-16.00	Preparation of semisynthetic diet and media for mass production and handling of biocontrol agents in the laboratory	Dr.R.D.Gautam & Dr.Kavya Dashora
16.00-16.15	**Tea/Coffee Break**	
16.15-16.30	**Summary and Way forward**	Dr. Krishnan Srinivasaraghavan, APCTT-ESCAP
16.30-16.45	**Feedback and Training Evaluation**	Mr. Suraj Pandey APCTT-ESCAP
16.45-17.00	**Concluding Remarks**	NARC, Representative

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Annex 3: List of Participants

List of Participants-SATNET Asia National Training Program on Biological Control of Agricultural Pests and Diseases 5-7 March 2014, Kathmandu, Nepal

S.No	Name of the Participant	Designation	Organization	Email Address
1.	Purushottam Jha	Scientist	NRRP, Hariharbhawan	Jha.purushottam19@gmail.com
2.	Saraswati Neupane	Scientist	NGLRP, Rampur	sarusanu8@yahoo.com
3	Subash	Scientist	SLRP, Rampur	Subedi.subash@yahoo.com
4	Sunita Adhikari	S1 Scientist	RARS	pkrsunita@hotmail.com
5	Md.Farhat Ali	T 6 Entomology	RARS	md.farhatali85@yahoo.com
6	Naresh dangi	T6	Ent Division	fromnaresh@yahoo.com
7	Sunil Aryel	T6	Ent Division	Sunilamyal2005@gmail.com
8	Sudeep Kr.Upadhaya	S1 Scientist	RARS	sudeeppdi@gmail.com
9	R P Mainali	T 6	Ent Division	Mainalism.rp@gmail.com
10	Janarjan Gautam	S1 Scientist	NGRP	gjanarjan@gmail.com
11	Ram B Khadka	S1 Plant pathology	RARS khajur	Ramkhadka_22@yahoo.com
12	Roshan Basnet	S3 Scientist	NWRM Bhairahan	basnetroshan@hotmail.com
13	Kashinath Chiluwal	S1 Scientist	RARS Luink	chilukn@gmail.com
14	Ram Chandra Gouri	T6	Ento Div Khumaltar	gouriramchandra@yahoo.com
15	Resma Simkhada	T4	ARS Malepatan	Resma.simkhada@gmail.com
16	Kishor Bhandari	S1 Scientist	NCRD Paripate	12.kishor@gmail.com
17	Nabin Kumar Dangal	S1 Scientist	RARS Tarahar	nabindgl@yahoo.com
18	Ghanshyam Bhandhari	S1 Scientist	NWRP, Rampur	Bhandarigb_1978@yahoo.com
19	Vinita Sharma	S1 Scientist	NWRP, Bhairawa	Vinitasharma.bhw@gmail.com
20	Chetna Manandhar	S1 Scientist	NARC Khumaltar	Chetna_m@gmail.com
21	Dr.Deepak Bhardan	S4 Scientist	Plant Pathology	Deepak359@hotmail.com
22	Manoj	PPO	PPD	manojpkrl@gmail.com
23	Kuldip Ghimire	PPO	PPD	ghimirekuldip@yahoo.com
24	Babudev Sharma	PPO	PRMD HariharBhawan	Basupokhrel30@gmail.com
25	Shalik Ram Adhikari	PPO	RPPL HariharBhawan	salikram@gmail.com
26	Rajiv Das rajbhandari	Sr. Plant Protection Officer	Plant Protection Directorate	Rajit99@gmail.com
27	Samudra Lal	Principal Scientist	Ent.Division	samudralaljoshi@hotmai

S.No	Name of the Participant	Designation	Organization	Email Address
	Joshi			l.com
28	Dr. Kiran Raj joshi	Sr.Scientist	NARC	Kiran_raj_joshi@yahoo.com
29	Yamuna Prasad Sah	Scientist-2	ARS Dhanusha	Yp_sah@yahoo.com
30	Dr.Budhhi R khidge	CEU	BTOD	Budhi.khidge@gmail.com