ABCOP
ASIA-PACIFIC BIOPESTICIDES COMMUNITY OF PRACTICE

ABCoP 2025
The Rewind

''For the promotion of biopesticides and enhancement of trade opportunities''

Prepared By
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1. Introduction

Excessive reliance on chemical pesticides poses well-documented risks to environmental sustainability and contributes to concerns over pesticide residues in food commodities. These risks apply to the management of both insect pests and plant diseases. In this context, biopesticides—including microbial, botanical, and biochemical products—represent environmentally compatible alternatives for the control of insect pests, pathogens, and nematodes, and can be strategically tailored to specific crops, target organisms, and agroecological conditions.

Although controlled laboratory and glasshouse studies provide strong evidence of the efficacy of biopesticides against pests and diseases, consistent performance under field conditions remains a major challenge, contributing to low levels of farmer adoption. Key limitations include formulation stability; effective delivery of active agents to target pests and pathogens under variable environmental conditions; limited investment in research and development; and limited adherence to recommended application guidelines.

Nevertheless, biopesticides contribute significantly to reducing maximum residue levels (MRLs), improving food safety, facilitating access to export markets, and enhancing the overall resilience of agri-food systems.

About the ABCoP Platform

The Asia-Pacific Biopesticide Community of Practice (ABCoP) was launched by APAARI in May 2024 as part of the sustainability plan of the "Asia Pesticides Residue Mitigation through the Promotion of Biopesticides" project, funded by the Standards and Trade Development Facility (STDF). ABCoP brings together industry leaders, researchers, policymakers, government agencies, NGOs, and other stakeholders to share experiences, address regulatory and technical challenges, and promote sustainable pest management solutions.

The community continued its engagement through 2025, with active participation from experts across the region and beyond. Over 500 participants from the Asia–Pacific, Europe, and Africa regions registered, representing the private sector; government (including ministers and NPPOs); academia (universities); and national and international organizations (Figure 1). All resources (recordings, presentations, and abstracts) from all sessions can be viewed here: ABCoP .

The objectives of ABCoP are to:

- Sustain regional and international collaboration to improve biopesticide adoption, use, and safe trade across the Asia-Pacific region
- Provide a platform for engaging diverse perspectives and fostering knowledge exchange

"ABCoP 2025 – The Rewind" presents key highlights from the sessions, responses to critical questions, and insights into current and future opportunities in the biopesticide sector.

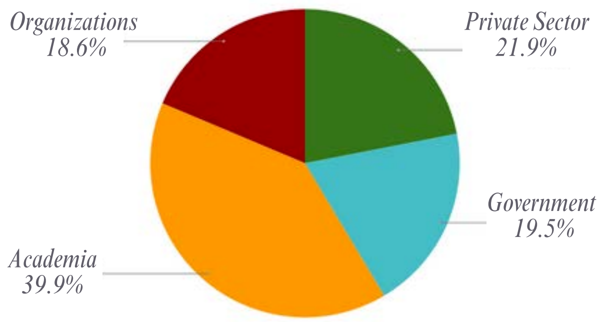


Figure 1: Percentage representation of Key Stakeholders in ABCoP

Quick Recap to the "Asia Pesticide Residue Mitigation Through the Promotion of Biopesticides and Enhancement of Trade Opportunities" Project

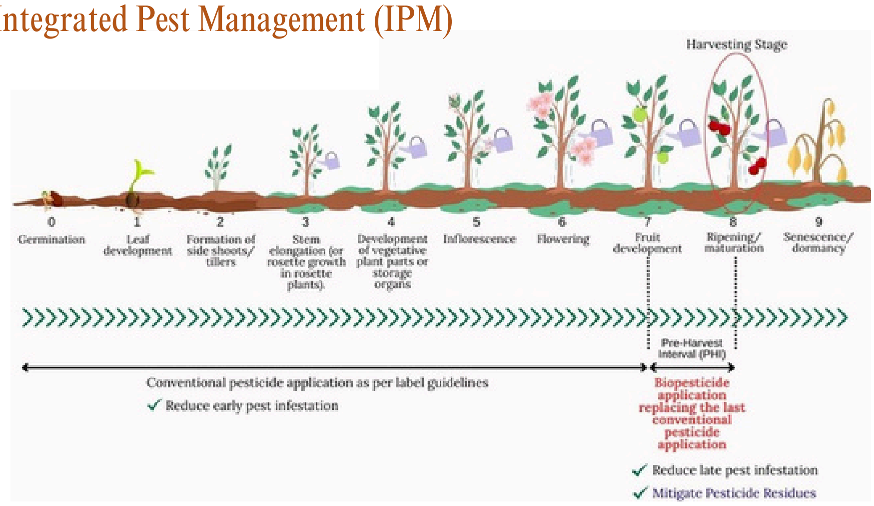
Dr. Ravi Khetarpal
Executive Director
Asia Pacific Association of Agricultural Research Institutions (APAARI)

APAARI is developing pathways to strengthen agri-food research and innovation systems across several thematic areas. The project activities led by APAARI address two of these areas—risk mitigation and policy advocacy—by assisting beneficiary countries in strengthening their institutional capacities. As a part of these efforts, "Asia Pesticide Residue Mitigation Through the Promotion of Biopesticides and Enhancement of Trade Opportunities" project was successfully concluded.

- **Project Objective :** Increase awareness of how pesticide residue issues impact trade and develop methods for overcoming these trade barriers
- **Beneficiary countries :** Bangladesh, Cambodia, Indonesia, Lao PDR, Malaysia, Sri Lanka, Thailand, Vietnam
- **Funding Agency :** Standards and Trade Development Facility (STDF)/World Trade Organization (WTO)
- **Implementing Agencies :** Asia-Pacific Association of Agricultural Research Institutions (APAARI), AgAligned Global, United States Department of Agriculture (USDA)
- **Partners :** Singapore Food Agency, Asia Farmers Association for Sustainable Rural Development (AFA), CropLife Asia

The Innovative Approach - Integrated Pest Management (IPM)

Projects's innovative approach — substituting the final conventional spray with a biopesticide — has been validated as an effective residue mitigation strategy for horticultural crops while controling pests during the pre-harvest interval (PHI)



A key lesson learned was that both technical and functional capacity development were essential for achieving the project's objectives.

- Over 170 government officers were equipped with enhanced technical capacities (knowledge) and functional capacities (soft skills) on residue mitigation studies, biopesticide production, and regulatory harmonization
- The project successfully developed 18 standardized protocols for four major commercial crops—cabbage, sweet basil, dragon fruit, and chili pepper.
- Field studies demonstrated that the proper use of biopesticides toward the end of the growing season reduced pesticide residue levels by up to 50%.

All workshops and trainings were carried out following Good Field Practices (GFP) and Good Laboratory Practice (GLP) to enance knowladge gaps and practical skills. Adopting a Training of Trainers (ToT) approach proved highly effective in building capacity across participating countries. This was further strengthened through South-South Cooperation (SSC) and active knowledge exchange

Regulatory frameworks and regional harmonization remain uneven, with biopesticide regulations established in only a limited number of countries. In most countries, such regulations are either absent or insufficiently developed, and alignment with ASEAN guidelines remains low. The Policy Brief was developed to highlight key policy recommendations.

2. Top Biologicals Companies by Revenue

(FY2024 / Rolling)

Did you know ?

The global biologicals market is still highly fragmented, with approximately 35% of total bio-solutions sales concentrated among the top eight players—highlighting both rapid growth and **significant room for new entrants and innovation!**

Let's explore a consolidated overview of leading global biologicals (biosolutions) companies, including biopesticides, biostimulants, biofertilizers, pheromones, and macro-biologicals (beneficial insects, mites, pollinators) (5, 3).

Rankings reflect disclosed FY2024 revenues where available, complemented by credible industry estimates and strategic scale indicators. Where revenues are not publicly disclosed, this is explicitly stated (1).

- Pure-play biosolutions companies derive the majority of revenues from biologicals, whereas agrochemical majors currently generate approximately 1–10% of crop-protection revenues from biologicals (4, 8).
- The global biologicals market remains fragmented, with the top approximately eight players together accounting for around 35% of total biosolutions sales (5).
- Multiple companies have articulated ambitions to reach approximately USD/EUR 1–2 billion in annual biologicals revenues by the late 2020s, notably Corteva, Syngenta, and RovensaNext (4, 8, 1).
- UPL NPP and FMC BioSolutions have reported more than 20–30% year-on-year growth in recent periods (9, 10).
- Bayer and BASF are expanding biologicals primarily through partnerships and open-innovation models rather than major acquisitions (12, 13).

Ranking Table (FY2024 / Rolling)

Rank*	Company (Biologicals Unit)	FY2024 Biologicals Revenue	Bio Products / Scope
1*	**RovensaNext (Rovensa Group)**	Not publicly disclosed; corporate target ~€1.0B by 2025 (1)	Complete biosolutions portfolio: biostimulants, biofertilizers, biocontrols, adjuvants (2)
2	**BioFirst Group (Floridienne – Life Sciences)**	€507.1M (FY2024 turnover) (3)	Integrated biocontrol & pollination: beneficial insects, mites, pollination plus biopesticides and biostimulants (3)
3	**Corteva Agriscience (Biologicals)**	~$476M (FY2024) (4)	Microbial & plant-derived products: biological seed treatments, biostimulants, pheromones (4, 5)
4	De Sangosse	~€420M (≈2023–early 2024 pro-forma) (6)	Biofertilizers, biostimulants, bio-insecticides, bio-fungicides, bio-adjuvants (6)
5	Koppert Biological Systems	€417M (latest disclosed: 2022) (7)	Macro-biologicals, pollination, plant health biostimulants (7)
6	Syngenta (Biologicals)	~$476M (FY2024) (8)	Biostimulants (Valagro), biofungicides, microbial enhancers, nematicides (8)
7	UPL – Natural Plant Protection (NPP)	~$365M (FY2024 est.) (9, 5)	Microbial & biochemical crop protection, biostimulants, plant strengtheners (9)
8	FMC Corporation (BioSolutions)	~$240M (FY2024) (10)	Pheromone-based insect control, bio-insecticides, bio-fungicides, biostimulant seed treatments (10)
9	Bayer CropScience (Biologicals)	~$215M (latest disclosed estimate: 2022) (11, 5)	Microbial biopesticides, biostimulants, biological nematicides, partnership-driven (12)
10	BASF (Biologicals / BioSolutions)	Not disclosed (13)	Microbial products, plant extracts, biostimulants via partnerships (13)

**Ranking basis: Combination of disclosed revenue, estimated turnover, and demonstrated strategic scale (5)*

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3. Key Insights from Discussion Topics

Potential of Biopesticides to gradually replace chemical pesticides: A myth or a reality ?

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India's agriculture sector, which supports nearly half of the population, experiences substantial pest pressure, leading to crop losses of 10–30% annually and economic losses estimated at INR 2.25 lakh crore per year. Pest management is guided by Integrated Pest Management (IPM), which prioritizes biological control alongside cultural and chemical measures for native pests, while invasive pests are managed through pre- and post-entry quarantine systems.

Current patterns of pesticide use reveal significant scope for biological solutions.

- Chemical pesticides only: ~52% of crop land area
- Biopesticides only: ~7.5%
- Chemical + biopesticides: ~10.2%
- No pesticide use: ~30%

Over the past decade, biopesticides have shown much faster growth than chemical pesticides.

- Biopesticide use: 4,237 MT → 9,321 MT (2009–10 to 2021–22)
- Chemical pesticide use: 41,821 MT → 63,284 MT over the same period

Biopesticide consumption more than doubled between 2009–10 and 2021–22, compared with a moderate increase in chemical pesticide use.

Although chemicals still dominate total volumes, this growth trend reflects increasing policy support, market interest, and farmer awareness of safer pest management options.

Under the Insecticides Act, 1968, a substantial number of bio-insecticides and bio-fungicides have been registered. Commercial biocontrol products are dominated by microbial formulations.

- Registered products:
  - 71 bio-insecticides
  - 31 bio-fungicides

- Estimated companies involved: ~600

- Product composition:
  - Fungi-based: 66%
  - Bacteria-based: 29%
  - Virus-based: 4%
  - Other: 1%

Government support has played a critical role in scaling biological control. Through long-term investments in mass production and field deployment of macrobial and microbial agents, public programs have demonstrated that biocontrol can be implemented at scale under farmers' field conditions.

- "All India Coordinated Research Project on Biological Control of Crop Pests" (AICRP) on Biological Control (1990–2024): ~5.9–6.2 lakh ha covered

Furthermore, Invasive pests present both a major risk and a strategic opportunity for biopesticides. Chemical management of invasive species is often costly and unsustainable, as demonstrated by cases such as tomato pinworm, where control costs exceed Rs. 35,000 per hectare, representing a substantial economic burden.

1.1. Management of Fall Armyworm *(Spodoptera frugiperda)* in Maize: Indian Experience

Fall Armyworm (FAW) invaded India in 2018 and rapidly emerged as a serious pest of maize, with infestations also reported on several other crops. During the initial invasion, damage levels reached up to 70% in affected fields, necessitating urgent intervention.

In response, India implemented an integrated biocontrol-based management strategy that combined semiochemicals, parasitoids, microbial biopesticides, entomopathogenic nematodes, and native natural enemies.

1. **Biocontrol Strategies Implemented**

A) Pheromone Traps and Egg Parasitoids
B) Microbial Biopesticides
C) Entomopathogenic Nematodes (EPNs)

2. **Role of Native Natural Enemies**

Apart from introduced biocontrol agents, native parasitoids have contributed significantly to controlling fall armyworm.

3. **Microbial Pathogens**

It is reported that , In Meghalaya area, 56.6 -- 73.1% of fall armyworm larvae were parasitized or infected by entomopathogens. This indicates a strong natural pest regulation system in the region.

4. **Development of Biocontrol Formulations**

A) Entomopathogenic Bacteria

- Product: SHATPADA ARMOUR
- Microbial Constituent: *Bacillus thuringiensis* var. tolworthi strain NBAIR Bt25

B) Entomopathogenic Virus

- Product: *Spodoptera frugiperda* NPV NBAIR1 (FLW Kill)

C) Entomopathogenic Fungus

- Product: *Metarhizium anisopliae* ICAR-NBAIR Ma 35

D) Entomopathogenic Nematodes

- Strains Tested: *Heterorhabditis indica* NBAIR H38 and *Steinernema carpocapsae* NBAIR S59

1.2. Management of Rugose spiralling whitefly, *Aleurodicus rugioperculatus*: Indian experience

The rugose spiralling whitefly was first detected in India in 2016 on coconut in Pollachi, Tamil Nadu, and subsequently spread across several regions of the country. The pest was initially reported on coconut, but it subsequently spread to other crops including arecanut, banana, maize, oil palm, mango, cashew, and ornamental plants.

Biological control proved to be an effective and sustainable management option under farmers' field conditions. Key biocontrol agents:

- Parasitoid: *Encarsia guadeloupae*
- Fungus: *Isaria fumosorosea*

Field efficacy: 70–76% control in coconut and oil palm

Operational innovations were critical for successful implementation.

- Delivery innovation:
  - Drone-based application for tall canopies
- Technical improvement:
  - Oil-based formulation eliminated nozzle clogging
  - Ensured uniform and effective coverage

1.3.Management of Cassava Mealybug (*Phenacoccus manihoti* Matile-Ferrero): Indian Experience

The cassava mealybug was successfully controlled in India through classical biological control using the parasitoid *Anagyrus lopezi,* introduced from Benin. After its release in cassava-growing regions, the parasitoid established widely and dispersed up to 30 km beyond initial release sites, demonstrating strong adaptation and self-perpetuating control.

Severe infestations had reduced cassava yields from normal levels of 20–25 t/ha to 6–8 t/ha. A single release of *A. lopezi* restored yields to pre-infestation levels, eliminating the need for repeated interventions.

1.4.Management of Invasive Thrips (*Thrips parvispinus*): Biological Control Experience in India

Thrips parvispinus, an invasive Southeast Asian, has emerged as a serious pest of chilli in India.

- Pest status: Invasive, polyphagous, quarantine significance
- Major affected crop: Chilli
- Risk: Severe damage to horticultural systems

Field-based evaluations identified several effective microbial agents and consortia for managing T. parvispinus.

- Microbial agents evaluated:
  - *Pseudomonas fluorescens* (NBAIR-PFDWD)
  - *Beauveria albus* (NBAIR-BATP)
  - Consortium: NBAIR-PFDWD + NBAIR-BATP
  - *Metarhizium anisopliae* (NBAIR-Ma4)
  - *Beauveria bassiana* (NBAIR-Bb5a)
- Field efficacy: ~80% control
- Validation sites: Multiple AICRP centres across India

A critical finding was that the success of biological control depended strongly on strain and isolate selection. Climatic variability influenced performance, and isolates effective in one region were not necessarily effective elsewhere. This highlighted the importance of matching microbial strains to local agro-ecological conditions.

The gradual replacement of chemical pesticides with biopesticides is not a myth when its challenges are successfully surmounted.

Searching for microbial solutions to enhance rice disease resistance

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Rice is a vital staple food and cultural cornerstone, serving as the primary food source for about 4 billion people worldwide, including nearly 87% of Asia's population, and supporting the livelihoods of around 144 million farming families. With approximately 91% of global production concentrated in Asia, rice contributes an estimated USD 206 billion annually, representing nearly 13% of global crop value.

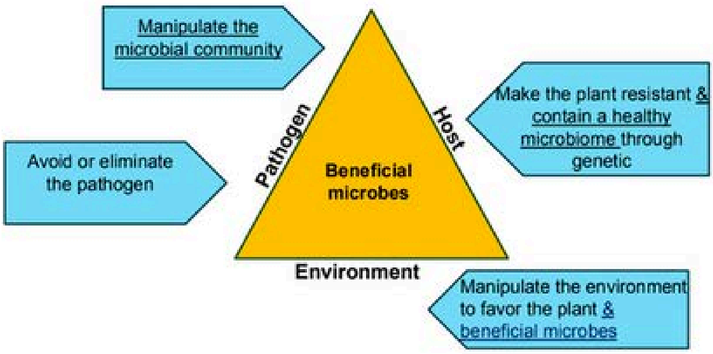
However, rice cultivation faces significant challenges, as nearly half of Asia's rice-growing area is affected by abiotic stresses alongside widespread biotic stresses across regions.

In response, ongoing research is focused on developing microbial solutions to reduce rice diseases and enhance the sustainability and resilience of rice production systems.

Disease Management

Effective prevention and management of rice diseases rely on the disease triangle. Disease occurs only when a susceptible host, a virulent pathogen, and favorable environmental conditions coincide, highlighting the need for integrated management strategies that address all three components simultaneously.

- **Disease management has expanded beyond the classical disease triangle to include a fourth dimension: the microbiome.** This approach focuses on manipulating microbial communities to increase the abundance and activity of beneficial microbes, achieved through developing crop varieties with healthier microbiomes, identifying plant genes that recruit beneficial microbes, or modifying environmental conditions to favor these communities.



Key Research Questions

Three key research questions are being addressed to better understand the role of the rice microbiome in disease management and crop resilience. In this context, biological control is defined as the use of living organisms to suppress pathogenic microorganisms and plant diseases.

1. **How do rice cultivation practices impact its associated microbiome?**

In particular, how do nitrogen and water management **influence** microbial communities in the rhizosphere and bulk soil? Understanding these effects will allow us to recommend rice cultivation practices that favor beneficial microbes, including biological control agents.

2. **How does the rice host control its own microbial profile?**

Specifically, are there host genes that enable rice plants to **recruit** beneficial microbes, including biological control agents, or regulate the structure of their associated microbial communities? If such genes are identified, they can be used in breeding programs to develop rice varieties with healthier and more resilient microbiomes.

3. **Who are the beneficial microbes of rice?**

Once beneficial microbial species, including biological control agents (BCA), are **identified** and effective inoculum is developed, these microbes can be reintroduced into rice fields.

Overview of Three Studies Designed to Address the Key Questions

Study 1: Impact of N fertilizer on soil and rhizosphere microbial community

This study examines how long-term nitrogen (N) fertilizer management influences soil and rhizosphere microbiomes under continuous rice cultivation. The research is based on the IRRI long-term experiment established in 1962, where rice has been continuously cropped for three seasons per year under four nitrogen treatments: untreated control, 65 kg N/ha, 130 kg N/ha, and 195 kg N/ha.

Paired rhizosphere and bulk soil samples were collected from plots under these long-term N regimes and analyzed using shotgun metagenomic sequencing to characterize the full microbial community—including bacteria, archaea, fungi, viruses, and small eukaryotes—and their functional potential.

- Results showed no significant differences in overall species richness across nitrogen treatments, although microbial diversity was higher in the topsoil layer.

- While total species numbers remained stable, shifts were observed in the relative abundance of specific microbial groups.

Study 2: Identification of Rice Genes That Control the Leaf Microbiome

This study investigates how rice host genes influence the composition and structure of the leaf-associated microbiome, with a particular focus on plant defense–related genes.

- The research tests the hypothesis that sucrose transporter genes involved in sucrose leakage during pathogen infection also regulate leaf microbiome structure.

Targeted gene editing is used to compare microbiomes of modified plants and wild-type controls under both pathogen-challenged and non-challenged conditions.

In parallel, additional defense-related genes linked to secondary metabolite production and antimicrobial activity are being examined. This work is ongoing, with further data generation and analysis in progress.

Study 3: Searching for Native Biocontrol Agents

This study is focused on biological control, with the objective of identifying potential native biocontrol agents for the management of rice diseases. These organisms may function by **directly attacking pathogens, competing for ecological niches and resources required for pathogen colonization, or enhancing plant defense responses through induced systemic resistance (ISR),** including phytohormone-mediated signaling pathways. In many cases, biocontrol agents operate through a combination of these mechanisms.

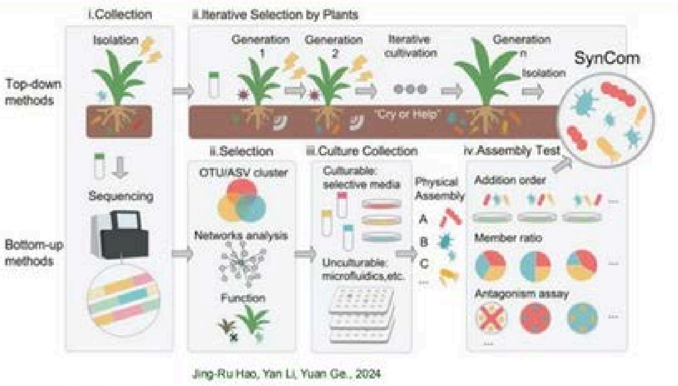
- Between 1986 and 2003, extensive research at IRRI focused on isolating microbes—particularly from seed-associated communities—and evaluating their antipathogenic potential. This work resulted in the establishment of a collection of **163 native Philippine microbial isolates** that have demonstrated biocontrol activity against major rice diseases, including sheath blight, leaf blast, brown spot, and nematode-associated diseases

- As biocontrol agents are living microorganisms, challenges are encountered in their application and in achieving consistent effectiveness under field conditions. Variability in performance has limited farmer acceptance. The use of **microbial consortia**, comprising groups of compatible microorganisms, has therefore been proposed as a strategy to compensate for variability and to stabilize biocontrol effects under field conditions.

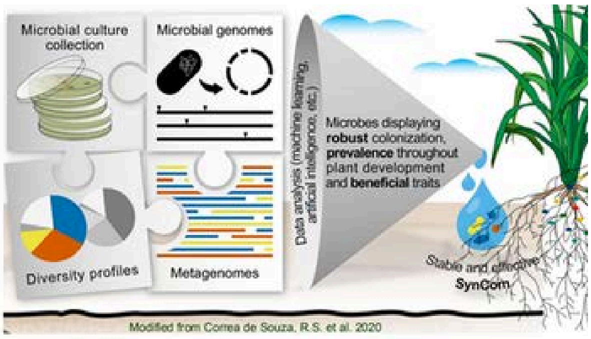
The top-down approach
This begins with a pathogen-infected host plant, from which the associated microbial community is isolated and reintroduced into plants. Through repeated pathogen challenge and host selection (serial passaging), the community becomes enriched with microbes that suppress the pathogen. This strategy aligns with the "cry-for-help" hypothesis, where stressed plants actively recruit protective microbial partners.

The bottom-up approach
This begins with sequencing and other omics-based analyses to identify microbial taxa or functional traits associated with disease resistance. Representative strains are then cultured, when possible, assembled into defined consortia, and evaluated for protective functions under controlled experimental conditions.

Whole Genome Analysis for Biocontrol Consortium Design
A newer strategy combines large microbial culture collections with genome-scale analysis and computational tools to improve the design of biocontrol communities. Whole-genome sequencing is used to generate detailed functional information, which is integrated with experimental data and analyzed using machine learning and artificial intelligence to guide consortium selection.



Jing-Ru Hao, Yan Li, Yuan Ge., 2024



Modified from Correa de Souza, R.S. et al. 2020

As a result of these efforts, a total of 303 new isolates has been added to the collection, comprising:

- 242 bacterial endophytes
- 61 fungal endophytes

Among these, 23 isolates have demonstrated antagonistic activity against Magnaporthe oryzae.

This study has focused on the direct identification of beneficial microbes and on efforts to assemble synthetic microbial communities. Progress has been made through the expansion of microbial collections; however, further characterization of these isolates is still required.

By addressing the three key research questions, it is anticipated that both host genetic mechanisms and the microbial community itself can be better understood and managed. Disease and pest management can be achieved either through the introduction of new biocontrol agents or by modifying environmental conditions to favor beneficial microbial communities.

If the full potential of beneficial microorganisms is effectively harnessed, rice disease management can be improved while reducing overall negative environmental and health impacts.

Biological Crop Protection; Some key facts on actual situation in Russia

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Russia

The Federal State Budgetary Institution “All-Russian Plant Quarantine Center” (FGBU “VNIIKR”) plays the unique role in the system of Rosselkhoznadzor institutions. It is the central Russian plant quarantine laboratory, managing a robust network of regional branches and laboratories, and a scientific center of international importance.

Strategic Imperatives for Expanding Biopesticides and Safer Plant Protection in Russia

By 2030, Vladimir V. Putin, President of the Russian Federation, has set ambitious national targets to increase agro-industrial production by 25% and expand agricultural exports by at least 1.5 times compared to 2021 levels. Achieving these objectives will require plant protection systems that are more sustainable, competitive, and aligned with international regulatory and market requirements.

- Despite strong global momentum, Russia's biopesticide market currently accounts for less than 0.5% of the global market. In contrast, the global biopesticides market is projected to grow at a compound annual growth rate of 16% between 2022 and 2029, exceeding USD 18 billion by 2029. This trend presents a significant opportunity for Russia to strengthen its position in international agri-food markets.

- Regulatory developments further emphasize the urgency of this transition. As of December 2024, the European Union regulates 1,480 pesticide active ingredients, of which 953 are not approved for use, reflecting stricter safety standards and ongoing revisions of maximum residue limits (MRLs). In contrast, Russia uses 95 active ingredients not approved in the EU, incorporated into more than 880 pesticide products, representing 44% of all pesticides used domestically.

- Over the past 20 years, the number of pesticide trade names registered by the Russian Ministry of Agriculture has increased fourfold, from 524 to approximately 2,100, indicating growing reliance on chemical inputs. These trends raise several associated risks linked to intensive chemical pesticide use At present, approximately 98 biopesticides are registered in Russia, including products based on Bacillus thuringiensis and *Trichoderma* spp. for the control of lepidopteran pests and soil-borne pathogens.

While this represents important progress, there remains substantial scope for improvement. To address this, Russia is actively seeking new collaboration opportunities and welcomes engagement with institutions involved in biological crop protection. Stakeholders are also encouraged to participate in collaborative initiatives aimed at advancing sustainable plant protection.

Advancements and Prospects of Biopesticides for Sustainable agriculture: Insights from Sri Lanka

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There is a growing interest in biopesticides in Sri Lanka, particularly within the organic farming sector. In 2021, the Government of Sri Lanka imposed a ban on synthetic pesticides. Although the abrupt implementation of this ban created several challenges for the agricultural sector, it has reinforced the policy focus on promoting organic farming through a more systematic and gradual approach.

Widely used biopesticide products in Sri Lanka include *Bacillus thuringiensis* (Bt)–based and neem-based formulations, representing both microbial and botanical biopesticides.

Several national institutions play an important role in research, development, and promotion of biopesticides and organic farming practices, including the Department of Agriculture (DOA), CIC Holdings, Tea Research Institute (TRI), Coconut Research Institute (CRI), Industrial Technology Institute (ITI), Institute of Fundamental Studies (IFS), and universities.

Oppertunities

- The export potential of tropical botanicals has already been recognized, creating favorable conditions for investment in bio-based plant protection products.

- High-value botanicals such as neem, Ceylon cinnamon, and citronella offer significant opportunities for botanical biopesticide development.

- Some research efforts include a red palm weevil repellent gel and nano-emulsion–based biopesticide formulations. The red palm weevil repellent gel has been commercialized in selected provinces, while nano-emulsion biopesticide formulations have been developed for the management of fall armyworm and selected rice pests. At present, the nano-emulsion products targeting rice pests are undergoing evaluation and have not yet been released to the market.

Recommendations & way forward

- **Government policy transition:**

Sri Lanka has promoted organic and eco-friendly farming practices, particularly following the 2021 ban on chemical fertilizers and pesticides, which significantly increased attention on biopesticide alternatives.

While experience has shown that a complete and immediate ban on synthetic pesticides is not practicable, a phased and stepwise transition toward reduced chemical use and increased adoption of biopesticides is both necessary and feasible.

- **Strengthening research and development:**

National institutions, including the Department of Agriculture and universities, are actively conducting research on indigenous microbial biocontrol agents and plant-based extracts for pest management.

Continued investment in applied research, field validation, and product development will be critical to translating these innovations into scalable and farmer-ready biopesticide solutions.

Lesson learned from Biologicals Promotion in Chiang Rai, Thailand

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Head of Field Operation Agriculture Cluster
GIZ Thailand

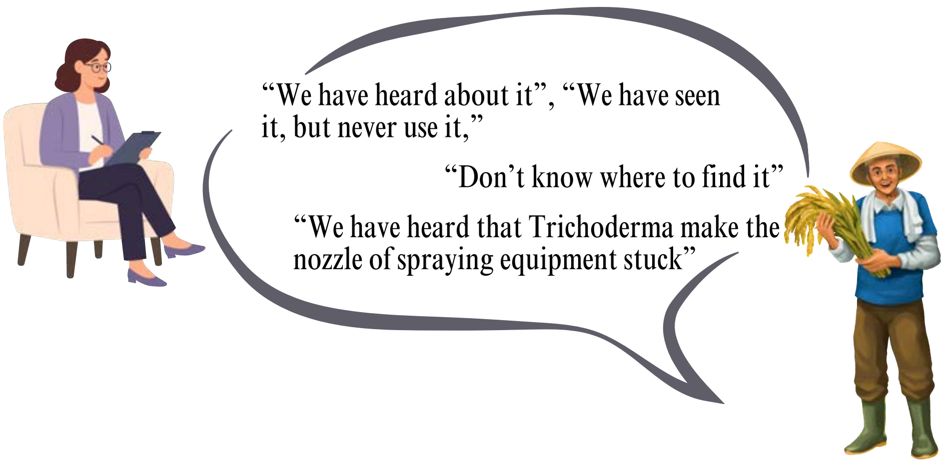
Thai Rice – Strengthening Climate-Smart Rice Farming

The project “Thai Rice: Strengthening Climate-Smart Rice Farming” was implemented primarily in Chiang Rai, in northern Thailand. The project worked with approximately 3,000 farmers operating in a unique mountainous agro-ecological zone. Unlike traditional lowland rice farmers in Thailand, farmers in this region benefit from higher altitude and reliable water sources, which enable diversified cropping systems.

Due to these favorable conditions, farmers cultivate three crops annually through crop rotation. Rice is grown as the primary crop, followed by potato as the second crop and sweet corn as the third crop. While this system provides income diversification opportunities, it also introduces complex agronomic and plant protection challenges across crops.

- The project hypothesized that early disease management interventions in rice—especially targeting fungal pathogens—could reduce disease pressure in subsequent cash crops, thereby lowering control costs and improving farm profitability.

Based on this rationale, biological control was introduced as a core tool within climate-smart agriculture and sustainable crop rotation systems. As an initial intervention, biological control agents, particularly *Trichoderma* spp., were selected and introduced to farmers for the management of fungal diseases across crops.



Facts

- No farmers reported that *Trichoderma* spp is ineffective; rather, most indicated that they have not yet used it.
- From an extension perspective, *Trichoderma* spp. is well recognized as an effective preventive biological control agent.

Key Assumption

- The challenge is not related to the efficacy of the product or technology, but to technology adoption by farmers.

- A demonstration on drone-based application of *Trichoderma* spp. showed that the main barrier to adoption was the application technique, not the technology itself, and that simple practical demonstrations can effectively change farmers' perceptions.

Given this understanding, the primary issue to address is how to increase the adoption rate of biological control practices among farmers. To guide this effort, the project examined "**Innovation Adoption Theory**".

- Key activities to promote biological control adoption among farmers resulted in an increase in *Trichoderma* spp. adoption from 5% at project initiation to 50% by the end of the season.

Biological Scale Up; Inclusive Sustainable Rice Landscapes in Thailand (ISRL)

The project was implemented in two provinces in Thailand—Chiang Rai Province and Ubon Ratchathani Province—representing two distinct cropping systems. In both regions, the project introduced Integrated Pest Management (IPM) approaches and provided targeted training to farmers.

Project Targets

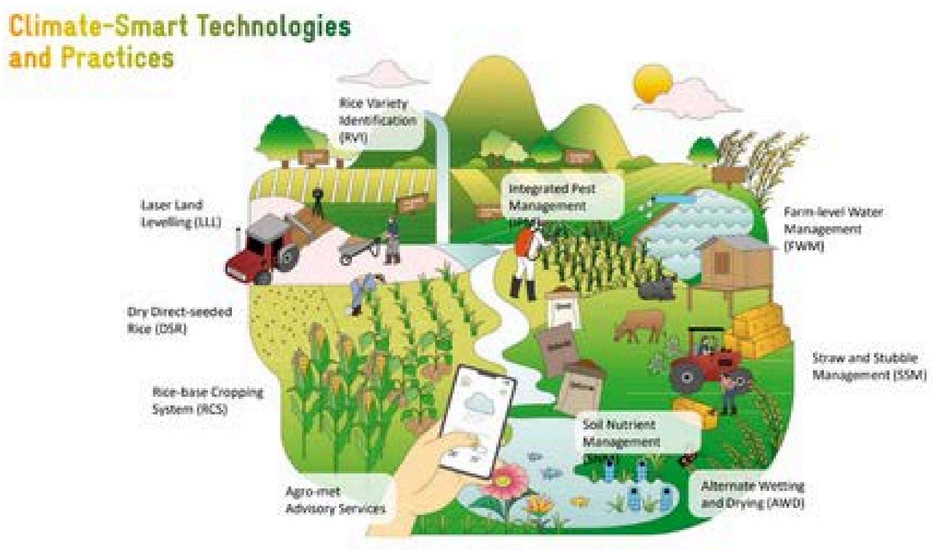
- Reduction of 100 tonnes of agrochemicals across the two provinces, with a strong emphasis on the adoption of biological control
- 45,000 farmers benefiting from improved agricultural practices
- 187,500 hectares of land under restoration
- 1 million tonnes of rice production supported

Thai Rice: Strengthening Climate - Smart Rice farming

The project aims to transition smallholder rice farming in Thailand toward a low-emission and climate-resilient pathway through the large-scale adoption of climate-smart technologies and practices.

- Project duration: Five years (Q1 2024 – Q4 2028)

Over the five-year implementation period, the project is expected to reduce vulnerability to climate risks and strengthen the climate resilience of approximately 253,400 smallholder rice farmers across 21 provinces in the Upper North, Northeast, and Central regions of Thailand.



Climate Smart Practices that are planned to be implemented, including Biologicals and IPM

Advancing innovation in agriculture for a sustainable future

Ms Delisa Jiang
Sustainable Pesticide Management Framework
CropLife International

As a global advocate for the plant science industry, CropLife International champions innovative technologies that enable farmers to sustainably increase productivity while addressing critical climate and environmental challenges. Over the years, CropLife International has built a strong and enduring partnership with the Standards and Trade Development Facility (STDF), working collaboratively not only in Asia but also across Africa and Latin America. In the Asia–Pacific region, this engagement has been particularly extensive, with a strong focus on innovation in biologicals and seed trade. These efforts support safe trade facilitation, compliance with Maximum Residue Limits (MRLs), and the strengthening of regulatory challenges and market access through safe trade.

Biologicals Market Drivers and Integrated Pest Management (IPM)

CropLife International's experience with biologicals highlights that they are often perceived as alternatives to synthetic pesticides. However, the current crop protection landscape demonstrates that biologicals are increasingly viewed as complementary tools. Alongside approximately 600 synthetic crop protection active ingredients, there are now around 300 biopesticide active substances and organisms, spanning several categories of biologicals.

Market demand for biologicals is driven by farmers' need for a more diverse pest management toolbox that combines both biological and synthetic solutions. This aligns with the principles of Integrated Pest Management (IPM), which brings together biological, chemical, physical, and crop-specific (cultural) practices to maximize yield resilience while minimizing risks to human health and the environment. CropLife International actively promotes IPM as a framework that expands farmer choice and supports sustainable production systems.

Challenges to Biologicals Adoption in ASEAN

Despite their potential, several challenges affect the adoption of biologicals across the ASEAN region:

1. Regulatory challenges
Effective regulations are essential to encourage market access while ensuring safe and effective use. CropLife Asia is actively engaged in regulatory capacity-building initiatives. For example, in 2023, the inaugural biologicals regulatory capacity-building workshop was held with Vietnamese regulators. Building on this momentum, discussions are underway with several countries to establish a regional harmonization initiative at the ASEAN level to accelerate registration processes and improve market access.

2. Field adoption and behavioral barriers
Biopesticides are not standalone solutions and do not follow a "one-size-fits-all" model. Even within IPM, approaches must be tailored to local contexts, considering cost structures, climatic conditions, and cropping systems. Experience shows that farmer behavior and entrenched practices can limit sustained adoption.

For instance, discussions with Indonesian regulators revealed that past programs providing subsidized or free biopesticides led to short-term trials, but farmers reverted to familiar practices once incentives ended. This highlights the importance of addressing habits, risk perception, and resistance to change. To overcome these barriers, CropLife International emphasizes:

- Training on IPM and safe use
- Capacity building for extension workers
- Engagement with exporter groups to create market-based incentives

One example is collaboration with Thailand's Rice Department and other partners to develop a sustainable rice platform standard. This standard incorporates IPM requirements and has been recognized both as a national and commercial benchmark, enabling exporters to source rice produced under verified sustainable practices. Such engagement has proven effective in incentivizing farmer adoption.

Data generation is also critical. CropLife International has supported resistance monitoring studies and evidence-based approaches to optimize field-level use.

3. Continued innovation

Further progress requires:

- Improved efficacy and affordability
- Enhanced practicality, including shelf life, storage, and large-scale production and application
- Localized trials and context-specific solutions

Fall armyworm management demonstrates the complexity of pest control decisions. Virus-based biopesticides can be effective but may act too slowly against highly invasive pests. Botanicals may be labor-intensive to prepare, predators may be cost-prohibitive for low-value crops, and cultural methods alone are insufficient. Pheromones have shown strong commercial success, yet optimized blends—such as those developed locally in Zambia—underscore the importance of localized innovation.

Desert locust management provides another example. Biopesticides offer promising options to reduce emergency reliance on chemical pesticides, but their effectiveness depends on advanced monitoring and early warning systems. Technologies such as drones and artificial intelligence can play a critical role. This illustrates that innovation extends beyond products to encompass integrated ecosystems that combine technology, data, and management practices.

Advancing sustainable agriculture requires not only innovation in products but also in regulatory systems, farmer engagement, data generation, and enabling technologies. CropLife International's experience underscores that biologicals, when integrated within robust IPM frameworks and supported by coordinated innovation ecosystems, can play a vital role in building resilient, sustainable agri-food systems for the future.

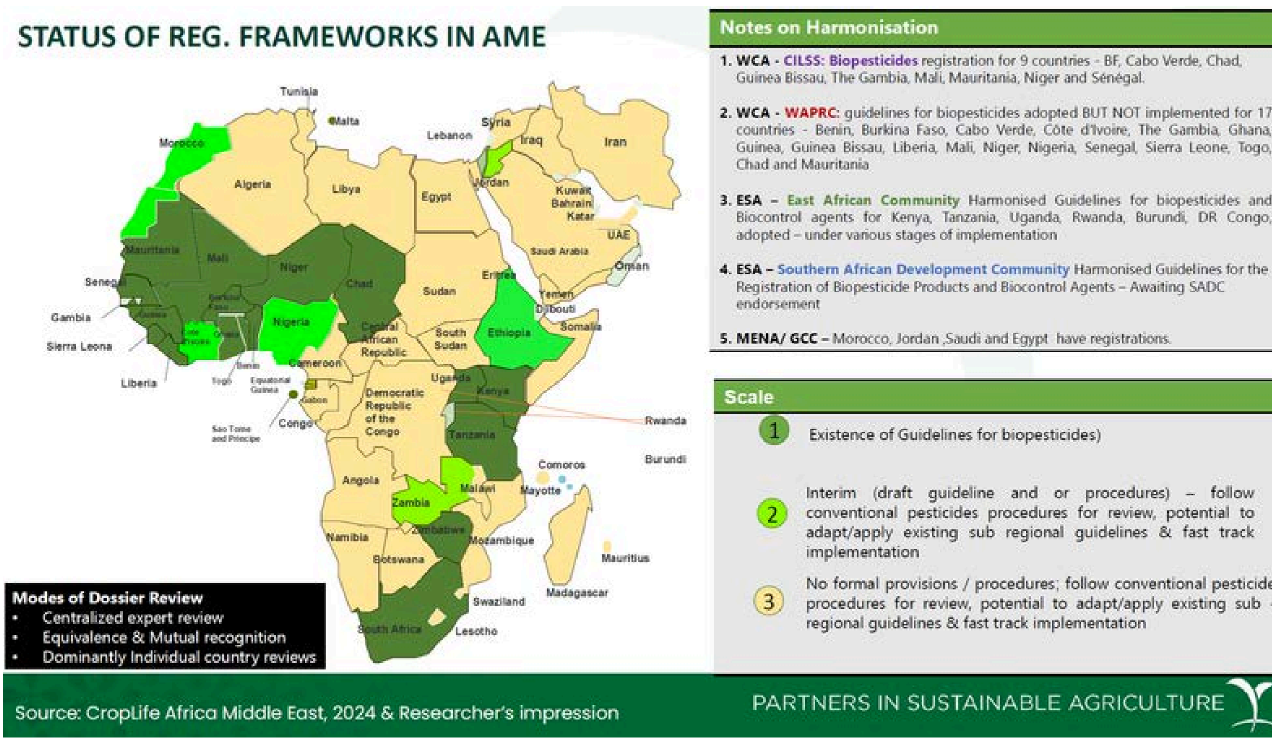
4. Beyond Asia -Pacific

Biopesticides in Africa and the Middle East: Market & Regulatory Perspective

Ms. Stella Siliyu Wafukho
Director - Regulatory Affairs
Croplife africa Middle East

The AME region comprises approximately 72 countries, many of which have agriculture-based economies that provide livelihoods for up to 65% of the population, and in some countries as much as 75–80%. The agricultural sector also contributes significantly to national economies, accounting for more than 25% of GDP in several countries.

- **Demographic challenge:** Agriculture in the region relies heavily on an aging rural population, while difficulties in attracting and retaining young people threaten the long-term sustainability of the sector.
- **Climate-related pressures:** Climate change intensifies flooding, environmental degradation, and pest and disease outbreaks, while farmers often lack adequate tools to manage these emerging risks effectively.
- **Sustainable food systems and market access:** There is a growing need to build sustainable food production systems that can manage pest and disease pressures, adapt to changing consumer preferences, and comply with increasingly stringent market and trade requirements, particularly in export-dependent AME countries.
- **Regulatory Challenges:** There are several regulatory challenges such as Absence of a dedicated regulatory framework for Biopesticides, lack of a harmonised definition for Biopesticides, absence of specific data requirements etc.



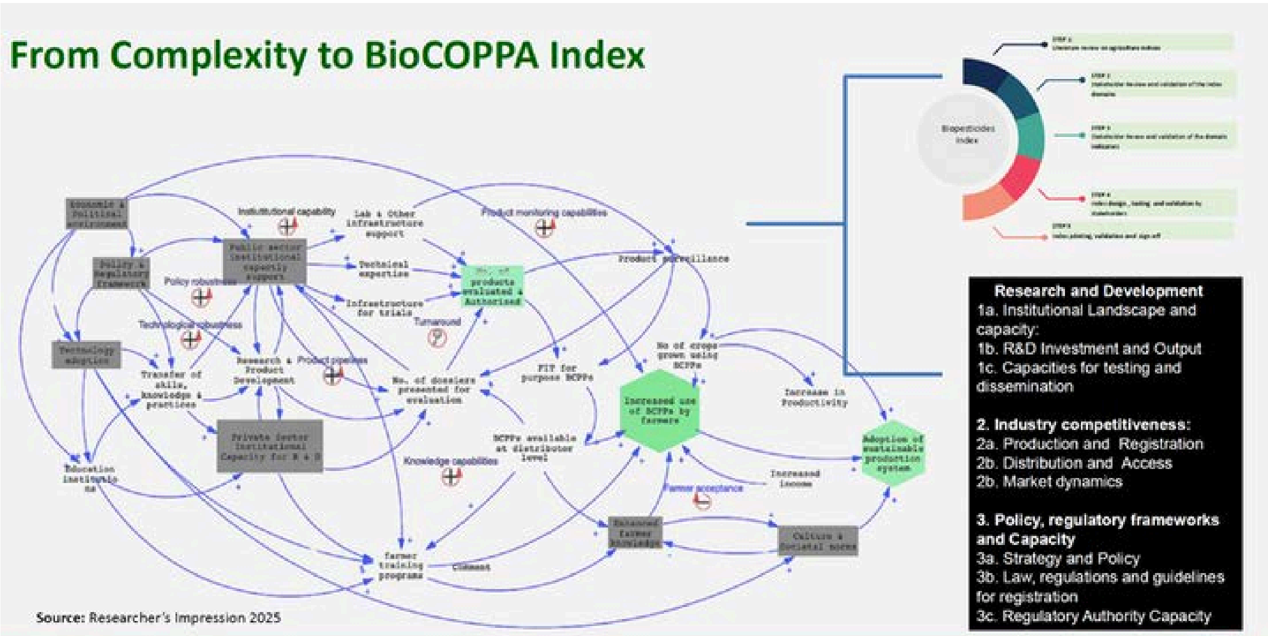
From Complexity to BioCOPPA Index

It was recognized that, due to the involvement of multiple stakeholders, the system is significantly more complex than isolated recommendations, and that decisions cannot be based on a single stakeholder perspective. Accordingly, a comprehensive and inclusive approach is required, supported by a robust process to assess, monitor, and measure progress on the ground.

A biopesticides index, referred to as the Biological Crop Protection Access Index (BioCOPPA), has been proposed to address the complexity of biopesticide adoption and scaling. The design of the BioCOPPA Index draws on a review of existing agricultural indices

- The objective is to promote the adoption of biopesticides within Integrated Pest Management (IPM) programs while simultaneously increasing the availability of biopesticide products. The index provides a structured, multi-domain framework that enables countries to establish a baseline and conduct regular assessments to track progress toward defined goals.

To enable this integrated approach, **causal loop theory** was applied to analyze relationships among key factors, identify feedback mechanisms, and trace interactions between interventions. This framework was used to identify critical leverage points and constraints affecting the scaling and adoption of biopesticides.



Causal loop theory : Positive (+): variables move in the *same direction* (If A increases, B increases — or if A decreases, B decreases), **Negative (–)**: variables move in *opposite directions* (If A increases, B decreases)

- The index is currently being developed for application in Africa and the Middle East (AME) in collaboration with partner institutions and universities, with a focus on accurately reflecting regional realities, challenges, and opportunities, while remaining adaptable for use in other regions. Successful implementation in the AME context will allow the framework to be refined and scaled globally.

- To ensure the relevance, robustness, and usability of the BioCOPPA Index, key stakeholders—including policymakers, regulatory authorities, private-sector representatives, researchers, and farmers' organizations—are invited to participate in its co-design, contributing diverse perspectives and expertise to strengthen the framework and its practical application.

5. Highlights from the Q&A

Dr. Ravi Khetarpal: What are the key comments and findings on awareness of biopesticides ?

Mr. Mizanur Rahman: Whenever we talk about pesticides—whether biopesticides or synthetic ones—we usually look at a few key risk areas: chemistry, human health or toxicology, residues, the environment, and efficacy.

However, when we come to awareness and actual use in the field, the main challenges relate to efficacy. Compared to synthetic pesticides, biopesticides often act more slowly, can give variable results, and require much better understanding from the user. Biopesticides work differently (different Mode of Actions). Pests are part of the ecosystem, and the key is monitoring.

Farmers need to understand concepts like the economic threshold level. As long as pest populations are below that level, intervention may not be necessary. Beneficial organisms and natural enemies are already working within the system. When pest levels rise above the economic threshold, that is when control measures should be applied strategically. For biopesticides, this requires careful consideration of the crop growth stage, pest population, pest life stage, and the characteristics of the product being used. Without this understanding, biopesticides may appear ineffective, even when they are not.

The message is clear: simply providing biopesticides to farmers is not enough. If farmers and growers do not have the necessary knowledge and understanding, these tools will not deliver the expected results. So, awareness must come first—understanding how, when, and why to use biopesticides. This is why awareness and capacity building are so important.

Dr. Malvika Chaudhary: I agree with Mr. Rahman on the importance of using biopesticides at the right time. I would also like to draw the forum's attention to *CABI's plant clinics*. These clinics were established to help farmers identify pest and disease symptoms at an early stage, so that appropriate recommendations—often centered on biopesticides—can be provided in a timely manner.

One of the key challenges, however, is institutionalizing these plant clinics. While they have been successfully mainstreamed in some countries, in others they remain relatively weak. Farmers would benefit greatly from one-to-one consultations, where they can better understand when and how to use biopesticides. In this context, field demonstrations are extremely valuable, as they translate advice into practical action.

Mr. Igor Rylkov, It is important not only to develop new innovations, but also to support them with an effective communication strategy. Farmers need to adapt to different approaches when applying biological products, and this requires guidance and confidence-building.

Within our Federal Service for Veterinary and Phytosanitary Supervision, under the jurisdiction of the Ministry of Agriculture, we have developed a dedicated digital platform called Agroex. This is a publicly accessible web portal that provides information and guidance to all stakeholders.

In addition, we conduct seminars, initiate field trials on the use of biologicals with farmers, and publish the results on publicly accessible platforms. While this is a complex and time-consuming process, we have seen encouraging outcomes.

Some farmers have become convinced—and even surprised—by the effectiveness of biological products when they are applied correctly and in strict accordance with guidelines.

Our approach focuses on on-site, field-based validation rather than laboratory-only studies. By demonstrating results under real farming conditions and within specific local contexts, we help farmers see that biopesticides can work effectively when used properly.

Dr. Ravi Khetarpal: Following the above question, if farmers are aware of biopesticides and their target specificity, are these products available in the market?

Dr. Malvika Chaudhary: This is an important issue is the availability and affordability of biopesticides. Although there are a limited number of small and medium enterprises producing biopesticides, ensuring that these products are accessible to farmers remains a challenge. One possible solution is to empower farmer producer organizations or similar associations to produce biopesticides locally. However, this must be accompanied by strong quality control mechanisms, potentially supported through a network of referral laboratories to ensure product standards.

Dr. Swapan Ghosh: As an industry representative I must say that product availability is a major challenge. Twenty-five years ago, when we developed biopesticide products, we had to go directly to farmers, often in remote villages, to demonstrate product efficacy and create awareness. I still remember traveling to interior villages to promote Trichoderma. Today, the situation has changed—farmers are actively asking for products like Trichoderma and Pseudomonas. The demand is clearly there.

However, the problem is that we are not always able to provide them with reliable solutions. Due to limited availability and inconsistent product quality, farmers lose confidence and often revert to chemical pesticides. This loss of confidence is a serious concern. Farmers recognize the need for biopesticides, but their trust is undermined by poor access and variable performance. At this stage, awareness is no longer the primary issue—it has been created. What we need to focus on now is strengthening the technology itself.

Dr. H.S Gour: One major concern is the storage of biopesticides in terms of technology development. They require specific storage conditions. However, many distributors and retailers do not maintain these conditions properly. I have personally seen biopesticides stacked by the roadside or kept on open shelves. When such products are used, we often find that the spores are either absent or dead, which significantly reduces the spore count and overall effectiveness.

There are also cases where a biopesticide appears to be effective in the field, but laboratory analysis shows that spores are not present at all. When we investigated further through chemical analysis, we found the presence of carbamates, indicating adulteration. This raises serious concerns on technology development.

Dr. Francois Stepman; Extending the shelf life of Biopesticides is a challenge. What type of expertise would you need ?

Dr. S. N. Sushil: At the research level, institutes such as ours are already making progress. For example, one of our products, PTK *(Trichoderma koningii)*, has recently been registered with the Government of India and is now being promoted widely, with three to four companies currently commercializing it.

In its original formulation, PTK achieved a shelf life of 18 months. More recently, the product has been reformulated into a capsule form, extending its shelf life to approximately two years.

These results indicate that while effective microbial strains are available, advances in formulation technology are critical to extending shelf life. Such improvements require specialized expertise from scientists and industry-led R&D systems, particularly in formulation science. Ongoing research efforts are therefore focused on further enhancing shelf life through improved formulation technologies.

Dr. Richard Roush: I would like to add a point on formulation. It is not only about developing formulations that keep living organisms viable; the real challenge lies in designing formulations that can also adhere effectively to the plant when applied. Many groups have worked on this, and it remains highly challenging.

A strong group of chemists at the University of Sydney, around 15–20 years ago, addressed similar challenges while developing fungicide formulations for fungal disease management. They developed an unusual *invert emulsion formulation*, which was sufficiently innovative to lead to a licensing agreement. This experience highlights how complex formulation science can be and underscores the need for expertise spanning both biological and chemical disciplines to successfully advance biopesticide formulations.

Dr. M. K Naik : Are there examples where breeding programs have explicitly targeted microbiome recruitment? More generally, can we assume a resistant variety will naturally host a dominance of beneficial microbes, or are there targeted breeding programs to promote beneficial microbiomes?

Dr. Van Schepler-Luu : We need coordinated breeding efforts, but plant breeders are not yet at the point of having clear genetic targets to select for microbiome recruitment. We cannot yet tell breeders "these are the exact genes or haplotypes to breed for." Right now our approach is twofold: (1) identify beneficial microbes, then ask which host genes are associated with recruiting those microbes; and (2) pursue an untargeted approach — conducting genome-wide association studies (GWAS) to find host loci linked to microbiome composition, then characterizing candidates individually. We are not there yet, but I hope these efforts will mature into actionable targets for breeders.

Authors : Since several technologies are being discussed, let's hear expert's insights on navel technologies.

Prof. Paul Taylor: There is substantial evidence from laboratory and glasshouse studies demonstrating the potential of biopesticides in sustainable agricultural systems. However, significant challenges remain in translating this success to field conditions. One of the major constraints is the effective delivery of biopesticides—whether living biocontrol organisms, secondary metabolites, or plant-derived oils—to the target pathogen or host tissue.

I would like to focus on emerging and cutting-edge technologies for biopesticide delivery, particularly nanoparticle-based formulations. I believe these approaches represent a promising direction for future research, development, and collaboration.

Nanoparticle formulations are advanced delivery systems designed to encapsulate active agents, improving their stability, bioavailability, and targeting efficiency. Nanomaterials used in agriculture may include:

- Chitosan nanoparticles
- Copper-based nanocomposites
- Silver nanoparticles
- Nano-emulsions of botanical oils

These nanoparticle formulations may function by enhancing the expression of defence-related genes, thereby strengthening plant immunity. In fungal and oomycete pathogens, they may also exert direct antifungal effects by disrupting spore germination and mycelial growth.

For example, a study demonstrated the use of silver nanoparticles (AgNPs) to control anthracnose (*Colletotrichum* spp.) as a post-harvest disease of chili fruit. Silver nanoparticles were shown to enhance plant immunity by regulating cellular osmolytes such as soluble sugars, amines, proline, and glycine betaine. They also acted as abiotic elicitors, generating reactive oxygen species (ROS) and activating calcium ion signalling pathways, both of which are critical for triggering systemic acquired resistance (SAR). In addition, AgNPs directly inhibited fungal growth by disrupting spore germination and mycelial development.

The adoption of biopesticides by farmers is likely to increase as such evidence-based improvements are validated through field trials. Advances in nanoparticle formulation technologies have the potential to significantly enhance the efficacy of biopesticides, support crop production under changing climatic conditions, and accelerate the widespread adoption of sustainable pest management strategies.

Dr. Ravi Khetarpal: In the context of public–private partnerships, what is currently ailing the system ?

Dr. Shekhar Bisht: If we look at the origin of most biopesticide technologies currently adopted by the private sector, the majority have come from the public sector. This contribution is extremely important and widely acknowledged. However, one key concern is that many public-sector-developed technologies are relatively old—often developed 30 to 40 years ago—based on the scientific understanding and market needs of that time. Today, market expectations have changed. What is increasingly needed is innovation in formulation science. Rather than relying primarily on live spores or traditional talc-based formulations, there is a need to develop more advanced products, including metabolite-based solutions, that offer faster efficacy and better shelf-life and stability under field conditions.

Dr. Ravi Khetarpal: Could you share your views on the policy and regulatory framework, particularly on biopesticide registration and related challenges?

Mr. Mizanur Rahman: When we look at evaluation and registration processes, the situation is quite similar across most countries. In many cases, biopesticides are assessed through the same regulatory pathways as conventional chemical pesticides. There are very few countries where a distinct or simplified pathway exists for biologicals. This creates an unnecessarily high regulatory burden and is one of the key challenges facing the sector.Regulatory authorities such as the Australian Pesticides and Veterinary Medicines Authority (APVMA), as well as their counterparts in other countries, operate within the limits of their national legislation. They generally have two options: either apply specific provisions already included in existing legislation or work toward developing separate or tailored regulatory frameworks for biologicals. However, regulatory reform is not solely within the control of public service agencies. It involves broader processes, including engagement with parliaments, policymakers, and ministers. As a result, multiple stakeholders are involved in shaping policy and regulatory frameworks. This is why harmonization of regulatory approaches is so important. Harmonization can help streamline research, development, registration, and use of biopesticides.

Mr. Peter Donelan: What actions should be prioritized in the short term versus the long term—for example, regulatory reform, demonstration trials, or public awareness?

Dr. Ravi Khetarpal: It really depends on the country we are talking about. Across Asia, countries are at very different stages when it comes to biopesticide regulation and adoption. Some countries—such as Malaysia, Thailand, and Japan—are quite advanced in terms of regulations, applications, and market readiness. In contrast, in some countries we don't even have a single biopesticide manufacturing company yet. For example, in Bangladesh, this is now starting to change. Through our efforts, we have encouraged an SME to begin research on biopesticides, with the aim of eventually moving into local manufacturing. We see this as an important starting point. The reality is that companies will not manufacture biopesticides if there is no demand. Creating demand—especially within the private sector—is therefore critical in many countries, including Lao PDR and Cambodia. In some cases, public awareness is almost nonexistent. More broadly, farmers still have a strong dependence on chemical pesticides. Regulatory reform is therefore essential—not only to guide safe use, but also to attract both public and private sector investment. Another challenge is that the benefits of biopesticides have not been adequately demonstrated in the field. Our experience shows that biopesticides are most effective when used in combination with chemical pesticides. There are many challenges, and they vary significantly by country. As a result, priorities—whether short-term or long-term—need to be country-specific.

Ms. Delisa Jiang: I agree with Dr. Ravi. Asia is a very diverse region, and no two countries are the same. From a short-term perspective, I believe biopesticide regulation should be a priority, because regulation provides the foundation for innovation. At the same time, there are strong opportunities in the Asia-Pacific region. Farmers here are very enterprising and open to new technologies—we've seen this clearly with the rapid adoption of drones, for example. Strong and enabling regulations can support this momentum, and in many cases, regulation can be the starting point for broader innovation and adoption.

6. Conclusion

The Asia-Pacific Biopesticide Community of Practice (ABCoP) will build on the momentum of 2024–25 as it moves into 2026, focusing on strengthening regulatory systems, accelerating adoption, and fostering an enabling innovation ecosystem for biologicals. The ABCoP Rewind provides a strong foundation for translating shared technical lessons and country experiences into an actionable agenda that balances near-term priorities—such as regulatory fixes, field demonstrations, and targeted investments for research and innovation in priority countries—with longer-term goals, including regional regulatory harmonization and stronger market pull. Achieving these outcomes will require coordinated action among regulators, researchers, private sector partners, funding organizations, and global biologicals organizations, with ABCoP's convening role driving sustained progress and scaling biologicals as effective tools within IPM and safe trade frameworks.

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