Mitigating pesticide residue through promotion of biopesticides in Asia

STDF/PG/634

FINAL PROJECT REPORT

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Acknowledgments

The Asia-Pacific Association of Agricultural Research Institutions (APAARI) extends its sincere gratitude to the individuals and organizations whose unwavering dedication and collaborative efforts have culminated in the successful completion of the Asia Pesticide Residue Mitigation Project through the Promotion of Biopesticides and Enhancement of Trade Opportunities.

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The successful completion of the project is a testament to the collaborative spirit and dedication of each individual and organization involved. APAARI looks forward to building on this success in future endeavors.

Sincerely,

Ravi Khetarpal
Executive Director and Project Lead
APAARI, Thailand

List of acronyms

AAG	AgAligned Global
ABC	Asia-Pacific Biopesticide Community
AFA	Asia Farmers Association for Sustainable Rural Development
AIS	Agricultural Innovation System
APAARI	Asia Pacific Association of Agricultural Research Institutions
ASEAN	Association of Southeast Asian Nations
BARI	Bangladesh Agricultural Research Institute
BCA	Biological Control Agents
BTWG	Bangladesh Technical Working Group
CABI	Centre for Agriculture and Biosciences International
CD	Capacity Development
CEECAC	Central and Eastern Europe, Central Asia and the Caucasus
DOA	Department of Agriculture
EIQ	Environmental Impact Quotient
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FDN	Field Data Notebook
GLP	Good Laboratory Practices
GCHERA	Global Confederation of Higher Education Associations for Agricultural and Life Sciences
Ha	Hectare
IAAS	International Association for Agricultural Sustainability
IAESI	Indonesian Agricultural Environment Standardization Institute
IASS	Institute of Agricultural Sciences of Southern Vietnam
ICGEB	International Centre for Genetic Engineering and Biotechnology
IICA	Inter-American Institute for Cooperation on Agriculture
IPM	Integrated Pest Management
KM	Knowledge Management
L	Litre
MAFF	Ministry of Agriculture, Forestry and Fisheries
MARDI	Malaysian Agriculture Research & Development Institute
ml	Millilitre
MoU	Memorandum of Understanding
MEL	Monitoring, Evaluation and Learning
MRL	Maximum Residue Limit
NGO	Non-Governmental Organization
PDR	People's Democratic Republic
ppm	Parts Per Million
PSC	Project Steering Committee
QA	Quality Assurance
SAARC	South Asian Association for Regional Cooperation

SD	Study Director
SFA	Singapore Food Agency
SOP	Standard Operating Procedure
SPCC	Southern Pesticide Control and Testing Center
SPTAC	(Bangladesh) Sub-Pesticide Technical Advisory Committee
SSA	Special Service Agreement
SSC	South-South Cooperation
STDF	Standards and Trade Development Facility
TAP	Tropical Agriculture Platform
ToT	Training of Trainers
UNDROP	United Nations Declaration on the Rights of Peasants and Other People
US	United States
USDA	United States Department of Agriculture

Table of Contents

Acknowledgments	3
List of acronyms	4
Executive Summary	7
Relevance	10
Project Implementation	11
Achievement of Results	13
Challenges, Risks and Mitigation	31
Lessons Learned	35
Communications & Outreach	39
Recommendations, Sustainability and Follow-up Actions	44
List of Annexures	47

Executive Summary

The STDF PG 634 regional project entitled "Asia Pesticide Residue Mitigation through the Promotion of Biopesticides and Enhancement of Trade Opportunities" was implemented by the Asia Pacific Association of Agricultural Research Institutions (APAARI). The project was implemented from February 2020 to December 2023. The original end date was 20 January 2023. Two extensions were requested from the STDF. One was granted in April 2022 and a second one in August 2023. Extensions were requested due to challenges associated with COVID-19, changes in the role of IR-4 (lead technical coordinator) and adverse weather conditions affecting the residue decline studies.

The project benefited eight countries including Bangladesh, Cambodia, Indonesia, Lao PDR, Malaysia, Sri Lanka, Thailand, and Vietnam[1]. Pakistan was involved in the project as part of similar work implemented by CABI through USDA funded project[2]. A total funding of US$ 899,586 was provided by STDF and US$ 370,017 was provided by the participating country partners budgeted as in-kind support. The project was managed through the Project Steering and Advisory Committee members.

The key project stakeholders in the public sector included: the Bangladesh Agricultural Research Institute (BARI); Ministry of Agriculture, Forestry and Fisheries – Cambodia (MAFF); Indonesian Agricultural Environment Standardization Institute (IAESI); Department of Agriculture – Lao PDR; Malaysian Agricultural Research and Development Institute (MARDI); Department of Agriculture – Sri Lanka; Department of Agriculture – Thailand; and Institute of Agricultural Sciences for Southern Vietnam (IAS). The key project stakeholders in the private sector included: CropLife Asia, Singapore and the United States (US); Dragonberry Produce Inc. USA; Ecosense Labs (I) Pvt. Ltd., India; Jagro Fresh Vegetable Association, Sri Lanka; and Singapore Food Agency. Other stakeholders included: the United States Development Agency (USDA), and the Asia Farmers Association for Sustainable Rural Development (AFA).

The project proposal was developed to mitigate pesticide residues and facilitate trade of Asian countries, based on a collaborative and regional approach. This pilot project aimed to test an innovative approach: combining the advantages of conventional pesticides (generally lower cost and generally greater efficacy) with the advantages of applying biopesticide at the end of the season, to result in lower residues while providing sufficient extension of pest control. This project promoted the use of biopesticides as a safer and more environment-friendly alternative to chemical pesticides. The project also aimed at increasing regional collaboration and capacity to generate and evaluate pesticide residue data (that combines conventional pesticides with biopesticides) to resolve trade concerns due to Maximum Residue Levels (MRLs). Biopesticides include microorganisms (e.g. fungi and bacteria), and biochemicals (e.g. plant extracts, minerals, pheromones). Biopesticides are different from synthetic pesticides in that they have natural origins and most do not produce residues and therefore, they are exempted from MRLs.

The project's approach to capacity development was based on the blending of technical and functional (soft) capacities for innovation, which was integrated into each training activity around the following outputs:

- New MRL data and improved knowledge to interpret this data on the use of biopesticides (combined with conventional pesticides) to mitigate pesticide residues
- Increased knowledge and skills on improved practices to manufacture microbial pesticides.
- Enhanced capacities for regulatory harmonization

[1] Nepal was initially included in the project design, however, the country unfortunately did not participate in the project implementation due to the change in management and of the key contact person.

[2] Project 'Regulatory harmonization in Pakistan for maximum residue limits and biopesticides' (March 2021-February 2024, USD 775,000).

- Extension and outreach activities facilitated for creating awareness and dissemination of project outputs.

The project team provided support and training to the study teams to ensure that they were equipped with the knowledge and skills needed to promote safe and sustainable agricultural practices in their respective countries.

Key results and achievements include:

- The regional biopesticide project, spanning eight countries in South and Southeast Asia, successfully developed protocols for four major commercial crops (i.e. cabbage, sweet basil, dragon fruit, and chili pepper).
- The project showcased a substantial reduction of 50% in pesticide MRL values through the different residue mitigation studies, which were conducted. Additionally, over 174 government officers (103 male and 71 female) from participating countries improved their expertise and skills in MRL data generation, biopesticide production, and regulatory harmonization, while they also strengthened their capacity to collaborate, reflect, and engage in policy dialogue that are envisioned to lead to improved technical and institutional innovation in their countries and the region.
- The project also fostered awareness and adoption of sustainable agricultural practices at the grassroots level, with AFA engaging over 327 farmers and representatives.
- The Training of Trainers (ToT) approach was applied to most trainings, and South-South Cooperation (SSC) was promoted through knowledge exchange and sharing of experiences between and within the participating countries to scale up and sustain the project's outcomes. This experience facilitated partnerships among the countries involved and built their networking skills which are crucial to the success of regulatory harmonization in the region.
- The initiative prioritized Good Laboratory Practices (GLP) for technicians involved in MRL analysis, training over 71 lab officials both online and in-person, with additional support for processing equipment, such as the supply of grinders to the participating countries.
- Furthermore, the project contributed to regulatory regional harmonization by guiding countries in compliance with the Association of Southeast Asian Nations (ASEAN) Guidelines on the Regulation, Use, and Trade of Biological Control Agents (BCA), strengthening relationships and collaboration between regulators through training sessions and workshops tailored to specific country needs.
- In addition, the project was able to leverage resources and/or projects from other donors (namely the US) for both Pakistan and Sri Lanka.

The project was designed in a way to mainstream the Common Framework on Capacity Development for Agricultural Innovation Systems (AIS) of the Tropical Agriculture Platform[3] in all technical activities of the project. The key objective was to support the partner countries in developing their capacities for innovation, not just technical but also institutional. This enabled the countries to expand their thinking beyond their technical areas of work, and thereby developing/strengthening their systems thinking and bringing more interdisciplinarity in their work that would improve their cross-sectoral collaboration for a higher impact. This was based on building the partner countries' soft skills (functional capacities) that would help speed up the effective application of the technologies promoted by the project in practice. In all capacity development activities, the project used the Framework's three-dimension model for capacity development, building capacities not only at the individual level, but also organizational and institutional (enabling environment) to make the project's capacity development more effective[4].

[3] The Tropical Agriculture Platform (TAP), hosted by FAO, is a G20 initiative to promote agricultural innovation in the tropics. *APAARI is an active member of this network. The Common Framework promotes capacity for innovation, specifically: capacity to navigate complexity, to reflect and learn, to collaborate, and to engage in political processes;* *The Tropical Agriculture Platform (TAP) Common Framework | TAPipedia*

[4] *The 3 Dimensions of Capacity Development | TAPipedia*

Several critical factors made it possible for this regional project to produce most of the intended results. Effective project management, characterized by meticulous planning and execution, played a crucial role in maintaining constant communication and flexibility with the participating countries to resolve implementation issues. A proactive approach of actively listening to countries and placing trust in their processes also significantly contributed to overcoming obstacles. Moreover, the timely and accurate allocation of funds, combined with the unwavering support from the STDF Secretariat, particularly during mid-term budget corrections and extensions, significantly contributed to the successful execution.

To ensure the sustainability of the project results, a lot of effort went into building technical, functional and institutional capacities, which now requires a commitment of the participating countries to maintain and further advance these skills to lead to concrete actions by the relevant stakeholders in the region. APAARI will continue liaising with these countries beyond the project through future activities building on existing results. The sustainability plan was produced to guide future actions and was submitted to the STDF. Part of the plan is to establish a virtual Community of Practice (CoP) for the Promotion of Biopesticides and Enhancement of Trade Opportunities that will be facilitated by APAARI. The APAARI project team will mobilize technical experts, government national study teams, and private industries to continue post-project activities as an 'Asia-Pacific Biopesticide Community (ABC)', which has already been established and launched on 31 May 2024. The CoP is envisioned to also support the development of the Theory of Change (ToC) for ABC. The involvement of growers, exporters, universities, national plant protection organizations (NPPOs), and rural advisory services will ensure their continued participation in project-related activities in the interest of sustainability. The biopesticide industries will keep the community updated on new interventions and technologies in the field of biopesticides.

Relevance

Many less developed economies in Asia face increasing challenges in conforming to CODEX and other trade partner pesticide MRLs, either because these MRLs are not established or because the MRLs are too low to reasonably comply with real-world use patterns by farmers. The potential of Asian trade is significantly constrained by rejections due to food safety issues, such as pesticide MRLs being exceeded for permitted pesticides, the presence of prohibited pesticides, quarantine plant pests and pathogens and food-borne pathogens.

The project aimed at solving this problem by developing and testing a new approach to overcome trade barriers caused by either a lack of an MRL, or an MRL that is lower than that resulting from the current use of conventional pesticides. This approach was based on the strategic use of non-residue producing biopesticides following conventional highly toxic pesticides.

This project is of high relevance due to its successful impact in several key areas, addressing crucial problems within the agricultural sector. It played a pivotal role in raising awareness about the use and benefits of biopesticides. The use of a biopesticide breaks up the continuous use of synthetic materials, helping them remain effective over time. Their value is not in providing similar control, but as part of a season-long systems approach to maintain the efficacy of stronger products. The MRL issues can be avoided with the use of biopesticides at the last spray in the season.

The project systematically identified and addressed capacity gaps in different countries. By understanding and bridging these gaps, the project contributed to the overall enhancement of the participating countries' abilities to implement effective pest management strategies. This capacity building is vital for ensuring the long-term success and sustainability of the promoted agricultural practices. The project also contributed to the recognition and understanding of the variations in agricultural contexts across the region that are crucial for tailoring pest management approaches to specific needs and challenges.

Through the adoption of ToT and the development of functional capacities, the project created a regional network through which it has facilitated SSC, promoting collaboration, partnership, networking and knowledge exchange among and within the countries in the region (and beyond through a similar STDF-funded project in Africa), thereby making the project outcomes more sustainable. This collaborative approach is essential for fostering a collective and regional response to agricultural challenges and regulatory harmonization, cultivating a sense of shared responsibility, and harnessing collective expertise.

Furthermore, the project contributed to data generation on crop residues to enhance the understanding of the environmental impact of pesticide use, and for making informed decisions regarding sustainable pest management practices. The knowledge outputs produced by the project (e.g. residue studies, activity synthesis, policy brief, and a policy background paper) will enable future activities to build on the existing knowledge base.

Through the overarching efforts to integrate biopesticides into national integrated pest management programmes (IPMs), the project has laid a foundation for addressing important issues in agricultural pest management.

Project Implementation

The contract signed between the WTO on behalf of the STDF and APAARI was signed in January 2020 with a start date of 20 February 2020 and the end date of 20 January 2023. Two extensions were requested in: (i) April 2022; and (ii) August 2023. Extensions were requested due to challenges associated with COVID, the stepping-out of the Technical Coordinator from IR-4 and adverse weather conditions affecting the residue decline studies. With the approval from STDF, the project was extended until December 2023. APAARI was responsible for the overall coordination of project implementation, financial management, logistical support and delivery of project outputs against the logframe and within the budget. Through the appointment of a Project Manager, APAARI provided strategic guidance, coordination with technical and country partners, backstopping with the participating countries and key project personnel, to ensure smooth implementation of the project and efficient use of resources in the participating countries.

Roles and Responsibilities

APAARI effectively oversaw project management by initiating the appointment of a dedicated Project Manager under the supervision of the Project Lead for coordinating stakeholder communications, overseeing all operational aspects, and managing the logistical and financial dimensions of the project. Regular updates and communication were maintained with key stakeholders from participating countries ensuring that key technical players were well-informed. Technical and managerial advice was sought as needed. The Project Manager supported the team in organizing meetings with country partners and the technical team, organizing capacity-building programmes, and implementing the project's Knowledge Management (KM) Strategy with support of the KM and Innovation Coordinator. Continuous monitoring of progress and addressing routine operational issues were inherent in the Project Manager's duties. The KM and Innovation Coordinator effectively ensured that each technical training is co-designed in an engaging way that fosters collective learning, knowledge/experience sharing, the development of capacities for innovation, and builds a community that continues networking beyond the project to ensure sustainability of the project's achievements.

According to the approved project document, the IR-4 Project was expected to provide scientific and technical expertise and coordination for the project. Following some institutional and other changes (after the project was approved), IR-4 was unable to take on this role as planned. In response, APAARI contracted AgAligned Global (AAG), to provide scientific and technical support for the MRL data generation and regulatory harmonization outputs. The MoUs were made with the participating eight country partners to enable them to conduct the MRL data generation studies in their countries. APAARI was responsible for reporting directly to STDF on project activities.

A Special Service Agreement (SSA) was signed by APAARI with Dr. Christopher Oates, international expert, to conduct an independent external end-of-project assessment of the project. The list of key personnel involved in the project, and their roles and responsibilities are provided in Annex 1.

APAARI also signed a Partnership Agreement with AFA valid from 15 January 2022 to carry out the farmers outreach activities in the region. APAARI provided a linkage with the experts from the national study teams and AFA provided the needed technical support to national-level activities in local languages.

Project Steering Committee and Advisory Committee

The Project Steering Committee (PSC) included experts from the Food and Agriculture Organization of the United Nations (FAO), Jagro Fresh (Sri Lanka), Dragonberry Produce (USA), International Centre for Genetic Engineering and Biotechnology (ICGEB), and Inter-American Institute for

Cooperation on Agriculture (IICA)[5]. The PSC met every six months to discuss the progress and challenges and guide the project implementation in line with the agreed logframe. Any deviations to the logframe were presented to the PSC and approved for mid-term budget corrections. This committee was also responsible for providing strategic direction and technical backstopping to each partner. The details of the PSC meeting are added in Annex 2.

The project also had an Advisory Committee that participated in the mid-term review of the project budget and schedule to ensure the project was in line with strategic goals and that resources were being used efficiently. The seamless execution of the project was guaranteed by their combined experience and input.

The list of project key personnel including all the Steering and Advisory Committee members and national study teams involved in the MRL studies is shown in Annex 3.

Budget

The total amount requested from the STDF for this regional project was USD 899,586 out of the total project cost of USD 1,269,603. It included expenditures for expertise, travel, training, workshops, minor equipment items, project management, general operating expenses, among others. Additional contributions (financial and budgeted in-kind) – amounting to USD 370,017 in total in the project application - were to be provided from different sources. The budget of USD 127,000 that was included in the design document to be covered from industry included in-kind contributions. For example, the private partner (CropLife Asia) and national partners provided in-kind contributions, e.g. training facilities, and staff cost and travel of their personnel. The total amount spent by APAARI from the STDF contributions was USD 899,586.

APAARI channeled resources to relevant agencies or institutions in each country to enable them to conduct field trials or hosting regional trainings. These resources were earmarked for specific purposes such as purchasing small materials, establishing contracts, and covering necessary reimbursements. Recipient agencies or institutions were required to promptly provide itemized expense reports to APAARI, either upon making purchases or upon the completion of services. This meticulous oversight and coordination ensured effective project management and financial accountability throughout the project lifecycle. The overall financial report for the project is added in Annex 4 (A and B).

[5] *ICGEB and IICA were invited given that they are the implementing partners for the related biopesticides projects in Southern Africa and Latin America, respectively.*

Achievement of Results

The activities implemented under different outputs along with the indicators and target are added in logframe matrix added in Annex 5. The results in terms of the outcomes and outputs are detailed in this section.

Outcome: Increased regional collaboration and capacity to generate and evaluate pesticide residue data (that combines conventional pesticides with biopesticides) to resolve trade concerns due to MRLs.

Indicators:

- Decline residue data
- Increased understanding among regulatory authorities of how time, IPM production practices and end of season mitigation impact residues
- Regional work-sharing framework for the identification of regional pesticide residue concerns for key export crops
- Government authorities in targeted countries have a regulatory system in place specific for biopesticides

Output 1: New MRL data and improved knowledge to interpret this data on the use of biopesticides.

General assessment of the output's achievement/performance

A methodical approach prioritizing technical support and capacity building under Output 1 enabled the effective completion of supervised field trials and laboratory analysis for pesticide residue studies, among other project results. The project effectively adopted the ToT model to prepare national teams for the effective delivery of residue mitigation studies. Key activities included group and individual training sessions tailored to each country's study needs. The Technical Study Director (SD) provided guidance and oversight, supporting countries in developing Standard Operating Procedures (SOPs), implementing Quality Assurance (QA) systems, and ensuring appropriate documentation and data management. Notably, countries like Thailand took on a leadership role in training and supporting neighboring countries like Lao PDR, promoting SSC. In-person field training sessions conducted by experts focused on GLP documentation, test substance handling, plot setup, application and sampling procedures, and study design. In May 2023, the Singapore Food Agency hosted a four-day training workshop on GLPs for agricultural researchers and technicians from nine Asian countries with 15 participants. The achievement of key indicators, including the completion of up to 18 field residue mitigation studies on specific pesticides/commodities, an increase in participants' knowledge through training workshops, and the assessment of countries' preparedness to initiate field trials by the SD, underscores the impact of the project training and mentorship initiatives.

Indicators

- Up to 15 field residue mitigation studies on specific pesticides/commodities
- Increased knowledge of participants attending training workshops
- Assessment by the technical director of the country's preparedness to initiate field trials
- Improved SOPs

The major component of the project involved the successful completion of supervised field trials and laboratory analysis for pesticide residue studies to prepare the national team for conducting residue decline studies. The overarching goal was to utilize biopesticides effectively to mitigate residues, ensuring compliance with MRL trade requirements. Technical guidance (via an SD) was provided to countries through group training and initiated through direct oversight (Activity 1.1). Singapore

supported the project by providing the lab facility for regional training or serving as a regional reference laboratory (Activity 1.2). The SD assisted countries in conducting actual trials under a supervised field trial operation (Activity 1.3).

The first year was dedicated to establishing critical field and laboratory preparations, including the development of SOPs, the implementation of a QA system, documentation procedures, data management protocols, and ensuring adequate facilities. It was planned with the initial application that Singapore, Malaysia, and Thailand would provide training to other participating countries. However, with COVID-19 and seasonal impacts, few countries started the trials ahead of these countries. Based on the SD's evaluation, it was decided that Thailand would be in a better position to train Lao PDR, which would also promote SSC beyond the project.

Technical background on the study

The residue mitigation study aimed to replace the last spray of chemical pesticide with biopesticide to reduce the MRL level in the crop thereby supporting the export of product by keeping the MRL within the required limit. The SD worked with the countries to finalize the crop-chemical combinations and collected the label information to be used for the trials. The summary of the study details and procedures shared with the countries is added in Annex 6. The field supply checklist and the label information collected from the countries are added in Annex 7A and 7B. Table 1 provides a list of crops, pesticides, and crop timing for the training of NPPOs prior to the studies.

Table 1 Crops and pesticides list finalized for countries based on the initial assessment

Countries	Introductory Meeting (Date)	Crop	Pesticides	Crop Timing
Cambodia	02-12-2021	Basil	Chlorpyrifos cypermethrin	1st season-Jan-Feb; 2nd season-March-April
Thailand	15-12-2021	Chili Pepper	Imidacloprid acephate profenophos	Grown year-round; avoid late June-October which is Thailand's rainy season
Vietnam	09-02-2022	Dragon Fruit	Metalaxyl hexaconazole propiconazole	March-April (1st season); May-August (2nd season)
Indonesia	13-12-2021	Chili Pepper	Imidacloprid acephate profenophoschlorpyrifos - *added abamectin and fipronil*	Conduct of the trial in the dry season. Dry season is July-Oct
Malaysia	07-12-2021	Chili Pepper	Added *Abamectin, Acetamiprid,Amitraz, Cypermethrin, Diazinon, Fipronil and Malathion* imidacloprid chlorpyrifos	March-early April is when the chili transplanted on 2/1/22 will be plentiful
Sri Lanka	07-12-2021	Chili Pepper	Imidacloprid acephate profenophos	April 2022 - nursery establishment; May 2022 field planting
Lao PDR	07-02-2021	Basil	Chlorpyrifos cypermethrin	The dry season is Nov-May; the best time for the product is the end of March
Pakistan	06-07-2021	Chili Pepper	Profenophos	Requested an early start
Bangladesh	23-11-2021	Greens - Cabbage	Acetamiprid imidacloprid malathion cypermethrin and Chlorpyrifos	Oct/Nov to Feb/March; both crops are grown also April/May to Aug/Sep but not as much as winter season

The residue mitigation study consisted of two phases. **Phase 1** consisted of a decline trial where multiple chemical formulations were mixed in one tank and applied to the crop and samples were collected on that same day (day 0) followed by additional (6) sampling time points from day 3 to day 28 (depending on the crop). Phase 1 determined the active ingredient to use in Phase 2, as well as the time in which residue levels declined to a level that met trade MRL standards. **Phase 2** involved the introduction of a biopesticide to replace the last conventional application of the labeled formulation determined from the decline study.

Before any experimentation started, many training sessions were provided to each country. The first training was a group training, which provided a general overview of the project. Consequently, individual training emphasized the country's study and how to conduct Phase 1 and 2 of their residue mitigation study. Ms. Lennon, SD, and Dr. Rice, Bioefficacy expert visited Vietnam, Indonesia, and Cambodia to provide in-person training between August and September 2022 (Picture 1).

The various field topics covered in the in-person training included GLP documentation, test substance handling, plot set up, sprayer and speed calibrations, field residue application and sampling procedures, proper shipping procedures, and documentation of field residue notebook. In-person field training concerning proper calibration techniques for the spray system and walking speed, application calculations, sample collection procedures, and study design for Phase 2 were discussed with the team and conducted during the experts' visit. Training and guidelines on transferring the samples to the laboratory within 2 hours after sampling was provided.

The field data notebook (FDN) from Phase 1 was discussed in detail with the countries that were conducting the trial for the first time. A synthesis of the training and the presentations are added in Annex 8A and Annex 8B. A detailed protocol based on label information and crop timing was developed by the SD for each country. All eighteen protocols and amendments developed from the project can be found in Annex 8C. In the country field training, the protocol and protocol amendment were reviewed in detail to ensure the country teams were familiar with the study requirements. Many of these trainings were conducted over zoom, with the exception of Phase 1 training for Vietnam, Phase 2 training for Cambodia and Indonesia, which were all conducted in person.

Picture 1. In-person trainings provided by Ms. Lennon and Dr. Rice in South-East Asian countries

Good Laboratory Practices Training

APAARI, in collaboration with the Singapore Food Agency (SFA) and AgAligned Global, USA, conducted a successful training program on Good Laboratory Practices (GLP) in Singapore from 2 to 5 May 2023 (Picture 2). The programme successfully enhanced the skills and knowledge of researchers, laboratory managers, and technicians in GLP to ensure quality and safety in agricultural

research. A total of 15 participants from Bangladesh, Cambodia, Indonesia, Lao PDR, Malaysia, Singapore, Sri Lanka, Thailand, and Vietnam attended the four-day training programme and learned about the principles of GLP, sample grinding, sample extraction, instrumental analysis, sample clean-up, raw data and record-keeping, reporting, electronic data, data processing and reporting. In addition to 16 participants, one faculty from Agalligned Global and one APAARI staff supported the training program. The synthesis and materials of the training can be found in Annex 9A and 9B.

Picture 2. Good Laboratory Practices Training at Singapore Food Agency, Singapore

Results

The pesticide MRL trials conducted across multiple countries focused on evaluating the effectiveness of biopesticides compared to conventional chemical pesticides in controlling pests on various crops, such as chili peppers, cabbage, basil, and dragon fruit. The findings from these trials are promising and highlight significant achievements as summarized below:

- **Reduced pesticide residues**: The trials consistently demonstrated that using biopesticides resulted in much lower pesticide residues on the crops compared to conventional pesticide treatments. This reduction ranged from 2% to an impressive 50%, depending on the specific pesticide and crop.
- **Environmental impact**: Lower pesticide residues mean less harm to the environment. Biopesticides, as researched by the project, have proved to break down more quickly and have lower persistence, which benefits ecosystems, wildlife, and ultimately human health. Adopting biopesticides aligns with sustainable agriculture practices, promoting biodiversity and reducing reliance on chemical inputs. This contributes to long-term environmental sustainability.
- **Improved access to trade**: By achieving a reduction in pesticide residues by using biopesticides and meeting MRLs required for international trade, the use of biopesticides can enhance market access for farmers.

In the study, some crops and chemicals that were tested did not have established MRLs. Therefore, default MRL values were used as a reference point to assess the reduction in MRLs achieved through the use of biopesticides compared to conventional pesticides. The introduction of a biopesticide to replace the last conventional application could reduce pesticide residue by up to 50% in comparison to a conventional plot with only conventional applications. The results also showed that pesticide residues remaining after using biopesticides were within the limits established by CODEX MRLs for the available crop data. This indicates that the use of biopesticides can help keep pesticide residues on crops at safe and acceptable levels according to international standards.

Table 2 below provides an overview of the key research commodities, pesticides and pests in the participating countries.

Table 2 Crops, active ingredients and pests listed for Phase 2

Country	Commodity	Pesticide	Pest
Bangladesh	Cabbage	Chlorpyrifos	Thrips, aphids, whiteflies
Cambodia	Basil	Cypermethrin	Aphids, whiteflies
Indonesia	Chili Pepper	Profenophos	Thrips, aphids, whiteflies
Laos	Basil	Chlorpyrifos	Aphids, whiteflies
Malaysia	Chili Pepper	Acetamiprid	Thrips, aphids, whiteflies
Pakistan	Chili Pepper	Profenofos	Thrips
Sri Lanka	Chili Pepper	Imidacloprid	Thrips, aphids, whiteflies
Thailand	Chili Pepper	Prothiofos	Thrips, aphids, whiteflies
Vietnam	Dragon Fruit	Chlorothalonil	Anthracnose

A detailed technical report on the results and analyses from the MRL data generated is provided in Annex 9C.

Results of the functional aspects integrated into Output 1 activities

All technical programmes under the project, including the GLP training, were designed in an engaging manner to develop functional capacities (soft skills) – not general, but those particularly needed for innovation in the thematic context of the project, to encourage the involved scientists to think beyond their scientific work and reflect on why it is important and how they could contribute to its nation-wide promotion of biopesticides in their countries. As such, the ToT methodology was integrated under Output 1, which enabled the participants to interact, explore and the main competencies and attitudes of effective trainers and learn various tips and principles of adult learning that they can apply themselves when replicating the training in their organizations. In this context, the use of personal logbooks was encouraged to reflect the participants' reflections and observations after each day of training. Collective situation analysis was used to explore how the participants will communicate with their supervisors and colleagues about a request for this training in their organizations. Organizational analysis was used to explore which activities need to be improved through this training and target group. The task analysis method was used to define the task elements that the target group is expected to be carrying out. Training needs assessment was used to help the participants assess their training needs by comparing them with the skills that the lab training builds. A joint after-action review was conducted to provide a constructive reflection on how to improve future technical training of the project and beyond.

The Environmental Impact Quotient (EIQ) was estimated to understand which pesticides have the least impact on the environment. The study found that neem (specifically its purified component, azadirachtin) has the lowest environmental impact among the pesticides examined. Neem's EIQ was 12.10, much lower than conventional pesticides like Profenofos (59.53) and Chlorpyrifos (26.85). Neem also had lower impacts on farm workers, consumers, and ecological factors compared to other pesticides.

The EIQ considers factors like toxicity to different organisms (birds, fish, bees), how long the pesticide stays in the environment (soil half-life), and risks to farm workers and consumers. Neem stood out as having the least impact across these categories.

This project supports reducing environmental impact by highlighting which pesticides are safer for the environment. Choosing pesticides with lower EIQ values, like neem, can help minimize harm to ecosystems, farm workers, and consumers while still effectively controlling pests. A detailed analysis of the methodology and results is added in Annex 9D.

Feedback surveys and Knowledge, Attitude and Practices (KAP) evaluations were conducted after the training. The MRL training survey response is added in Annex 10.

Output 2: Increased knowledge and skills on improved practices to manufacture microbial pesticides.

The key indicators under Output 2 for improving production efficiency and developing capacity in the manufacturing of microbial biopesticides in participating nations were partially met within the project lifespan. Notable progress was made in developing capacities and integrating functional components for sustainable biopesticide production through an online lecture series and practical face-to-face training in Vietnam. The online course reached 63 participants from multiple countries, covering essential topics in biopesticide production, while the hands-on training provided knowledge on fungal biopesticide production techniques. Participants gained practical skills in isolation, screening, fermentation, and quality control of fungal biopesticides, complemented by insights into business model development for biopesticide commercialization. This approach encouraged the participants to think beyond microbial biopesticide production and integrate the system thinking of the purpose, and factors to be considered in the promotion, commercialization, and scaling up of biopesticides while contributing to the improved governance of their national biopesticide systems.

Indicators:

- 20% average increase in production efficiency of manufacture of microbial pesticides in participating countries. While the target of hosting a workshop and increasing capacity (knowledge and skills) was 100% achieved, the specific indicator of a 20% increase in production efficiency of microbial pesticides in participating countries could not be directly controlled or measured within the project's timeframe. Achieving such an increase involves commitments from governments, industries, and farmers of the participating countries, which extend beyond the project's direct influence. Therefore, this indicator is considered not applicable (NA) for immediate evaluation. A more accurate assessment of the project's impact on production efficiency will be possible through post-project evaluations and impact studies to be conducted 3-5 years after project completion.
- List and type of biopesticides produced and registered in participating countries.

Main activities implemented

The microbial biopesticide manufacturing was initially planned to be organized in Nepal to focus on small-scale community manufacturers. However, with no response from the Nepal team, APAARI initiated discussions with other country partners interested in hosting the workshop. For example, it was explored to host the workshop in Sri Lanka, which could not materialize due to the economic and political instability that made it difficult to travel to the country. Finally, the Vietnam team agreed to host the face-to-face training at the Institute of Agricultural Sciences of Southern Vietnam, Ho Chi Minh City, Vietnam. The workshop was a combination of an online lecture series on microbial biopesticide production, hands-on training in microbial biopesticide manufacturing, the development of videos on lab techniques and processes involved in microbial biopesticide production, and the exploration of possible business models for biopesticide promotion and commercialization.

Online lecture series on microbial biopesticide production

The online course benefited 63 participants and 40 official participants got certificates from government organizations, universities, plant protection centers and private companies from Bangladesh, Cambodia, Indonesia, Lao PDR, Malaysia, Pakistan, Sri Lanka, Thailand and Vietnam on 10 and 11 May 2022. The course covered insect pathogenic fungus isolation and identification; secure accession of candidate strains for future use; screening criteria for the best candidate; mass production; and quality control. The recordings of the lecture series are available in APAARI's YouTube channel:

- Microbial Biopesticide Production in Detail | APAARI, STDF-YouTube
- Microbial biopesticides manufacturing - Part 1 | APAARI, STDF - YouTube
- Microbial biopesticides manufacturing - Part 2 | APAARI, STDF - YouTube

Hands-on training in microbial biopesticide manufacturing

One-week intensive hands-on training on microbial biopesticide production that took place from 24-31 October 2022 in Vietnam benefited 19 participants (12 females and 7 males) (Picture 3). The facilitators included Dr. Jaronski, Adjunct Professor, Virginia Polytechnic and State University, USA. Ms. Martina Spisiakova, KM Coordinator and Dr. Rajendran, Project Manager from APAARI. The participants represented the Department of Agro Industry MAFF (Cambodia), Plant Protection Wing, Department of Agricultural Extension, (Bangladesh), National Agricultural and Forestry Research Institute (Lao PDR), Ministry of Agriculture and Forestry (Lao PDR), Horticultural crops research and development institute (Sri Lanka), Indonesian Agricultural Environmental Research Institute (Indonesia), Institute of Agricultural Sciences for Southern Vietnam (Vietnam), Southern Pesticide Control and Testing Center (Vietnam), Nong Lam University (Vietnam), Yergat Food Company Limited (Vietnam), and the Center for Business Incubation of Agricultural High Technology (Vietnam).

Picture 3. Dr. Jaronski demonstrating the microbial biopesticide production method and participants at the end of the workshop with completion certificates

The training covered all the essential steps in the production of the fungal biopesticides, including isolation of the fungus, identification of the morphology, screening, spore production, inoculation, fermentation process, drying and harvesting of the spore, and quality control of the spores. Case studies on the application of *Beauveria* and *Metarhizium spp*. were also discussed. A visit to the Hi-Tech Agricultural Park at Ho Chi Minh City, Vietnam was organized, to learn about the different equipment needed for the production of fungal biopesticide.

Results of the functional aspects integrated into Output 2 activities

Furthermore, the participants were introduced to the key concepts of developing a business model for biopesticide development to start thinking about biopesticides' commercialization aspects (beyond their scientific work). The key topics included the initiation of the development of a business model for biopesticide development and promotion in the participants' countries; understanding the system for biopesticide development (beyond production) applying the system perspective for biopesticides; stakeholder mapping; structural and functional areas of developing the business model; the biopesticide development process; organization of the production business (structure and functions); and the features of the cost-benefit analysis. The participants also engaged in group discussions to conduct the SWOT analysis of the biopesticide production and presented the analysis from each country that was discussed with other country participants. They also explored what could be the possible feasible structure of the proposed business in their countries (e.g. private, joint venture among government and the private sector, or public-private partnership with the government playing an enabling role); how can the biopesticides be distributed/promoted to farmers; what markets could be served; what biopesticide production site would be considered; how will the biopesticides be priced; and what would be the implications on the farmers' production cost. The whole session was very interactive, resulting in short country briefs. The synthesis of this session,

including respective country information is provided as a policy brief on “Promoting the use of biopesticides for improved trade and environment in Asia” in Annex 11.

Training materials and the documents including outcomes from the workshop can be found in Annex 12. A KAP survey conducted after six months collected information focused on what the participants changed in their work as a result of the training, how they are applying the new knowledge that they have acquired, and to what extent they have shared the new knowledge with their national teams. A Survey Report on MRL training and KAP evaluation of the surveys is provided in Annex 13.

Output 3: Enhanced capacities for regulatory harmonization of biopesticides and biocontrol agents.

Under Output 3, the project successfully facilitated the development of a knowledge network to promote dialogue among government authorities and regional bodies, fostering harmonization of biopesticide regulations across Southeast Asian countries. Through workshops and direct engagement, the project analyzed the status of the alignment of national regulatory frameworks with ASEAN guidelines, enhancing the capacity of regulators and industry stakeholders to manage biopesticide registration and adoption, while strengthening their regional cooperation on improving regulatory framework for biopesticides and biocontrol agents that is envisioned to facilitate more registrations of safer pest control tools and mutual acceptance and recognition of product registration among the countries in the region. As an example, the key achievements in Bangladesh included the establishment of technical working groups, the translation and approval of updated biopesticide regulations and the organization of regulatory workshops to address regional regulatory challenges and promote harmonization. Bangladesh was also successful because of reinforcing the regulatory activities with USDA funding.

Indicators

- Network developed to facilitate dialogue between government authorities and other regional bodies on the harmonization of their systems
- Project facilitated cooperation with CropLife Asia on a USDA-ASEAN CropLife sponsored programme
- One workshop organized on biopesticide regulatory harmonization

Main results achieved

South East Asian participating countries

- Reviewed several biopesticide regulations and the 2014 ASEAN Guidelines on the Regulation, Use and trade of Biological Control Agents (BCA) (April 2014)
- Conducted regional workshops (capacity building trainings) on biopesticide regulatory issues
- Surveyed status of biopesticide regulations
- Conducted country-specific online discussions
- Ensured that biopesticide products tested in the efficacy trials were commercially available in the participating countries
- Implemented a Biopesticide Regulatory Workshop (April 2023) that engaged and developed capacities of biopesticide regulators and related officials, as well as industry actors, recommended specific actions to be taken at the regional level to ensure successful regulatory harmonization

Bangladesh

- Conducted capacity-building workshops on biopesticide regulatory issues and formed a Bangladesh Technical Working Group (BTWG).
- Conducted extensive work with the BTWG to update biopesticide regulations (August 2022)

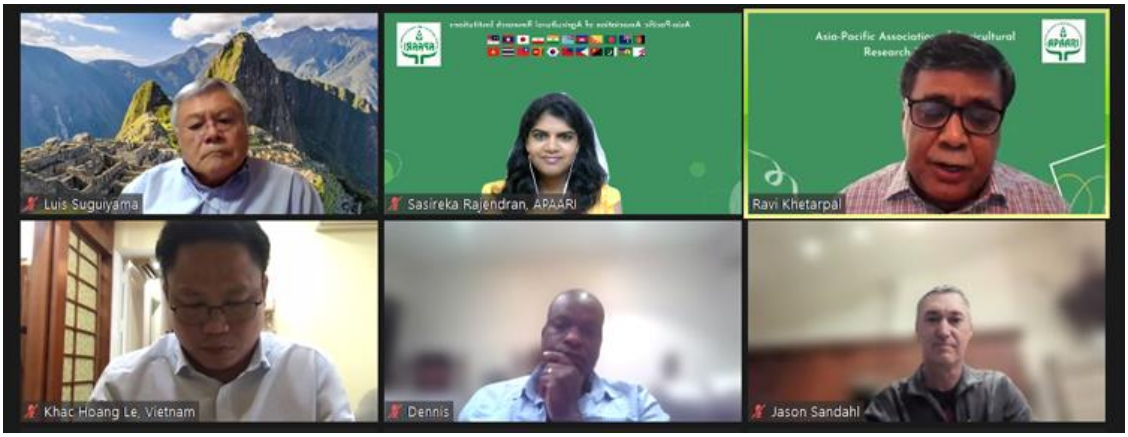
- Translated the updated regulations to Bengali (November 2022) and validated it by BTWG.
- Presented the revised final draft to the Bangladesh Sub-Pesticide Technical Advisory Committee (SPTAC) in November 2022.
- Submitted the final draft to the Bangladesh PTAC (full Committee) for final approval by the Plant Protection Division.
- The Plant Protection Division of the Bangladesh Ministry of Agriculture formally approved the updated biopesticide regulations in July 2023.

Main outputs

- The project addressed the slight differences in regulating biopesticides and biocontrol agents through direct interactions and surveys with all regulatory contact points in the participating countries.
- The project determined the status of biopesticide regulatory development in alignment with the ASEAN Guidelines on the Regulation, Use, and Trade of BCA.

Regulatory workshops

The first Biopesticide Regulatory Harmonization training workshop involving all regulatory contact points of the participating countries was conducted on 18 March 2022 (Picture 4). Prior to the workshop, a survey collected information on the status of biopesticide regulatory development in the participating countries. The training aimed to confirm the commercial availability of biopesticide products selected for the efficacy trials as residue mitigation tools. The project ensured that the participating countries have biopesticide regulations in place in alignment with the 2013 ASEAN Guidelines on the Regulation, Use and Trade of BCA.[6]



Picture 4. First Regional Regulatory Workshop (Virtual)

The second regional biopesticide workshop was conducted face-to-face from 3-5 April 2023 in Bangkok, Thailand (Picture 5). It was built on previous interactions with the regulators from the participating countries, and facilitated knowledge sharing, learning, networking and building of regional collaboration combining the technical and functional aspects in the regulatory harmonization

[6] Indonesia, Thailand, Malaysia and Vietnam have developed their own biopesticides regulations which were aligned and harmonized to ASEAN guidelines through the Biopesticide Regulatory Workshop. Through this workshop, countries such as Cambodia and Laos were sensitized to establish biopesticide regulations. As ASEAN members, Cambodia and Laos are working towards adopting the ASEAN guidelines and are in the process of translating the document into their respective vernacular languages. Countries like Sri Lanka, Bangladesh and Pakistan are not ASEAN members. Sri Lanka does not have biopesticide regulations and harmonization with ASEAN guidelines has not materialized. While, in Bangladesh, APAARI's collaboration with the USDA Phytosanitary project has led to the development of revised biopesticide guidelines to the government and is in the final stages of approval. Similarly, the USDA project implemented by CABI in Pakistan has resulted in the approval of biopesticide regulations by the Pakistani government.

discussions. The workshop also identified various gaps that were discussed with the regulators, such as:

- The expectations/aspirations of participating countries (role of regulators) with regard to biopesticide regulatory harmonization
- The number of current registered biopesticide products in the participating countries
- The incentives that countries provided in terms of minimizing the regulations on biopesticides
- The combinations of crop/pest in which the development of biopesticides is needed or desired
- Several other related biopesticide registration topics

Picture 5. Regional Biopesticide regulatory harmonization Workshop

Challenges and Gaps

The remaining challenges and gaps for approving more biopesticide products and promoting its increased adoption in the participating countries in Asia is encapsulated in Table 3:

Table 3. Challenges and gaps for approving more biopesticides products in Asian countries

Needs	Needed Activities	Expected Outcomes
Develop and make more biopesticide products available	•Information sharing and research •Incentives	• Increased availability of biopesticide products for priority crops/pests
Capacity building for regulators and personnel resources	•Continuing training series •Resources for regulators, chemists and field researchers •Motivating employees •Promoting institutional innovation (e.g., innovation awards) •Promoting public-private community collaboration	• Increased regulatory efficiency • Ability to make science-based decisions • Qualified and knowledgeable personnel • Good institutional performance • Public trust • Better results of motivational and extension activities
Education and outreach for farmers and agricultural dealers	•Field days, farmers training, demonstrations •Developing training materials in local languages •Materials for biopesticide and agricultural dealer training •Collaboration of researcher and farmers •Providing financial incentives to farmers to use the biopesticides •Government working on the development of biopesticides with local manufacturers to ensure reasonable price for farmers	• More farmers using biopesticide • Agricultural dealers with a better understanding of biopesticides

	• Improving understanding of government officials to train the farmers and address farmers' queries • Encouraging the model farmers to motivate other farmers in the locality • Developing guidelines and success stories in the local languages	
Quality of products	• Strengthening existing laboratories and establishing new laboratories for testing biopesticides • Training of human personnel on biopesticides for quality control and inspection • Creating proper storage facility for the biological agents • Developing protocol/SOP for testing the quality of biopesticide products • Monitoring product during production and post-production • Partnership agreement with institutes that have testing facilities	• Availability of quality biopesticide products • Increased farmers' trust and satisfaction to use biopesticides
Priority target crops	• Mapping of top 10 crops and pests • Mapping of top 10 available biopesticides	• Development of a strategic plan for biopesticide usage
Efficacy of biopesticides	• Mutual acceptance of data • Developing regional policy document • Linking and developing capacities of testing centers • Harmonizing the protocols/pilot projects with common pest and crop	• Minimized number of efficacy trials
Registration of biopesticides	• Speeding up the process of registration • Exemption of data requirements • Streamlining registration process • Waiver of registration fees • Data protection and sharing for similar testing protocols • Avoiding the duplication of data and encouraging regional collaboration to use the already available data • E-submission of documents needed • Regulatory officials to be part of regular multi-stakeholder discussions • SOPs to be developed for registration of tool kits	• Efficient biopesticide registration process • Increased number of biopesticides registered and available for usage

Addressing the challenges and gaps (potential actions)

Farmers

- Ensure access and availability of biopesticides at the farm level
- Technical support to farmers through field demonstrations, training and education (effective use, benefits)

- Farmers' certifications and awards for the best user (knowledge and skills)

Research-extension

- Strengthen research/extension activities by integrating biopesticides into farming integrated pest management strategies
- Support testing centers (quality, residue, efficacy, toxicity) in order to expand registered active ingredients
- Improve R&D funding to encourage the development of new, safer/and more effective products

Industry

- Need for incentives for biopesticide companies
- Public-private partnerships between government, biopesticide manufacturers, and agricultural associations to promote the use of biopesticides
- Education and training programmes on the use and benefits of biopesticides
- Reduction in cost and time for registration
- Reduction in data requirements compared to conventional chemical pesticides

General public

- Massive awareness campaigns and education programmes for farmers, communities and the general public on the benefits of biopesticides in terms of health, environment and biodiversity

South-South Cooperation: Technical assistance from countries with efficient biopesticide regulatory mechanisms

- Collaboration facilitated by international organizations (e.g. FAO, USDA, USAID, APAARI, CABI, industry, or STDF)
- National and international expert working groups on biopesticide regulations with participation of technical and regulatory personnel
- International capacity development programmes (funded by international organizations or through public-private partnerships)
- Multi-stakeholder development of comprehensive guidelines on safe and effective production and use of biopesticides that can lead to harmonization

A detailed summary of the status of the biopesticide regulation in the region is added in Annex 14. A list of biopesticides registered in the participating countries is pooled during the workshop and included as Annex 15.

Functional components integrated with Output 3

- Discussion on the types and importance of functional skills for regulators to enable them to successfully regulate the biopesticide development in their countries and promote further innovation in this field.
- Brainstorming on what is innovative in this project, and the development and application of biopesticides was only identified as one element of innovation.
- Consideration of other types of innovation more related to processes, which require a set of functional capacities, such as understanding and regulating safety aspects of biopesticide development, explaining to diverse stakeholders what biopesticides are, how and why it is important to use them, more effective awareness and advocacy with farmers, promoting what farmers already know, broadening awareness to communities and consumers, and improving the legal framework, which is missing in some countries.

- Understanding of the concept of Agricultural Innovation Systems (AIS), capacities for innovation and their importance.
- Strengthening collaboration among countries in a way that leads to harmonization, particularly by facilitating discussions that would lead to a consensus and individual country follow-up after the workshop.

A KAP evaluation was conducted to collect information on what the participants know about the topics covered in the workshop, what has changed in their work as a result of the discussions, and how they are applying the knowledge that they have acquired. The survey conducted with participants revealed several key insights and outcomes from the workshop. Participants acquired significant abilities, particularly in understanding the status of biopesticide regulatory harmonization in ASEAN countries, good regulatory practices, and the impact of MRLs on pesticides. Post-workshop, many participants reported a better reception to biopesticide registration regulations, initiatives to modify training curricula, development of testing protocols, and steps towards harmonized biopesticide regulation approval. The application of new knowledge and practices, such as understanding good regulatory guidelines and promoting biopesticide use, was evident among participants. Efforts were made to share this knowledge with colleagues, policymakers, and through training sessions, emphasizing the need for harmonization and quality control in biopesticide regulation. However, some areas still require further information and capacity building, particularly in microbial biopesticides, standard formulation, and local biopesticide production and promotion.

A report of the surveys is added in Annex 16.

Output 4: Extension and outreach activities facilitated for creating awareness of and dissemination of project outputs.

Since the project launch, the project team integrated knowledge management (KM) and communications in the project activities. During the Inception Workshop (6-7 August 2020), the participants had the opportunity to learn about the important role that KM plays in strengthening agricultural research and innovation systems, and in the project itself, and explore the importance of functional capacities (soft skills) in ensuring successful project outcomes. Consequently, a KM Survey was conducted among the project partners in September-November 2020, to seek their input on the types of KM processes, tools, and mindsets needed to effectively implement the project and deliver its objectives, thereby, contributing to and sustaining the project outcomes even beyond the life of the project (Sep-Nov 2020). The Project's Knowledge Management and Communication Strategy was developed in 2020, focusing on knowledge sharing and learning, development of functional capacities (soft skills), engagement, and project outreach and awareness to different audiences. The key KM achievements can be summarized as follows:

- **Creating knowledge:** Strengthened knowledge base through collection, analysis and processing of data and information to generate knowledge, particularly through MRL studies, which fed into eleven infographics.
- **Knowledge sharing:** Strengthened knowledge sharing among the project stakeholders by facilitating engagement, collaboration, learning and knowledge exchange, blending of technical and functional capacities. (Throughout the KM integration in all project activities).
- **Policy advocacy:** Development of a policy brief and a background document for policy and decision makers, use of innovative facilitation methods in the harmonization workshop and training.
- **STDF Monitoring, Evaluation, and Learning (MEL) Framework**: Ensured learning and improved performance of the project implementation and expected results based on regular reporting, KAP surveys, and training evaluations.
- **Communicating results:** Communicating the project knowledge to various audiences and stakeholders at national, regional, and global levels, and advocating for MRL compliance and use of biopesticides. (Throughout the developed and regularly updated project webpage: Asia Pesticide Residue Mitigation through the Promotion of Biopesticides and Enhancement

of Trade Opportunities, Social Media posts, and articles in APAARI's partner communication tools featuring the project)
- **Improved farmers' knowledge:** Collaboration with AFA on raising awareness among farmers, and integrating the use of biopesticides in their current pest management practices.

Indicators

- Number of people trained on GLP (disaggregated by sector and gender)
- Number of people trained in microbial pesticide manufacturing (disaggregated by sector and gender)
- Online media briefings facilitated by the project
- Number of knowledge products developed by the project

Activities

The project's KM Strategy (Annex 17) focused on enhancing knowledge sharing and engagement of the project partners to improve collective learning as a basis for sustainable networking and collaboration. It integrated strategies to improve the functional capacities of project partners to enable them to better apply technical knowledge from the project, train other stakeholders, and thereby assure compliance with pesticide MRLs. A significant focus of the strategy was on engaging the diverse groups of stakeholders of the project to solicit their inputs into various project activities and encourage the use of project-generated knowledge in practice. Specific strategies were also developed to intensify the project's outreach to raise awareness about pesticide MRLs and the benefits of biopesticides, especially to feed into the decision- and policy-making processes, and to enable the project stakeholders to learn about and better manage risks related to awareness building on biopesticides. The status of the activities is reported in the logframe added to the report (Annex 5).

The strategy also guided the project's activities in reaching out to farmers to enhance their capacities. As such, APAARI collaborated with AFA to enhance farmers' capacity to integrate the use of biopesticides in their pest management practices. The partnership aimed to increase farmers' awareness of biopesticides; positively influence farmers' perceptions; document farmers' indigenous practices and innovations to manage pests; and identify ways to develop their skills and organizations in using biopesticides as an alternative to chemical pesticides.

AFA members in Bangladesh, Cambodia, Indonesia, Lao PDR, Vietnam, and an NGO partner in Pakistan organized six farmers' learning sessions with a total of 238 participants (Table 4). The majority of the participants are members of the national farmers' organizations practicing organic farming, IPM, as well as those relying on conventional pest and disease management practices. The learning exchanges between farmers and government officials from the agriculture agencies led to an increased interest in integrated plant health management or one health approach at the national level.

Table 4. Learning sessions with farmers

Country	National Organization	Details
1. Bangladesh	Kendrio Krishok Moitree/ ActionAid Bangladesh	Date: 11 May 2022 Mode: In-person Total: 19 participants (14 farmer leaders, 2 government officials, 1 AFA staff, 2 ActionAid staff
2. Indonesia	Aliansi Petani Indonesia	Date: 25 May 2022 Mode: Virtual Total: 70 participants (at least 22 women, 41 men)

3. Lao PDR	Lao Farmer Network	Date: 28 April 2022 Mode: Virtual Total: 33 (22 women and 11 men)
4. Pakistan	Agribusiness Support Fund (ASF) (NGO)	Date: 30 June 2022 Mode: Virtual Total: 32 (6 men, 26 men)
5. Vietnam	Vietnam Farmers' Union	Date: 5 September 2022 Total: 47 participants (21 women, 26 men)
6. Cambodia	Farmer and Nature Net Association	Date: 17 October 2022 Total: 37 (17 women, 20 men)

In addition, two regional learning exchanges were done with a total of 89 participants. The first one took place on 29 July 2022, and the second regional activity took place on 18 October 2022, during the in-person AFA General Assembly in the Philippines with 60 participants. During this event, 4 representatives from farmers' organizations and an NGO shared the outcomes of the national-level farmer learning sessions that they have organized.

Results

KM Strategy 1: Enhance knowledge sharing and engagement of the project partners to enhance collective learning as a basis for sustainable networking and collaboration

- Regular sharing of project experiences – Pre-event questionnaires, knowledge sharing integrated into technical activities, post-event mentoring support, web articles, project webpage with links to all project resources, and Social Media posts.
- Development of an advocacy toolkit – Policy Brief and MRL factsheets based on residue mitigation studies to be available on the APAARI project page (the factsheets were replaced by user-friendly infographics with key findings from the undertaken research).
- Documentation of learning and experiences of knowledge application – KAP surveys.

KM Strategy 2: Improve functional capacities of project partners to enable them to apply technical knowledge from the project, train other stakeholders, and thereby assure compliance with pesticide MRLs

- Integration of innovative KM processes into project training and events to promote reflection, learning, collaboration and engagement – World café, group work, "bridge" exercises, joint situation analysis, and stakeholder analysis.
- KM in the context of pesticide mitigation and biopesticide promotion – The planned joint webinar with CABI was not delivered due to the unavailability of the expert, but will be replaced by a regional webinar as part of COP network activities in 2024.
- Risk communication to raise awareness of different stakeholders, including consumers, about the risks and benefits of pest mitigation and biopesticides – Webinaron effective Risk Communication Strategies for Agricultural Trade and Food Safety (29 males; 16 females).

KM Strategy 3: Engage diverse groups of stakeholders of the project to solicit their inputs into various project activities and encourage the use of project-generated knowledge in practice

- Development of simple training materials showing the MRL residue mitigation process and development of biopesticide –
    - Microbial Biopesticide Production in Detail
    - Microbial biopesticides manufacturing - Part 1 | APAARI, STDF
    - Microbial Biopesticides Manufacturing - Part 2
- Development of collaboration and engagement on MRLs with the higher education sector – Planned for the regional webinar that will include all APAARI's higher education members and stakeholders of the "Transforming Higher Education in Agriculture Project".

KM Strategy 4: Intensify project outreach to raise awareness about pesticide MRLs and benefits of biopesticides, especially to feed into decision- and policy-making processes

- Development and dissemination of a policy brief and a background document for the regulatory environment
- Development of a communication campaign around the studies on residue decline and biopesticide efficacy – Infographics with first-hand information from the residue studies
- Broad media awareness campaigns to raise awareness about pesticide residue mitigation – health and environment – and the project work. At the global level (TAP[7], GFAR), APAARI regularly promoted the project activities and contributed articles to partners' communication tools.
- Social media awareness campaigns to raise awareness about pesticide residue mitigation – health and environment – APAARI Social Media channels have been used to promote the project activities. This will intensify with the development of infographics (May-June 2024).

More details on the communication activities is also discussed under the section "Communications and Outreach" of this report.

Farmers' outreach activities

The outreach activities with farmers found that most farmers are aware of the importance of biopesticides and other eco-friendly practices as an alternative to chemical pesticides. They are also aware that it is much cheaper if they produce their biopesticides. However, it was expressed that the use of biopesticides such as biological control agents is more tedious compared to conventional methods because they have to apply them at different stages, from seed until the crops are almost ready for harvest. Using plant extracts would also require one to source materials and experiment with different formulas or mixtures.

In Lao PDR, local technicians or extension staff are not yet fully trained in plant protection. This is one of the reasons why many farmers would opt for readily available and less labor-intensive options, such as the use of chemical pesticides. Formulating the right mix for it to be effective would usually take time and biopesticides cannot completely control pests, thus, there is a need to implement an integrated approach.

There have been many pest outbreaks so farmers have to rely on readily available chemical pesticides that can also give immediate results. In Indonesia, most of the participants, who shared their experiences stated that biopesticides were a last resort because materials may not be readily available at the time they need them and that it would take some time to manufacture biopesticides.

Farmers revealed that commercial biopesticides are being sold in local markets, but also noted that the policy environment is not supportive of the shift from purely chemical pesticides to using integrated pest management. Thus, there is a call to continuously advocate for policies to support the scaling out of eco-friendly production practices, such as agroecology and sustainable agriculture.

When done collectively, organic farmers tend to sustain their practice and rely more on biopesticides in addition to other practices because they produce them in a larger quantity and have mastered the formula. Documenting them and continuous exchanges have been expressed as an important undertaking to support the shift to less harmful options. There is interest in doing more intensive training at the farm level especially since the tips shared by resource speakers were very practical.

Participants discussed their experiences related to sustaining and scaling out eco-friendly production practices, including alternative pest management, with some identified key lessons:

[7] *APAARI is an active member of this network hosted by FAO. The Common Framework promotes capacity for innovation, specifically: capacity to navigate complexity, to reflect and learn, to collaborate, and to engage in political processes; The Tropical Agriculture Platform (TAP) Common Framework | TAPipedia*

- The promotion of alternative pest management is not new. However, the sustainability of this approach was a challenge because there is insufficient support for farmers. Prices of products produced using organic or safer methods are the same as those produced using conventional methods. Thus, it is important to have a mechanism that would recognize or incentivize farmers, who are producing food in an eco-friendly manner. Market support is very important for farmers practicing eco-friendly practices.
- In Cambodia, the rice price guarantee, the strengthening of local cooperatives, and partnerships with companies allowed rice farmers to sustain and expand their organic rice production because they were able to sell directly to a company at a reasonable price.
- In Lao PDR, because of the many pest outbreaks, farmers have created a WhatsApp group chat following the learning session so they can easily exchange ideas on how to manage pest infestations. Recommendations included: i) harnessing digital technology to disseminate to farmers the much-needed information on biopesticides and other alternative pest management approaches; ii) fostering collaboration and productive partnerships; iii) establishing plant clinics; and iv) reliance on local resources.

A detailed report on the national and regional events as provided by AFA is added in Annex 18.

Other key results/spillovers not foreseen in the logical framework

- Pakistan was not initially one of the STDF's project beneficiaries. However, it was involved in the project as part of similar work implemented by CABI through a USDA-funded project called "Regulatory harmonization in Pakistan for maximum residue limits and biopesticides", running from March 2021 to February 2024, with a budget of USD 775,000. This guaranteed complementarity between the two projects and avoided overlaps.
- In Sri Lanka, thanks to the positive experience with the STDF/APAARI project, Sri Lankan authorities became even more interested in the topic and requested more specific and tailored support through the US Commerce Department (Commercial Law Development Program: CLDP), and obtained a new two-year project called "Risk Assessment for Pesticides and Contaminants".
- In Bangladesh, APAARI received collateral funding from USDA, to support phytosanitary development activities. These have complemented the STDF project activities and enhanced its impact in the country.

Project's contribution to gender equality

The project's contribution to cross-cutting issues, notably gender, was minimal, largely due to its brief inclusion in the project design and without specific targets or activities. Regarding gender, the project did not explicitly cater to women's inclusion, and there was no specific indicator of women's participation. However, gender balance was promoted in training, and women scientists equally conducted the residue data generation study. In terms of the end-beneficiaries, in the project countries, minor-use crops tended to involve small-sized farms. Women tend to share in the farm duties, so whatever benefits accrue (e.g., better protection habits, lower-risk pesticides, higher incomes due to greater demand for their products, etc.) farm women and families are likely to benefit. In addition to technical capacities related to the project objectives, women’s functional capacities (soft skills) were developed to enable them to harness and manage their newly acquired knowledge and build and maintain partnerships as described in the section.

Project's contribution to environmental sustainability

This regional pilot project tested an innovative approach of combining the use of conventional pesticides and substituting the final application with microbial-based biopesticides at the end of the crop season (at a given pre-harvest interval), to control key pests. Such an approach was expected to have a positive environmental impact through a reduction of conventional pesticide

usage, resulting in reduced environmental pollution, health risks for farmers, environmental exposure for bees and other sensitive species, and improved biodiversity.

The project contributed to reducing environmental impact by identifying and promoting pesticides with lower Environmental Impact Quotient (EIQ) values, such as neem (specifically azadirachtin), as has been shown in diverse studies. Through comprehensive analysis and comparison, the project demonstrated that neem has the lowest environmental impact among the pesticides examined, with an EIQ of 12.10 compared to much higher values for conventional pesticides like Profenophos (59.53) and chlorpyrifos (26.85). Neem's lower EIQ signifies reduced toxicity to organisms, shorter environmental persistence, and lower risks to farm workers and consumers. By highlighting Neem's environmental benefits and advocating for the use of pesticides with lower EIQ values, the project actively promotes sustainable pest management practices that minimize harm to ecosystems and human health while effectively controlling pests. The detailed analysis and results presented in the project documentation (Annex 9D) provide valuable insights and evidence to support informed decision-making aimed at reducing environmental impact in agriculture.

Challenges, Risks and Mitigation

APAARI faced several challenges throughout the project implementation which were overcome by innovative approaches and actions taken by the project team. The project team remained strongly committed to implementing the activities despite the delays related to several factors. The key challenges, risks and mitigations were mainly due to COVID-19, technical team change, administrative challenges, and climatic conditions.

COVID-19 factors

After contracting the project, just as APAARI planned to launch the project activities, there was COVID-19[8] breakdown resulting in a lockdown with restricted travel within the countries as well as globally. This significantly delayed the start of the project on the ground. The team could not manage to sign MoU or agreements with the implementing countries during this dormant phase of the project. Once the lockdown and quarantine restrictions were eased, APAARI launched the project through the Inception Workshop on 6-7 August 2020.

Even after the inception, there were delays due to COVID-19, which made it difficult for the partners to travel locally to conduct the field trials and lab analyses. It also had an impact on the delivery of the required supplies and equipment needed for the MRL studies. This had serious risks of finishing the project within the timeline. As there were unexpected delays, to ensure the project activities are completed, APAARI requested a no-cost project extension with STDF to implement the country activities even despite delays.

This also affected the sequence of activities initially planned, e.g. the GLP training, since the original plan included group lab training in person. Therefore, the attendees did not do the actual procedures themselves. The virtual meetings were not as long as an in-person meeting so they required twice as many days to provide the training. On the positive side, some countries had more attendance than otherwise would have been possible with a face-to-face meeting.

Technical implementation

Change of technical teams

APAARI faced an unexpected turn of events due to the sudden departure of Dr. Michael Braverman, Technical Coordinator, IR4 in the 13th month of the project (March 2021), there was an urgent need to create a new technical team to take over the project activities. APAARI tied up with Dr. Jason Sandahl from AgAligned Global on 1 August 2021 to get the project activities on the ground. Along with Dr. Braverman, there was also the exit of Dr. Thomas Jackel who was supposed to be working on biopesticide regulations activities for the project. A new team of experts was formed under the lead of Dr. Jason Sandahl. The details of the final technical team and experts roped in are added in Table 5.

Table 5: Technical team formed in 2021 for project implementation

Sl No	Personnel as per the Project Document	Changes made during the implementation
1	Jerry Barron, The IR-4 Project	Jason Sandahl, AAG
2	Michael Braverman, The IR-4 Project	Grace Lennon, Study Director, AAG Kevin Rice, Entomologist, Virginia Tech University
3	Thomas Jackel, Consultant	Luis Suguiyama, AAG

[8] Coronavirus disease (COVID-19)

APAARI had a series of meetings with the experts' team to provide updates on the finished activities and upcoming activities of the project. This change had a huge impact on keeping up with the project timeline as well as the project's anticipated budget. The SD from AAG did not have a clear track of the country partners' capacities to conduct the MRL trials. Stock-taking of the available resources and assessment of the ability of the teams to conduct the MRL trials were conducted jointly by Ms. Lennon and the APAARI team. To overcome the capacity gap, virtual and in-person training in addition to those provided by Dr. Braverman were needed for all the participating countries before they started the trials. Similar issues were faced for regulatory components by Mr. Suguiyama to pool the information from the previous activities to understand the project objectives and expected outcomes.

There was a change in personnel in APAARI with the replacement of Dr. Norah Omot with Dr. Sasireka Rajendran as the Project Manager from August 2022. This had little impact on the implementation as Dr. Rajendran was involved in the project activities with APAARI from the inception workshop.
When the project was submitted, APAARI had discussions with the regional FAO regional office in Bangkok to carry out the farmers' outreach activities. During the project implementation, due in part to COVID-19 reasons, FAO was unable to take on this role as foreseen initially. APAARI had discussions with AFA to take over the outreach activities to carry out national and regional awareness activities on promoting biopesticides in the participating countries. APAARI established a partnership with AFA in January 2022 to implement the outreach activities.

Conducting MRL trials on rice in Cambodia

As per the project document, it was planned that Cambodia would be working with two crops – basil and rice. A decision was made to continue with only basil based on the assessment from the SD on the team's capacity to conduct the MRL studies and budget issues. Considering these capacities and monitoring them during the in-person visit, there is a strong recommendation from the AgAligned Global team that it would be difficult for the Cambodian team to proceed further with studies on rice. The monsoon weather and budget constraints add to the fact of not being able to proceed with the studies related to rice. Unlike other crops, the Bioefficacy study for rice is a complicated procedure and might be tough on Cambodian teams who are performing their MRL studies for the first time. A letter from the Cambodian team on difficulties in conducting trials with climate change impacts was received and submitted to the STDF requesting to proceed with only basil for Cambodia. With discussion and approval from the SC members, the project team proceeded with only basil for MRL study in Cambodia.

Administration and partnership

One of the main challenges in signing Memorandum of Understanding (MoUs) with the participating country partners was due to lockdown and quarantine measures for COVID-19. This resulted in a significant decrease in staffing within government agencies in the cooperating counties. Furthermore, in response to the expressed preferences of our country partners, APAARI adopted a transition from MoUs to formal Partnership Agreements. This transition has been prompted by the desire to establish a more robust and formalized framework for collaboration. Despite the flexibility from APAARI, there were still delays in starting the MRL work with country partners due to staff turnover and bureaucratic processes within the government offices in the participating countries.

There was a lack of involvement from Nepal from the start of the project. APAARI has been approaching several departments in Nepal in the project. Since there was no response from Nepal, we reached Dr. Yubak GC Dhoj (Agricultural Officer, FAO-RAP, Bangkok), Steering Committee Member of the project, who was a representative member from Nepal in the implementation of PPG. A final mail was sent to the Nepal team by him in February 2022 to decide on the situation. Later STDF Secretariat pursued a WTO counselor in Geneva but with no success. Considering the lack

of response from the Nepal team, APAARI requested the STDF to continue the project without the involvement of the government of Nepal which was approved by the STDF.

Project management challenges

With a gap created by the transition of a new technical coordinator, APAARI started from the beginning with the project management by arranging introductory calls with the technical team and the country partners. There were also changes within the country's national study team. Between October 2021 to February 2022, APAARI worked closely with the countries to create a national study team for the project to get prompt responses and identify focal points for different outputs that are planned in the project. It was challenging to identify the contacts and build trust with the countries and the new project team. With several virtual meetings and the use of messaging tools including WhatsApp, Zalo, Line and Telegram APAARI was able to establish a strong network with the participating countries. This helped in getting information faster and moving forward to address the issues faced by the countries.

In least-developed countries, there were some delayed responses from the national study team. In-person visits from the APAARI team to the countries especially to Lao PDR and Bangladesh helped the project team to understand the ground difficulties which were unknown during the virtual calls. With these countries conducting the MRL studies for the first time, they were unclear about the objectives and procedures. To overcome the issues with the language and communication, APAARI arranged virtual and in-meetings for Lao PDR along with the Thailand team; for Bangladesh along with Indian experts to clarify the process as highlighted by the Study Director of the project (Picture 6). This south-south collaboration approach helped in strengthening the linkages between the countries in the region to support each other on the MRL trial problems.

Picture 6. Thailand and Lao team from the basil fields during in-person training and initiation of Phase 1 studies

Economic and political unrest in the participating countries

Sri Lanka has been facing challenges in implementing the project to political unrest and economic crisis[9]. There was lack of chemical supplies, lack of power supply to store the samples and chemicals following the field trials, internet access for the team, and a struggle in conducting farmers' outreach activities on biopesticide promotion. However, the team lead Ms. Magamage expressed their willingness to continue with the project and implement the project activities with some delays.

APAARI along with Ms. Lennon (Study Director for MRL studies) had several meetings with the Sri Lankan team to see how we proceed with the field trials. We received support from our steering committee member Mr. Jagath Fernando to arrange for the fuel to use the generators in the laboratory. Continuous monitoring on the situation was made to ensure full support to the Sri Lankan team. APAARI strongly commanded the interest and persuasion from the Sri Lankan team to proceed with the MRL residue decline studies, which made it possible to complete the trials as planned.

A similar situation also occurred in Lao PDR between April to August 2022[10]. There is a huge fuel shortage in the country and the Lao study team is facing difficulties traveling from the department to the field. However, the team has identified a farmers' field where they conducted their field residue studies. With limited resources, the situation has also affected farmers and other partners involved in project implementation in Lao PDR. The Lao team led by Mr. Souvandouane provided constant updates on the situation to APAARI and the AgAligned team with constant updates on the situation and possibilities to conduct the training at a suitable time. Despite the crisis in Lao PDR, APAARI made timely interventions and arrangements to take the Thailand national study team experts to Lao PDR with overall guidance from Ms. Lennon to help with the residue decline in field training and good laboratory practices training.

Financial management

COVID-19 posed a significant challenge to budget utilization and allocation. The travel and similar expenses estimated in the project almost increase twice or thrice from the initial factored values. Change in technical expertise from Dr. Braverman to the AAG team along the project implementation also needed a mid-term correction for smooth implementation of the project. With the support of APAARI's finance team, necessary modifications to the budget were made to accommodate the travel and staff time needs by adjusting with savings from different activities of the project. The staff time for all the changes and corrections needed to carry out the budget changes and finance management were contributed in-kind from APAARI. APAARI acknowledges the support received from the Steering and Advisory Committee members for the guidance and approval of the budget mid-term corrections.

[9] Sri Lanka's crisis explained in 500 words

[10] Looming debt crunch positions Laos as next possible Asia default

Lessons Learned

Elements of Success:

Key elements of success identified from the project are 1) Excellent support from STDF Secretariat for firefighting especially during mid-term budget corrections and extensions; 2) Project management; 3) constant follow-up with countries; 4) listening to countries when there is an issue in implementation; 5) trusting the countries process (even if it is slower); 6) correct disbursement of budget and 7) integration of functional capacity development (the 50% of the project success according to the participating partners).

National study teams

A National Study Team was formed in all the participating countries which helped in the successful implementation of the project. The team leader helped coordinate and facilitate the work in the countries. The national team was very active in deciding and making necessary changes for crop-pest combinations that need to be worked out for the efficacy of biopesticides. The countries/experts working on the project are active members of the regional technical working group (ASEAN TWG on Pesticide MRL). This project also helped in strengthening the network between countries in the region. South-South cooperation in project training helped in developing the mutual understanding and exchange of information with the partnering countries, especially with Thailand and Laos.

Mentoring and training

Capacity building between two countries through south-south cooperation - a well-experienced country helping to train an inexperienced country in GLP procedures for the field and laboratory. In-person training by the AAG technical team that provided theoretical and practical training to a few countries. The hands-on training resulted in a better understanding of the application and sampling procedures, as well as, counting thrips, whiteflies and aphids with proper procedures in documenting pest assessments. Additional FDN (where each section was explained in detail) was provided to the Cambodian team over Zoom. This intensive training described the GLP data recording principles and the reasoning behind detailed documentation, which resulted in a well-documented FDN for Phase 2.

Multiple communication channels

The project manager was available to be reached by the country partner beyond email to give updates which made the countries to report the issues. Regular updates were obtained from country leads through WhatsApp / Line / Zalo mobile apps. We found ways to get responses from countries through communication tools that they are comfortable with. Initially, when the study picked up, biweekly calls with implementing partners and national study teams helped to pick up activities after the COVID-19 period.

Partners' capability and understanding

Admin team connected with the personal contacts to sign an MOU. Even though the MOU processes were delayed, APAARI found innovative ways to work with them (paying directly to the dealers/ signing partnership agreements, being flexible with agreements, etc). One of the key lessons learned from the project is also the realization of the importance of the technical coordinator's role. It is important to be actively engaged with the project activities and with the project management team. A lesson learned by APAARI is that it is important to ensure that partner authorities are fully committed to the collaboration right from the beginning. The communication with partners by the technical team should be more regular. Team spirit and having a good relationship with the technically associated implementing partners helped in overcoming the difficulties with respect to different time zones and distances. Experts from the AAG and APAARI provided their honest opinion

regarding the situation and the ability of the country partners to conduct the trials and continue the study. This helped a lot in changing the approach with high flexibility and support to the countries that lagged in terms of capacity and resources.
APAARI has been actively engaged with the experts and country partners well ahead of the planned workshops to make sure the participants can attend the workshop without any trouble. A detailed discussion with the country partners helped us understand the importance of having a translator that helped us in making arrangements to have a translator for the workshop, especially for in-person training under Output 2 and Output 1. Adequate time given to clarify the doubts that helped in building a better mentor-mentee relationship was a good lesson learned.

Facilitating cross-regional learning and collaboration

The project's successful sharing of experiences with similar biopesticide project initiatives implemented in Africa[11] and Latin America[12] demonstrated the effectiveness of cross-regional learning. The exchange of insights on mistakes, extensions, and activities, particularly emphasizing the importance of functional capacities, proved invaluable for the broader learning community. The lesson learned highlights the significance of fostering collaborative networks and knowledge-sharing mechanisms across regions. This proactive approach enhances the overall effectiveness of projects by leveraging diverse experiences and expertise.
To sum up, the major lessons learned were managing the stakeholders with patience and poise and addressing their local needs for performing are of prime importance in undertaking the technical capacity.

Integration of functional capacity development in technical training

Each technical training needs to be co-designed between the technical and project management team, which includes knowledge and innovation management expertise, emphasizing that functional capacity development should not be seen as a separate lecture, course, session, or training – it needs to be fully integrated into the technical context to help deliver the desired impact. In addition, training facilitation rather than training delivery, means creating a “safe” space to encourage open and creative thinking, speaking and listening, while connecting different perspectives. Finally, ensure post-training support, to reinforce learning, address key concerns, and learn about progress and knowledge application (e.g. through WhatsApp, online discussions, and follow-up webinars).

Constraints Faced

Budgetary considerations for outreach

The project's execution brought to light how crucial it is to carefully evaluate and account for the financial needs of outreach initiatives. It highlights how important it is to an understanding of outreach needs, including communication platforms, community engagement strategies, and unforeseen challenges. Such projects should have a minimum amount of core funding for country partners to do outreach and carry forward the project outputs among local stakeholders to establish better linkages with experts from the environment.

Technical communication difficulties

To reconstruct a study, proper documentation is necessary. Some FDNs were provided that lacked the necessary data to calculate application rates or the timing of sample collections. If these countries were to attempt to conduct a GLP study in the future, extensive training would be required. One of the requests in the protocol is to contact the SD with any problems that arise in the study.

[11] Harmonizing regulations and mitigating pesticide residues in the SADC region | Standards and Trade Development Facility
[12] Mitigating pesticide residues in Latin America using biopesticides | Standards and Trade Development Facility

There were several issues with the trials that would have been rectified when SD was reached on time. A clear understanding of the protocol by the study team is highly essential.

Language barriers

The US technical team faced language difficulties in Cambodia and Lao PDR. To address the issue, APAARI sent a team of experts from Thailand to Lao PDR as Laotians understand Thai. This has strengthened the SSC.

Sustainability planning and budget mobilization

The project provided insight into the significance of incorporating sustainability plans into project plans. This calls for early preparation for ongoing financial assistance in addition to taking the project's long-term effects into account. One important lesson that came into focus was the need to mobilize funds to continue project activities after the initial stages. Robust sustainability plans and proactive measures to ensure continuous funding might be beneficial for upcoming initiatives.

Addressing climate and environmental dynamics

The unexpected turn of climate and environmental issues revealed the necessity of building resilience into project budgets. Unforeseen events, such as rainfall and COVID-19, can significantly impact the budget's adequacy including staff time. Incorporating contingency plans and flexible budgeting strategies to address unexpected climate-related issues emerged as a key lesson to enhance the project's adaptability and resilience.

Integrating gender and environmental focus

During the implementation and reporting periods, we realized the importance of clearly incorporating gender and environmental constraints into project planning. There were no specific activities included with a focus on addressing gender issues. There is a need for more comprehensive discussions and guidance from STDF on the specific requirements and support mechanisms for integrating a gender component. Ensuring a balanced gender representation among project participants proved challenging, primarily due to the nomination process conducted by country partners, despite recommendations from APAARI. Fortunately, with the active participation of women in the region, we were able to have more engagements of women in the project activities. Moving forward, a more proactive approach in collaborating with STDF and providing clearer directives on gender integration can enhance the project's inclusivity and effectiveness in addressing environmental considerations, fostering a more equitable and sustainable impact.

Managing project timelines and reporting delays

The challenges faced with project timelines and delayed report submissions from participating countries highlighted the need for meticulous timeline planning and effective coordination. In this project, the work plan and timeline were hugely impacted by COVID-19 and the change of the Technical Coordinator. With a tight timeline with each country at different progress levels in completing the project activities, it became difficult to interpret the data and report the project's progress and outcomes for the closing workshop. Enhanced responsibilities of the project team and country partners made it difficult to get the desired output in the short reporting period. Nevertheless, the team made sure to finalize the reports and interpretations along with the final project report.
The project's implementation taught us the value of careful budget planning, incorporating sustainability concerns, being resilient in the face of unforeseen obstacles, and managing project timeframes well. These findings offer helpful direction for upcoming initiatives, facilitating more knowledgeable and flexible strategies to guarantee effective execution and long-lasting effects.

Misunderstanding of the functional capacity development component

At the beginning of the project, there was a high misunderstanding of the functional capacity development component by the technical team. It was seen as a separate training to be provided to the participants. It took a lot of time to clarify its purpose in every partner meeting to consider it as fully complementing the technical content of the project when blended with technical subjects, to help speed up the knowledge/innovation application by the participating countries, and bring about the desired expected impact.

Communications & Outreach

Since the project launch, the project team integrated knowledge management (KM) and communications into the project activities. The Project's Knowledge Management and Communication Strategy was developed in 2020, focusing on knowledge sharing and learning, development of functional capacities (soft skills), engagement, and project outreach and awareness to different audiences. The results related to specific KM and communication strategies are summarized below.

Strategy 1: Enhance knowledge sharing and engagement of the project partners to enhance collective learning as a basis for sustainable networking and collaboration

- Regular sharing of project experiences – Pre-event questionnaires, knowledge sharing integrated into technical activities, post-event mentoring support, web articles, project webpage with links to all project resources, and Social Media posts.
- Development of an advocacy toolkit – Policy Brief and MRL factsheets to be available on the APAARI project page.
- Documentation of learning and experiences of knowledge application – KAP surveys.

Strategy 2: Improve functional capacities of project partners to enable them to apply technical knowledge from the project, train other stakeholders, and thereby assure compliance with pesticide MRLs

- Integration of innovative KM processes into project training and events to promote reflection, learning, collaboration and engagement – World café, group work, "bridge" exercises, joint situation analysis, and stakeholder analysis.
- KM in the context of pesticide mitigation and biopesticide promotion – The planned joint webinar with CABI was not delivered due to the unavailability of the expert, but will be replaced by a regional webinar. However, a training on effective Risk Communication Strategies for Agricultural Trade and Food Safety was conducted instead, to raise awareness among different stakeholders, including consumers, about the risks and benefits of pest mitigation and biopesticides.

Strategy 3: Engage diverse groups of stakeholders of the project to solicit their inputs into various project activities and encourage the use of project-generated knowledge in practice

- Development of simple training materials showing the MRL residue mitigation process and development of biopesticide –
    - Microbial Biopesticide Production in Detail
    - Microbial biopesticides manufacturing - Part 1 | APAARI, STDF
    - Microbial Biopesticides Manufacturing - Part 2 | APAARI, STDF
- Development of collaboration and engagement on MRLs with the higher education sector – Planned for the regional webinar that will include all APAARI's higher education members and stakeholders of the "Transforming Higher Education in Agriculture Project".

Strategy 4: Intensify project outreach to raise awareness about pesticide MRLs and the benefits of biopesticides, especially to feed into decision- and policy-making processes

- Development and dissemination of a policy brief and the background document focused on the enabling environment for biopesticides aimed at policymakers.
- Development of a communication campaign around the studies on residue decline and biopesticide efficacy – Infographics with first-hand information from the residue studies. Five out of eleven infographics have been developed based on the residue mitigation studies and disseminated within the APAARI community.

- Development of national press releases and dissemination to the local media – Asian national plant protection authorities discuss the gaps and capacity needs for boosting regional seed trade.
- Broad media awareness campaigns to raise awareness about pesticide residue mitigation – health and environment – and the project work. At the global level (TAP, GFAR), APAARI regularly promoted project activities and contributed articles to partners' communication tools.
- Social media awareness campaigns to raise awareness about pesticide residue mitigation – health and environment – APAARI Social Media channels have been used to promote the project activities.

Communication – Outputs

Communicating the project knowledge to various audiences and stakeholders at national, regional, and global levels, and advocating for MRL compliance and use of biopesticides. Throughout the project, APAARI developed and regularly updated the project webpage[13] , Social Media posts, and articles featuring the project listed below.

Articles published on the APAARI website, including 2 press releases can be found here:

1. APAARI successfully delivers Training of Trainers on Strengthening Agricultural Innovation Systems for Biopesticide Development in Africa through Capacity Enhancement
2. Pre-Inception Webinar: Asia Pesticide Residue Mitigation through the Promotion of Biopesticides and for Enhancement of Trade Opportunities
3. Virtual Inception Workshop for Asia Pesticide Residue Mitigation through the Promotion of Biopesticides and Enhancement of Trade Opportunities
4. Training on Good Laboratory Practices in the context of pesticide mitigation successfully delivered online
5. Field training workshop on Asia pesticide residue mitigation
6. First Biopesticide Regulatory Workshop, 16 March 2022
7. Asian biopesticide and pesticide regulation officers meet in Bangkok to strengthen their capacity in streamlining regulatory processes in their countries
8. Building Sustainable Solutions: Hands-On Training on Microbial Biopesticide Production in Vietnam
9. APAARI Conducts Successful Good Laboratory Practices Training in Singapore for Agricultural Researchers
10. APAARI Successfully Organized a Webinar on Effective Risk Communication Strategies for Agricultural Trade and Food Safety
11. APAARI's Biopesticide Project Concludes with a Successful Closing Workshop in Bangkok
12. The Evolving Status of Biopesticide Regulation in Asia
13. The Evolving Status of Biopesticide Regulation in Asia
14. Regulations Across the Globe - AgriBusiness Global-(Press release picked up by another player in the region)
15. Asian national plant protection authorities discuss the gaps and capacity needs for boosting regional seed trade (Press release by APAARI)

The average impressions of all project-related posts on **LinkedIn** have been **540 impressions to date.** Similar posts have also been disseminated through APAARI Facebook and Twitter:

1. https://www.linkedin.com/feed/update/urn:li:activity:7106899638602903552
2. https://www.linkedin.com/feed/update/urn:li:activity:7102891441168773120
3. https://www.linkedin.com/feed/update/urn:li:activity:7092792412225306625
4. https://www.linkedin.com/feed/update/urn:li:activity:7089851120906379265
5. https://www.linkedin.com/feed/update/urn:li:activity:7061596803892150272

[13] Asia Pesticide Residue Mitigation through the Promotion of Biopesticides and Enhancement of Trade Opportunities

6. https://www.linkedin.com/feed/update/urn:li:activity:7056913534512762882
7. https://www.linkedin.com/feed/update/urn:li:activity:7026155253284675584/
8. https://www.linkedin.com/posts/apaari-community_stdf-safetrade-biopesticides-activity-7158576792725839872-zcCm/
9. https://www.linkedin.com/posts/apaari-community_stdf-pg634-biopesticide-activity-7003621224584998912-oJRL
10. https://www.linkedin.com/posts/apaari-community_apaari-stdf-usda-activity-6999212133343219712-as86
11. https://www.linkedin.com/posts/apaari-community_apaari-basil-stdf-activity-6998940359556780032-fIiO
12. https://www.linkedin.com/posts/apaari-asia-pacific-association-of-agricultural-research-institutions_stdf-agriculture-training-activity-6959755753557504000-wukh
13. https://www.linkedin.com/feed/update/urn:li:activity:6907569334739189760/

Other articles featuring the project that have been published and disseminated through the TAP and received global visibility include:

1. APAARI participates in the 10th Partners' Assembly of the Tropical Agriculture Platform (TAP) from 21-23 November 2023 – TAP Newsletter Issue November 2023 (period: August - November 2023)
2. APAARI developed a post ToT refresher course on applying TAP tools in technical projects – TAP Newsletter Issue November 2022 (period: August - November 2022)
3. Lessons learned from APAARI Training on Good Laboratory Practices TAP Newsletter - Issue April 2021 (period: February - April 2021)
4. Inception Meeting for the Asia Pesticide Residue Mitigation Project (APRMP) (TAP Newsletter Issue October 2020 (period: July - September 2020)
5. APAARI technical project on pesticide residue mitigation TAP Newsletter - Issue April 2020 (period: January - March 2020)

Furthermore, the lessons learned and the "blending" approach used in the project have been integrated in the E-learning course on Capacity Development for Agricultural Innovation Systems (AIS) that will be part of the FAO Learning Academy at the beginning of 2024.

Presenting project activities and outputs in regional meetings

Asia-Pacific Economic Cooperation - Food Safety Cooperation Forum (FSCF), 17-18 June 2021

The Asia-Pacific Economic Cooperation Food Safety Cooperation Forum (FSCF) organized a webinar on Pesticide Maximum Residue Level (MRL) Harmonization: A Trade Facilitative Approach to MRL Compliance that took place from 17-18 June 2021. APAARI made a presentation on "Biopesticides for breaking non-tariff barriers and related capacity building" that highlighted the key aspects of the project, including how the project supported the capacity of the participating countries to develop MRL residue data. A synthesis of this presentation is given in Annex 19.

AGRICONNECT Conference & Exhibition 2023

The German Agricultural Society – DLG, in collaboration with the Ministry of Agriculture and Cooperatives, Thailand, organized the AGRICONNECT Conference & Exhibition 2023 from 24-25 May 2023 in Bangkok, Thailand (Picture 7). AGRICONNECT 2023 brought together over 300 international participants, including agricultural experts, industry leaders, researchers, policymakers, and farmers. APAARI highlighted the project and the need to promote biopesticides for safe production and consumption, as well as how shifting to environmentally friendly agriculture mitigates risks and could enable global safe trade. The challenges in mainstreaming biopesticide usage, such as improving registration processes, addressing skill shortages, fostering collaboration, and

enhancing testing capabilities were also discussed. The presentation made in the conference is added in Annex 20.

Picture 7. Dr. Khetarpal's update and presentation on "Promoting Biopesticide Usage for Safe Production and Consumption" at the AGRICONNECT Conference and Exhibition 2023.

Regional SPS Workshop for Central and Eastern Europe, Central Asia and the Caucasus (CEECAC) - 2023

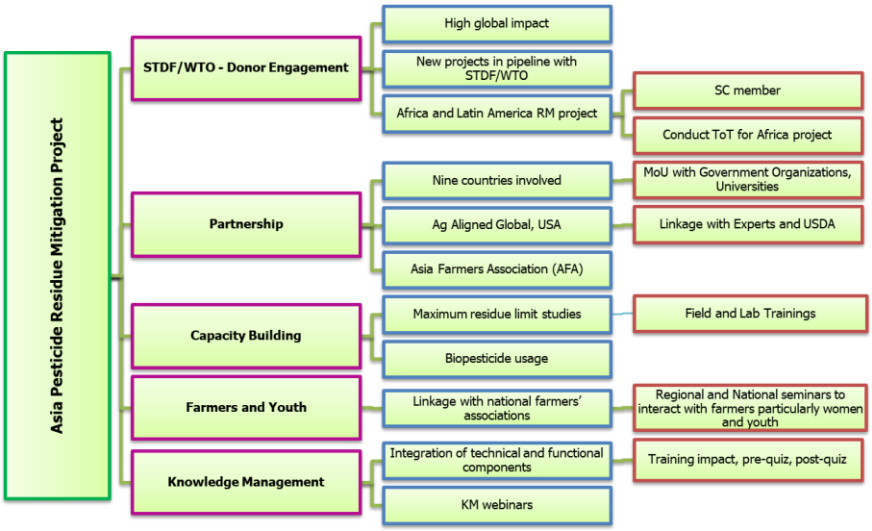
The project was also presented at the Regional SPS Workshop for Central and Eastern Europe, Central Asia and the Caucasus (CEECAC) organized by the WTO from 18-21 July 2023 in Vienna, Austria. APAARI shared insights on selecting and contracting agreements with the country partners, the role of APAARI as implementing partners, and lessons from implementing STDF projects in the region.

APAARI Members Meetings

The project activities and updates are systematically communicated to APAARI members through quarterly members' meetings, offering an opportunity for ongoing communication, feedback, and discussion. The highest level of engagement is achieved during the General Assembly meeting, where participation from all 80+ APAARI members ensures widespread dissemination of project information and fosters a collective understanding of achievements, challenges, and future directions and the project's impact areas were presented to the members (Picture 8).

International meetings

The project's work and its innovative aspects were presented in a number of international meetings organized by the TAP/FAO, the Global Confederation of Higher Education Associations for Agricultural and Life Sciences (GCHERA), and the International Association for Agricultural Sustainability (IAAS). In the context of TAP/FAO, the project was featured during the annual World Food Forum (16-17 October) side events, as well as a Regional Training of Trainers (ToT) on Multi Stakeholder Policy Dialogue (18-20 September 2023) for selected representatives of regional national agricultural research system (NARS) organizations. Furthermore, APAARI shared the project work, particularly with reference to enhancing agricultural innovation to attract youth during the international conference on "Transformational Change in Higher Education to address challenges of the 21st Century" that took place from 21-23 September 2022. Lastly, APAARI showcased the project's innovative methodology at the Innovation Forum organized by IAAS in the University of Reading, UK from 7-9 August 2023.



Picture 8. Impact areas of STDF project in the region through APAARI

Quotes from beneficiaries, regarding the project as a whole:

- *"Thanks to the STDF project, we have been able to get additional, complementary support under a new two-year project "Risk Assessment for Pesticides and Contaminants" funded by the US Commerce Department." - Dr.* Ruwanthi Mandanayake, Assistant Director of Agriculture (Research), Field Crops Research and Development Institute, Department of Agriculture, Mahailuppallama, Sri Lanka

- *"A wonderful and satisfying training event (group residue decline study training). I am most grateful to have been invited to attend. I have learnt a great deal, and this will aid my job in that my capacity and understanding has been increased." – Ms. Karen Muirhead, ICGEB (implementing partner for the STDF Africa project)*

- *"This is a timely relevant training program (microbial biopesticide manufacturing online lecture series) for as a research scientist of rice pathology. With the government policy of Sri Lanka, this is the most important topic to raise international knowledge related to organic agriculture." – Ms. Kankanamalage Rukmali Dayani Gunapala, Assistant Director of Agriculture (Research), Department of Agriculture, Sri Lanka*

- *"Very effective training conducted by the project team. I have understood more on using field data notebook effectively after the training" – Ms. Salma Binte Zaman Sharna, Quarantine Pathologist, Plant Quarantine Wing, Department of Agricultural Extension, Bangladesh on attending Residue Decline Field and Good Laboratory Practices Training for Bangladesh.*

Recommendations, Sustainability and Follow-up Actions

Final Meeting of the Project

A project closing workshop was organized from 23-24 January 2024 in Thailand. The event brought together approximately 35 participants, including representatives from the STDF, country partners, technical teams, and private industries, such as CropLife Asia and Jagro Fresh Sri Lanka. The workshop highlighted the achievements of project activities on capacity building and awareness activities related to new MRL data interpretation, improved practices in manufacturing microbial pesticides, regulatory harmonization, and extension and outreach activities. Furthermore, key outcomes of the project, such as the successful integration of biopesticides alongside conventional pesticides to reduce pesticide MRLs, were discussed. The closing workshop facilitated fruitful discussions on potential pathways forward and the formulation of a robust sustainability strategy (discussed more under the section “Recommendations, Sustainability and Follow-up Actions”). The project team and the country partners summarized project activities, challenges, outcomes, and lessons learned, paving the way for continued collaboration and knowledge sharing in the field of biopesticide research and implementation.

Actionable Recommendations, Sustainability Plan and Follow-up Actions

While the project has successfully achieved most of its intended results, the journey towards sustainability is important for ensuring that the positive changes brought about through the project go beyond its timeline. Sustainability goes beyond the immediate outcomes and demands a stakeholder commitment to maintaining, enhancing and using the developed capacities. By strategically engaging with national decision-makers, APAARI will work towards embedding the residue mitigation approach as one of the priorities for participating countries. With the integration of the development of institutional capacities, the results will be presented to APAARI member countries to build on the existing outputs and make use of the resources available with the participating countries.

Recognizing that the success of the Biopesticide Project lies in its adaptability to emerging challenges, the sustainability plan places a strong emphasis on continuous improvement. The project team with the technical experts, government national study team and the private industries will be continued as a *“Asia-Pacific Biopesticide Community (ABC)”*. Opportunities and updates related to biopesticide promotion, MRL activities will be shared to the community beyond the project timeline. In addition, specific approaches under the engagement for the biopesticide community are added below:

Virtual community of practice

As part of the project’s sustainability plan, APAARI will be facilitating the virtual community of practice by interacting with its members, and other stakeholders, including the countries involved in the project and the industry.

Continued Networking and Collaboration

APAARI will persist the networking activities with ABC partner countries to monitor the use of project knowledge and new capacities, while mobilizing necessary resources to ensure replication and sustainability of the project’s outcomes. Regular quarterly interaction with member partners in Asia will further contribute to these efforts.

Private Sector Engagement

The involvement of growers, exporters, universities, government officials, and extension services will be maintained particularly through the ABC network to ensure their continuation of the project's mission. Each of these stakeholders is envisioned to share their interventions, processes and tools for enhancing the biopesticide sector, which is expected to build more trust and relationship among them.

International Support

The outputs from similar projects implemented in Africa (by ICGEB) and Latin America (by IICA) will be shared with the ABC network to facilitate cross-learning. Ongoing support from the Minor Use Foundation, The IR-4 Project, USDA, FAO, CropLife Asia, and participating pesticide manufacturers will provide technical guidance, regulatory harmonization, and training support, ensuring the project's long-term success.

Dissemination and Outreach

The dissemination plan includes the sharing of the results of the project through the different communication channels of APAARI, ICGEB, IICA, Minor Use Foundation, IR-4 Minor use portal, country-specific extension websites, and APAARI's YouTube channel. Materials will be shared on the STDF platform, and pamphlets in local languages will explain the importance of pesticide residues in trade. The materials produced through the Africa and Latin America project will be made available for the ABC and will be translated into local languages based on the resources available. Webinars targeting specific stakeholders, e.g. the academia, will be organized. Country partners would be invited as speakers to share their interventions related to biopesticide and pesticide MRL residue studies.

Professional Engagement

Results will be presented at higher-level meetings of APAARI, international and regional fora, and other professional gatherings, fostering collaboration and encouraging the adoption of biopesticide strategies in the broader market.

Targeted Engagements

All the future interventions post-project will include clearly identified target groups for each activity, including academia, government agencies, policymakers, farmers, NGOs, sub-regional bodies and private industries.

Blending of technical and functional capacity development model

The model of the blending of technical and functional capacity development that was developed by APAARI has been internationally recognized as adding value to highly technical and scientific projects in agriculture. APAARI will continue promoting and improving this model in future projects.

Country's Commitment to the Sustainability of the Project

The project team discussed with the participating countries their interest and sustainability plans to continue the project work to deliver the desired impact. Some of these sustainability measures include:

- Publishing the results from the residue mitigation studies in blogs, social media, and articles.
- Organizing a dissemination workshop about the mitigation studies to agricultural cooperatives, private sectors, biopesticide traders, and government agencies.
- Collaborating with local universities, research institutions, and international agencies to expand the research on MRLs establishment to other potential crops and biopesticide integration with chemical pesticides to improve the food safety aspects.
- Exploring funding models that can support the establishment of MRL for Cypermethrin on Basil.
- Working with relevant inter-departments (MAFF), and policymakers to update the MRLs.
- Developing a standardized guideline for biopesticide registration, testing and safety evaluation, as well as ensuring that these guidelines are adopted uniformly across the participating countries.
- Implementing communication campaigns to raise awareness about the benefits and appropriate usage of biopesticide among farmers and the public.

The APAARI project team reached out to various countries in the region with multiple follow-ups on the sustainability plan. The sustainability reports were received from three country partners and are added in Annex 21.

The project has met most of its objectives and has laid a strong foundation for sustainable agricultural practices in the participating countries (Annex 22). The list of participants for various events are included in Annex 23. The proposed sustainability plan, encompassing continued collaboration, private sector engagement, international support, and comprehensive dissemination, will help in the enduring impact of the project. Countries' commitment to the proposed plan is seen as vital in the process. This plan will be instrumental in maintaining the SSC and relationships built during the past years of project implementation.

List of Annexures

- Annex 1. Roles and responsibilities of Key personnel involved in the project activities
- Annex 2. Details of Project Steering Committee meetings
- Annex 3. Key personnel including all the Steering and Advisory Committee
- Annex 4A. PG 634 - Financial Statement
- Annex 4B.PG 634 - Budget vs Expenditure
- Annex 5. Project Logframe Matrix
- Annex 6. Residue Mitigation Study Summary with plot design
- Annex 7A. Field Supply checklist from the countries
- Annex 7B. Label information received from the countries
- Annex 8A. Field Training Synthesis
- Annex 8B. Field Training Phase 1 and 2 Presentations
- Annex 8C. Protocols and amendments developed under the project
- Annex 9A. Lab training-Synthesis along with feedbacks received
- Annex 9B. Presentation materials from Lab training
- Annex 9C. Detailed results of the residue mitigation studies
- Annex 9D. Environmental Impact Quotient Analysis
- Annex 10. Feedback Report on MRL training and KAP evaluation report
- Annex 11. Policy Brief Promoting the use of biopesticides for improved trade environment in Asia
- Annex 12. Biopesticide Manufacturing Workshop Training Materials
- Annex 13. Survey Report on MRL training and KAP evaluation
- Annex 14. Status of biopesticide regulation in Asia
- Annex 15. List of Biopesticides registered in participating countries
- Annex 16. Biopesticide Regulatory Workshop - Pre-workshop and KAP evaluations
- Annex 17. Project Knowledge Management Strategy
- Annex 18. Final report on national and regional farmers outreach activities from AFA
- Annex 19. Synthesis of APEC webinar and presentation
- Annex 20. Presentation from AGRICONNECT conference
- Annex 21. Responses from country on sustainability plan
- Annex 22. List of key activities under the project
- Annex 23. List of participants for various events conducted