Australian Government

Australian Centre for International Agricultural Research

Final report

Small research and development activity

project	**Plant Health – A major challenge to achieving sustainable ‘green’ agriculture in Myanmar**
project number	CROP/2019/103
date published	30 September 2021
prepared by	Sivapragasam Annamalai
co-authors/ contributors/ collaborators	George Rothschild[1], K.L. Heong[1], Monina Escalada[1]; Loke Wai Hong[2], Myint Thaung[2], Nwe Nwe Yin[3], Phyu Moe Hnin[4]; Nilar Aung[5] and Chan Fook Wing[6] [1]Consultant, [2]CABI Associate, [3]DAR, [4]YAU, [5]DoA [6]CABI-SEA
approved by	Eric Huttner Research Program Manager (Crops) ACIAR
final report number	FR2021-041
ISBN	978-1-922635-48-8
published by	ACIAR GPO Box 1571 Canberra ACT 2601 Australia

This publication is published by ACIAR ABN 34 864 955 427. Care is taken to ensure the accuracy of the information contained in this publication. However ACIAR cannot accept responsibility for the accuracy or completeness of the information or opinions contained in the publication. You should make your own enquiries before making decisions concerning your interests.

Contents

1 Acknowledgments

The project ‘Plant Health – A major challenge to achieving sustainable ‘green’ agriculture in Myanmar” was funded by the Australian Centre for International Agricultural Research (ACIAR) from April 2019 to mid-December 2020. We are deeply grateful for the financial support of ACIAR and the administrative/professional guidance of Dr. Eric Huttner, Research Program Manager (Crops), ACIAR. We are also grateful to CABI for supplementary funding and in-kind support to complement the ACIAR contributions.

We greatly appreciate the involvement of the key partners in Myanmar’s Ministry of Agriculture, Livestock and Irrigation (MoALI). Their technical assistance, contributions and cooperation throughout the duration of the project, especially during this COVID 19 pandemic, were pivotal towards delivering on the outputs/outcomes in the respective work packages. We would like to especially acknowledge Dr Tin Htut, the former Permanent Secretary of MoALI, for his inspiration and staunch support during the initial proposal development phase. We are also most grateful for the support and guidance from the heads of the departments involved in this project. In particular, we are deeply grateful to the Director Generals of the Department of Agriculture (DOA) and the Department of Agricultural Research (DAR), respectively, and to the Rector of Yezin Agricultural University (YAU). We also greatly appreciate the participation of the selected farmers in the various pilot demonstration trials. Their support and enthusiasm were highly beneficial and truly motivating factors

2 List of acronyms

AARRDAS - The Myanmar Alliance for Agricultural Research, Rural Development & Advisory Service

ACIAR – Australian Centre for International Agricultural Research

CABI – Centre for Agriculture and Biosciences International

DAR - Department of Agricultural Research

DoA – Department of Agriculture

FAO UN – Food and Agriculture Organisation, United Nations

FGD - Focus Group Discussions

GAP - Good Agricultural Practice

GEGG - Green Economy Green Growth

IFAD – International Fund for Agricultural Development

IPM - Integrated Pest Management

IRRI – International Rice Research Institute

LIFT – Livelihoods and Food Security Fund

M&E - Monitoring and Evaluation

MoALI - Ministry of Agriculture, Livestock and Irrigation

MRL - Maximum Residue Limit

NGOs – Non-Governmental Organisations

OECD – Organisation for Economic Co-operation and Development

PPD – Plant Protection Division

PPE - Personal Protective Equipment

SRA – Small Research and Development Activity

YAU – Yezin Agricultural University

3 Executive summary

Background and Objectives: In Myanmar, there is an emerging crisis due to farmers' indiscriminate pesticide use. The Centre for Agriculture and Biosciences International, in collaboration with the Department of Agriculture (viz. Plant Protection Division and Project Planning, Management and Evaluation Division), the Department of Agricultural Research and Yezin Agricultural University, implemented an ACIAR-funded Small Research Activity "Plant Health – A major challenge to achieving sustainable ‘green’ agriculture in Myanmar". The two key objectives were (1) To address the information gaps concerning the sustainable integrated management of rice and vegetable pests in Myanmar, with particular reference to pesticide use and misuse in the Ayeyarwady Delta and Central Dry Zone; and (2) To understand the current situation regarding the management of rice and vegetable pests in the Ayeyarwady Delta and Central Dry Zone, including pesticide use and misuse.

Significant findings: Overall, there were four sets of key findings/outputs: **(1)** Comprehensive review of literature and information gathering initiatives involving various stakeholders and international players which showed that: (i) information was fragmented and skewed, with significant lack of published information on pesticide residues; (ii) >50% of the registered pesticides are banned in the EU and low-cost unregistered products, including illegal imports and counterfeits, are widely used; (iii) there is lack of loss quantification due to pests in rice and vegetable production; and (iv) there is paucity of information, in particular, for vegetables, on effectiveness and costs of pesticides to address losses; **(2)** Baseline insect pests susceptibilities to major pesticides and the stability points were established for the two key pests (the rice brown planthopper and the diamondback moth); **(3)** Assessments of farmers' knowledge, attitude and practices, their key beliefs and the factors driving their pest management practices suggested that 90% of the insecticides used in rice were misuses which were driven by two belief items, viz. 'the rice crop at the younger stages needed insecticide protection' and ‘during the first 40 days after sowing, pesticides should be used to prevent pests and diseases’. Insecticides provided only marginal gains (about USD35 per ha per season) in rice. This scenario differed in vegetables; **(4)** Evaluation of the bio-based IPM approach in vegetables (cauliflower, summer and monsoon rice) clearly demonstrated the benefits of IPM when compared with farmers' conventional/Non IPM approach, as it reduced the number of insect pests and the number of sprays per season, yielded equivalent/higher yields and generated higher economic returns.

Potential impacts, conclusions and recommendations for future actions: Despite the relatively short project duration, impacts are evident from the economic (yield and net revenue), environmental (rice ecosystem health) and human health (safety) aspects. The ‘utility’ of the project was ‘galvanized’ for wider uptake through the Final Workshop (held virtually) involving regional partners working similarly in neighbouring countries. We concluded that Myanmar farmers can be much better off using less pesticides or even no synthetic chemical pesticides. Their economic expectations and livelihoods would be intact and their produce can have better chances of accessing wider markets. It is recommended that strategic structural reforms in plant protection services be done to professionalise plant protection. Future work should focus more on tackling the ‘people dimension’, especially in changing farmers' beliefs and their behavioural practices using a bio-based agroecosystem-centric approach supported by innovative knowledge tools/mobile apps/media rather than just transferring information/technologies per se. We also recommend that the pilot-scale bio-based IPM approach be further refined for scaling-up and scaling-out to underpin country-wide transformations from the current pesticide-driven system to one that caters more holistically to Myanmar's aspirations towards sustainability and ‘greening’ of its agricultural systems.

4 Background

Myanmar's agriculture, which aims to ensure food and nutritional security, enhance rural development and increase foreign exchange earnings through exports, is currently undergoing a major transformation, if not a paradigm shift. The sector is dominated by rice, but pulses have also become major export crops, and there is extensive vegetable and fruit production in rural and peri-urban areas. Rice remains at the forefront and there is potential for Myanmar to become a major global rice supplier as it was in the past. Based on a recent White Paper (WP) published in 2016 (*Vegetable Sector Acceleration Taskforce (VSAT); 2016; mimeograph)* entitled "Myanmar vegetable farmers are in business: accelerating the growth and development of the vegetable sector in Myanmar", the vegetable sector has also the potential to become one of the most important agricultural sub-sectors in terms of economic growth, rural employment and income generation.

Recent developments, such as the intensification of rice and vegetable production followed by increases in agro-inputs, such as pesticides, are increasingly posing challenges found elsewhere in Asia through periodic devastating crop losses due largely to outbreaks of insect pests (e.g. the brown planthopper) triggered by insecticide misuse (e.g. Heong et al., 2013; Heong *et a*l., 2015). Myanmar is seeing a rise in pesticide importations, which have been gradually increasing with about 20,000 tons of legal imports in 2018 compared to 11,000 tons in 2011. As of May 2019, the total number of registered pesticides in Myanmar was around 3767 compared to just a year before (May 2018) when the number stood at a total of 2748, and 309 active ingredients were granted pesticide registration licenses (*Source: https://agrochemical.chemlinked.com/chempedia/overview-pesticide-market-and-registration-myanmar*). This is about a 37% increase from the base 2018 figure as the pesticide business has become an easy entry for an increasing number of foreign players, lucrative and competitive market. This 'formal' market doesn't account for the extensive illegal cross-border trade in pesticides. Invariably, being the largest cultivated crop by acreage, rice receives most of these imported pesticides. Further, with pesticides available to farmers largely as Fast-Moving Consumer Goods (FMCGs) (Heong *et al*., 2013), and at competitive prices leading to a price war amongst producers, there is an emerging and increasing crisis due to pesticide misuse. In general, most of the rice farmers in Myanmar use chemical insecticides to control insect pests of rice. In an article written by Barlow (2016) entitled "IPM and pesticide safety a desperate need in Myanmar" (*Source: https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=20945)*, he highlights the fact that "chemical pesticide use in Myanmar is intensive with little regulation or guidance. Chemical contamination of agricultural crops is widespread and there have been increases in pesticide-related poisoning in rural communities – a health issue that is now a matter of major national concern in Myanmar (Suthep *et al*., 2016; Thein *et al*., 2012; Aung *et al.,* 2017). A recent study supported by ACIAR (Thi *et al* 2019) analysed pesticide residues in five vegetables grown in five villages and three markets in the Inle Lake region of Myanmar and found that over 75% of vegetables sampled from both villages and markets had detectable insecticide residues. The frequency of pesticide use varied from twice to 10 times in a season. On a regional scale, studies from the World Vegetable Center (Schreinemachers *et al*., 2015, 2017) exemplify the extent of the problem. The studies alluded to the fact that strong action will be needed to reduce Southeast Asia's reliance on pesticides.

There is an emerging crisis through pesticide misuse and given the fragmentation of existing knowledge (many local case studies or generic statistics at national level; refer to Work Package 2; Section 8 for more details), the need for robust data and evidence is imperative. Further, it is noted that the evidence of misuse is usually piecemeal and not well documented.

This project was implemented between 1st April 2019 and mid- December 2020. It is a contribution towards achieving 'green' agriculture in Myanmar, particularly, in rice and vegetables. The Small Research Activity (SRA) project was aligned with, and drew experiences from various other related Myanmar-based projects such as the ACIAR-DFAT's MyFarm program specifically with the MyFish project (https://mohinga.info/media/by_organisation/AU-5/by_activity/MM-FERD-ID7628/myanmar_policy_brief-web.pdf); CABI's 5-year old Plantwise program in Myanmar ((https://www.plantwise.org/) as well as the Myanmar Plant Health System Strategy (https://www.plantwise.org/Uploads/Plantwise/Mphss%20English.pdf) and the IFAD-funded FARM project (Costa *et al.,* 2020).

Against the above backdrop, and to help obtain the evidence required to achieve its objectives, the following questions were posed in the project: (i) What is the seasonal abundance of rice and vegetable pests and what losses can be attributed to them? (ii) What measures are presently used for controlling these pests, including chemical pesticides? (iii) What are the pesticide distribution/marketing systems, both legal and illegal (cross-border trade) with emphasis on compounds now used for controlling rice and vegetable pests? (iv) Have any adverse effects been noticed in terms of human or livestock health, or other non-targets such as fish in rice-fields or bees? (v) What roles do the public and private sectors play in research and extension for rice and vegetable production systems? (vi) What is the capacity of stakeholders to understand IPM principles in addressing pesticide use/misuse in the public and private sectors, including farmers and rural communities? (vii) What is the current level of training and other capacity-building initiatives on Integrated Pest Management (IPM) and responsible pesticide use?

Broader questions that also needed addressing included: (i) why do farmers do what they do?; (ii) whether the use of chemicals balances out farmers' return on investment based on his/her labour, especially when we are confronted with acute shortage of farm labour?; (iii) Is the problem of using chemicals one underpinning a social dilemma and not a technical one; (iv) whether the adoption of practices depends on the farmer's world view and on their livelihoods as they are faced with the imperatives of survival and economic well-being?; (v) whether the consequences of environment and safety are external to the farmer and that externalities need to be paid for; (vi) verifiable evidence of human poisoning attributable to pesticides; (vii) how adaptable and adoptable are the developed practices and (viii) what practical, actionable ideas and advice can the project provide to the government and farmers in Myanmar.

Given that this project falls in ACIAR's category of a 'Small Research Activity', it focused on selected issues of highest priority in assessing the challenges of pesticide use and misuse in Myanmar and options for addressing these. The SRA addressed a number of the above questions to develop preliminary recommendations on best practices which were evaluated on-farm by rice and vegetable farmers in the pilot areas. Building on the outcomes of the SRA and lessons learned from these pilot trials, a more comprehensive follow-on project is planned for up-scaling and out-scaling best practice outcomes at district and regional level. Focus on the fundamental ecological, biological control, baseline resistance and IPM studies etc. that form the basic pillars of sustainable pest management are still lacking in Myanmar. It is also recognized that there will be significant challenges in shifting the current paradigm of over-dependence on synthetic pesticides to the 'new normal' focused on bio-based and 'green' approaches that the project is initiating. Our preliminary baseline studies revealed that only about 20% of farmers were using any form of bio-based products, pointing to an uphill task in implementing these programs. Nevertheless, the project provided a window of hope and opportunity to explore a bio-based 'green' IPM approach for rice and vegetables that strengthens FAO's vision "Towards a Non-toxic South-East Asia".

5 Objectives

The main objective of this project was to address the issue of pesticide misuse and its associated challenges in Myanmar using rice and vegetables as exemplar crops in the Delta and Central Dry Zones. The project's overall goal was bench-marking farmers' current pest management practices and pesticide use/misuse in rice and vegetables in major production regions and develop practical recommendations and actions to address current and potential future problems.

Specifically, the two key objectives and associated activities of the project were:

<u>Objective 1</u>
To address the information gap concerning the sustainable integrated management of rice and vegetable pests in Myanmar – with particular reference to pesticide use and misuse in the Ayeyarwady Delta and Central Dry Zone.

<u>Related activities</u>
Develop and provide the foundation for an open-access resource on research outputs and other relevant information on: IPM, pesticide use/misuse, pesticide-residues in food, water and soil, public health impacts together with linked issues in Myanmar – all with special reference to rice and vegetable production in the Ayeyarwady Delta and Central Dry Zone.

Content will relate to: (i) the sustainable integrated management of rice and vegetable pests (including invertebrate and vertebrate pests - but diseases and weeds will not be emphasised at this stage in the SRA); (ii) pesticide use and misuse; (iii) food safety; (iv) soil and water pollution issues; (v) impacts on public health, and regulatory issues.

<u>Objective 2</u>
To understand the current situation regarding the management of rice and vegetable pests in the Ayeyarwady Delta and Central Dry Zone, including pesticide use and misuse.

<u>Related activities</u>
Develop a database as a benchmark from which subsequent changes attributed to the project can be measured (also drawing on data compiled through Objective 1). Identify priority areas linked to farmer practice, and research and development. The baseline data will by and large include the following aspects:

(i) Current status of rice and vegetable pests (insects, other invertebrate and vertebrate pests), in terms of seasonal abundance and losses attributable to them;
(ii) Control options, including chemical pesticides and biopesticides, being used to control these pests;
(iii) Current status of pesticide importation and distribution/marketing systems, both legal and illegal (including cross-border trade, focusing on compounds presently used to control rice and vegetable pests;
(iv) Current status of insecticide resistance: as funds are too limited in the SRA to undertake resistance tests of key species and compounds, this first benchmarking phase will draw on peer-reviewed resistance data on the same pests and insecticides from nearby countries including China, Thailand and Vietnam;
(v) Role of government and private sector (agro-dealerships etc) in providing advice on pest management to rice and vegetable producers;
(vi) Capacity (numbers, skills, gender sensitive) of personnel with understanding of ecological and IPM principles and pesticide use in rice and vegetable production,

emphasising government agencies, but also relevant private sector groups, including agro-dealers;

(vii) Level of understanding of IPM principles amongst farmers and rural communities with special reference to those producing rice and vegetables;

(viii) Assessing the current extent of training and other capacity-building initiatives on IPM and pesticide use in rice and vegetables; including the adoption of digital tools (e.g. recent launch by PPD/MoALI of ‘Plant Protection App’) for use by farmers and other stakeholders.

6 Methodology

6.1 Approach

As a benchmarking scoping project, the approach adopted overall was consultative and inclusive, emphasising full participation by all stakeholders in the work so that activities are tailored to their needs and priorities, and that as stakeholders they have full ownership of the outputs and outcomes. Only the preliminary desktop review of the published literature will be largely limited to project personnel. Unfortunately, in year 2, the project was impacted to some extent by the Covid-19 pandemic with movement restrictions imposed on the consultants and the Project management team. Based on this scenario, communications between the country partners and the project team was maintained via regular zoom calls.

In terms of project management, CABI, through its Southeast Asia regional office led the project and had the overall responsibility for ensuring that deadlines for specific activities are met and reports completed and delivered. CABI’s Associate in Myanmar, Dr Myint Thaung, was the local Project Coordinator. The Project Planning, Management and Evaluation Division (PPME), Department of Agriculture (DOA), Ministry of Agriculture, Livestock and Irrigation (MOALI), Nay Pyi Taw, under the guidance of project consultants, Dr. K.L Heong and Dr. Monina Escalada, played a prominent role in Work Package 3 (WP3) especially in organising the baseline surveys with farmers, farmer associations, and other Myanmar contacts, as well as providing data from its very extensive knowledge base. The Department of Agricultural Research (DAR), under the guidance of the project team led by Dr. Myint Thaung and Dr. Sivapragasam organized and implemented the IPM pilot trials in Work Package 4 (WP4). Given their extensive background and expertise, both PPME and DAR also helped coordinate and organise focus group meetings and other consultations and workshops that were crucial.

It was anticipated at the onset of the project that the key agencies such as DAR and PPME in MoALI will collaborate with The Myanmar Alliance for Agricultural Research, Rural Development & Advisory Service (AARRDAS) to be the main channel for translating the project’s outputs and outcomes into practical actions with farmers and other stakeholders to implement best practices in integrated pest management in order to reduce pesticide misuse in rice and vegetable production. However, AARRDAS had problems of registration as an NGO and therefore could not directly participate in the project. The project team then decided to work with the extension arms of the Department of Agriculture (DOA) and the Department of Agricultural Research (DAR) under MOALI to meet this purpose.

For the ease of implementation, the project was divided into work packages (see below), each addressing a specific component of the project towards achieving the two main objectives (outlined in Section 5 above). Under each work package, activities were carried out by assigned project personnel and led by work package leader(s).

(i) Work package 1 (WP1): Project Initiation/Background preparation
(ii) Work package 2 (WP2): Comprehensive literature review and information gathering (Objective 1)
(iii) Work package 3 (WP3): Situational analysis of pest status, pest management methods and pesticide trade (Objective 2)
(iv) Work package 4 (WP4): Develop improved practices and pilot field trials (Objective 2)
(v) Work package 5 (WP5): Project implementation and completion

The following methodologies were used in the project:

(1) Desk review
(2) Face-to-face (F2F) meetings/interviews
(3) Focus group discussions (FGDs)
(4) Stakeholder discussions/meetings and Key Informant interviews (KIIs)
(5) Baseline and structured surveys and interviews
(6) Laboratory training and assessments
(7) Pilot field trials:
(8) Farmer field-based trainings
(9) Planning, Review and Consultation Meetings/Workshops
(10) Monitoring and Evaluation
(11) Participatory impact pathway
(12) World Café approach

Which, when and how each of the above methodologies were used is illustrated in the specific WPs below:

6.2 Work package 1 Project Initiation/Background preparation

This WP used methodology 9 and 10 for the inception workshop in assembling the project team, planning and execution of the inception workshop and discussing to finalise the project's other work packages (activities, personnel, timelines and deliverables). The activities undertaken fell under 1.1 Project initiation in the project work plan. Specifically, the activities were to: (i) Assemble and commission the project team; (ii) Planning of Inception Meeting; (iii) Conduct consultation workshop and (iv) Review and finalise work packages.

The inception meeting report and workshop can be found on the project website link below: http://www.planthealthmyanmar.org/docs/InceptionMtg/SRAInceptionReport.pdf

6.3 Work package 2 Comprehensive literature review and information gathering (Objective 1)

Work package 2 used methodologies 1, 2 and 4. It focused on two activities: (i) Comprehensive 'desktop' review of published and unpublished ('grey') literature on each of the issues listed in the Objective 2 and (ii) Gather additional information through interviews with sources of literature in (i) above.

Desk review: a comprehensive desktop review of both published and unpublished literature on issues identified under Objective 2 of the project, WP2 obtained and gathered information from various sources in Myanmar including government institutions, universities, the private sectors, civil society organisations and outlets and the internet. The international sources of the information were obtained through the websites and publications of bilateral donor agencies from OECD and other countries as well as multilateral development banks, foundations and other international bodies.

F2F and Interviews with stakeholders: The project gathered additional information through F2F interviews and other means of communication. This was done through direct or phone interviews and email exchanges with Myanmar and international stakeholders. Those interviewed included selected Union Ministers, Deputy Union Ministers, regional ministers and senior advisers, permanent secretaries, departmental directors, agriculture/trade counsellors, development partners, NGOs, and representatives from the private sector, including industry groups and chambers of commerce and commodity associations.

6.4 Work package 3 Situational analysis of pest status, pest management methods and pesticide trade (Objective 2)

Work package 3 used methodologies 2, 3, 5, 6 and 11 that dealt with understanding the current situation of pest incidences, incurred losses, pest management practices and pesticide use and misuse, through the use of assessment techniques such as structured interviews, focus group discussions (FGDs) and baseline surveys**.** Other activities to better understand the pesticide trade and IPM practices included elucidating the situation of pesticide trade and other trade pathways, identification of public and private sector entities and assessing their capacity and knowledge on rational pesticide use and IPM, identifying training and capacity building programmes for the same and conducting training and baseline assessment of insecticide resistance for two key insect pests viz., the brown planthopper and the diamondback moth – please see below

Laboratory training: The Toxicology training in YAU was conducted from 19th August to 21st August 2019 with the objective to obtain the knowledge on the principles of toxicological research and analyses. The activities in the training included: 1. Principles of toxicological research and analyses 2. Importance of chemical dilutions 3. Insecticide mode of actions 4. Topical application - Importance of precise lab techniques 5. Insect culture and insecticide preparations, dosages, observations 6. Probit analysis (Finney, 1952) and interpretation of results 7. Laboratory practices. A total of 7 students (1 Ph.D and 6 M.Sc.) participated and gained from this training which is considered a ‘first’ in Myanmar.

Survey assessment: For the survey assessment, a Participatory Impact Pathway (PIP) approach was adopted which rather than being solely technology-oriented is people-centred (including farmers/farmer associations, processors, extensionists, agro-dealers, researchers, NGOs, CSOs, decision makers from relevant ministries). Steps in the PIP, firstly, engaged with ‘next users’, initially represented by the MOALI -YAU teams undertaking the structured base-line surveys, supported by the external advisers. The next steps in PIP was the analyses of the survey results and then synthesis of the outputs which was again participatory and involved consultation with key stakeholders in order to develop preliminary recommendations for best practices for IPM/ecological engineering in rice and vegetable production that avoid pesticide misuse. The final stage of the PIP was to disseminate these practices to rice and vegetable farmers and to other key stakeholders in the value chain, including input suppliers, was largely driven by MOALI which has proven linkages with all stakeholders that are also aligned with Myanmar Government policies and regulatory frameworks.

Another introduction to the theoretical background behind farmer surveys was *The Theory of Planned Behaviour* (TPB) (e.g. Escalada *et al*., 2006). This has been used in pest management to understand farmers’ decision making. Often farmers’ attitudes are predicted by beliefs about spraying (e.g. “spraying will increase yields”), insects (e.g. “all insects are bad”) and fear of loss (e.g. “with no sprays I will lose 50% of my yield”). The TPB asserts that the intention to behave in a particular manner is formed by the individual’s attitude toward performing the behaviour, the social pressure they feel to perform the behaviour and their perception of the control they have in performing the behaviour. The theory has been applied to determine which factors influence individuals to act in certain ways and to identify better ways of effectively communicating development-related messages.

Situational analysis and focus group discussions (Appendix 1): The WP3 project team designed and developed survey questionnaires on farmers' pest management practices (rice and vegetable farmers), pesticide residues and health issues related to pesticide use. Initially, a situational analysis and Focus Group Discussions (FGDs) were conducted to gain insights that were then used to improve the survey questionnaire especially about farmers' pest management practices as well as the pesticides they use, seeking to understand their current beliefs and practices as these practices directly influence their decisions. The results were used as basis for identifying knowledge and attitude gaps that needed to be addressed in future interventions. In total, six (6) FGDs were conducted between August 17 and 19, 2019. Three FGDs were carried out in Nyaung Shwe Township in Shan State, and another three in Lewe Township in Nay Pyi Taw. A total of 69 farmers participated in the focus groups held in villages where farmers were growing: 1) Mainly rice - Intein Village and Kawtmaungnge Village, both in Nyaung Shwe Township; 2) Vegetables - Ngaphaechaung Village, Nyaung Shwe Township and Thaekawlay Village, Lewe Township; and 3) Rice and vegetables - Khayankaing Village and Thaekawgyi Village, both in Lewe Township.

Farmer surveys, including pre-test and analysis of results: Using information gathered from the FGDs, a structured questionnaire was refined. The interviewer orientation was conducted involving 10 DOA Project Planning staff. During the orientation, the survey team went through each questionnaire item and clarified those that might likely be misinterpreted by farmers, particularly the belief statements and attitude scale. The translated questionnaire was then tried out on 18 farmers in Thaekawgyi Village, Lewe Township, Nay Pyi Taw. The questionnaire pre-test suggested improvements in the wording of the survey questions and the units of measure used, e.g., basket/acre for t/ha. The farmer survey was undertaken in three regions (Nay Pyi Taw, Shan State and Yangon) and in the respective townships with a total of 450 farmers, distributed as follows: 1- farmers who grow rice only, 2- farmers who grow rice and vegetables, and 3- farmers who grow vegetables only. When the survey field work was completed, all questionnaire data were encoded in Excel© spreadsheet for processing and analysis. The project team prepared the survey codebook and a data entry worksheet which was used by the Myanmar research collaborator (Nilar Aung) to facilitate encoding and minimize errors.

6.5 Work package Develop improved practices and pilot field trial (Objective 2)

Work package 4 used methodologies 3, 4, 5 7, 8 and 9. It entailed developing recommendations on improved/best practices after consultation with focus groups and stakeholders, and from pilot field trials in rice and vegetables. The stakeholders consulted came from the following groups: key private sector pesticide input suppliers/distributors; government agencies e.g. Occupational and Environmental Health Division, Ministry of Health, Plant Protection Division, Department of Agriculture; international organisations (e.g. ACIAR- IRRI MyFish project) and NGOs.

Stakeholder consultations and Key informant interviews: The consultation produced outputs that were based on rationalising the use of pesticides within the context of Good Agricultural Practice (GAP); the use of biopesticides or 'green' technologies towards quality, safe and sustainable production practices for rice and vegetables; understanding farmers' behaviours, perceptions and challenges faced pertaining to production issues and use of pesticides; need to strengthen the government's role in terms of product registration, governance and policy-based incentives for using less pesticides and increase the use of 'green' technologies to manage pests and diseases.

Baseline surveys: Before the pilot field trials, two rapid baseline surveys with farmers who grew rice and vegetables from Nay Pyi Taw and Yangon regions, respectively, were carried out (refer Appendix 3). The vegetable study involved 21 farmers who grew cabbage and cauliflower and 17 farmers who grew okra. Demographic and other socio-economic data were collected to have a better understanding of the farmers' background and current situation as well as to set the pre-IPM baseline parameters. The study also investigated the cropping patterns, socio-economic characteristics of the farmers, gender composition, constraints faced by the farmers, knowledge sources from which farmers obtain advice and major pests of the vegetables grown. A similar study was conducted on 20 rice farmers from Seinsarpin village and similar data were collected as for the vegetables. Additional data included rice varieties grown and farmers' perception on these varieties.

Pilot trials with selected farmers: Following the baseline survey results, participatory bio-based integrated pest management (IPM) pilot field trials of vegetables (e.g. cauliflower as model crop) and rice (summer and monsoon season) were conducted. The pilot field trials were meant to demonstrate the possibility and potential to grow vegetables and rice with the proper and judicious use of pesticides, incorporating bio-based inputs, such as biological, physical and cultural control measures, for managing pests and diseases. The major objective of the trials was thus to demonstrate the IPM approach versus the non IPM (NIPM) approach based on farmers' current practices to growing vegetables and rice. Essentially, IPM practices/packages were developed/refined and implemented with data obtained from the baseline surveys in the main production areas. Assessments using key indicators such as pesticide use, overall cost and yield data and net revenue were computed from the trials and with future IPM practices adoption data from farmer surveys. Potential factors affecting IPM adoption by men and women farmers, changes in pesticide use, economic benefits (by gender and level of well-being), etc. were also briefly assessed.

M & E, awareness and communication: An appropriate monitoring and evaluation (M&E), and to some extent, awareness and communication aspects formed an integral part of the project to monitor and effectively communicate progress in the diverse but inter-dependent and integrated elements of this project. Monitoring and evaluation were carried out in the pre and post-IPM trials. In assessing impacts of IPM Interventions, the effects of IPM practices/package versus 'farmer-based conventional practices' as the control were measured and the effects were added up over the target period. The evaluations were multi-disciplinary and began at the start of the IPM program (pre-IPM test) by doing baseline surveys, crop-pest monitoring and participatory assessments to prioritize research.

Trainings: The following communication and awareness activities, focused on farmers, were conducted to support the eventual adoption of the various bio-based technologies and approaches used in the IPM pilot trial. These included awareness on: (i) IPM and related components, targeting mostly farmers and extension agents engaged with the project; (ii) Basics of IPM and its use plus conservation of natural enemies in rice fields; (iii) Use of *Trichogramma japonicum* against rice stemborers and leaf-folders; (iv) Ecological engineering to encourage agro-biodiversity and reduce pesticide use in rice fields; (v) Use of neem and other bio-based products and their benefits for rice and vegetable production (courtesy of Marlarmyaing Public Co., Ltd. Nay Pyi Taw, a member of the project team); and (vi) Integration of rice-fish-pesticide use in the field conducted by the Rice-Fish Project with support from Mr. Than Aye, a member of the project team (ACIAR Project No. FIS/2016/135. The project also introduced an on-line version of web-based tools on Pest and Disease management to project partners. This latter tool was developed in collaboration between Plant Protection Division (PPD)-Department of Agriculture (DoA) and CABI's Plantwise program.

6.6 Work package 5 Project implementation and completion

Work package 5 used methodologies 9 and 10 focusing was on project implementation and completion entailing the drafting of progress reports, organising the mid-term review and final project workshops and the synthesis of the final report for submission to ACIAR. Similar to work package 1, this one was also led by CABI.

Planning, Review and Consultation Meetings/workshops: The progress reports were finalised and completed after CABI solicited inputs from all work package leaders, summarised the progress made up to that point, tabulating outputs against activity and reporting on the status for easier reviewing and reading by ACIAR.

The various workshops were organised through CABI's associate in Myanmar leveraging on our excellent relationships with key ministries and stakeholders thereby ensuring that the SRA activities had good visibility and exposure in Myanmar. Our local counterparts working with CABI's associate provided crucial logistics and operational support as well as secretarial services for the workshop.

During the mid-term project review, we also employed the **World Café approach** (Methodology No. 12) (http://www.theworldcafe.com/key-concepts-resources/world-cafe-method/) based on three themes. The themes were: Theme 1: Partner country development issues and priorities with regards to pesticide use in the future; (Theme 2: Key research questions and activities related to pesticides and Theme 3: Key impacts, research approaches and partnerships.

The meeting participants were assigned to three groups and the groups moved from one theme to another after spending 20 minutes with the previous one. The theme leader stayed with the same theme to brief on the findings from the previous group. He/she briefed the next group of participants on the outputs from the previous group and solicited further inputs, ideas and comments from the new group. The group discussion was an exercise to stimulate some thinking on significant issues and priorities concerning the pesticide problem currently and moving forward towards the future. It helped to set the stage for deeper thinking and deliberations to tease out a more comprehensive list for concerted planning and action as there could be more issues and categories that can be further identified.

Details of the outputs of the World Café Approach are provided in the mid-term report: http://www.planthealthmyanmar.org/docs/MidTermMtg/SRAMidtermReport.pdf

Internal and external project communications: CABI developed a dedicated project website for communication amongst project partners (http://www.planthealthmyanmar.org/index.aspx). The website held reports and documentation for all project activities (password-protected section) and provided updates and highlights of all activities (public access).

The website features a blogging mini-site as well for project partners to provide writeups of themes and topics of interest from the project. The blog website address is: http://www.planthealthmyanmar.org/blog.asp. The website and backend were developed using Microsoft Active Server Pages (ASP) technologies.

7 Achievements against activities and outputs / milestones

The project achieved its objectives through implementation of the following:

1. **Assigning work packages:** The project allocated key project activities into work packages, each addressing a specific component of the project towards achieving the two main objectives. Each work package was led by a work package leader(s) and activities were carried out by assigned project personnel working closely with the work package leader(s). Several of the project personnel also assisted the Project Leader across the work packages to ensure tasks and reports were completed well and delivered on time.

    - Work package 1 (WP1): Project Initiation/Background preparation led by Dr. Sivapragasam of CABI-SEA and CABI Associate Dr. Loke Wai Hong;
    - Work package 2 (WP2): Comprehensive literature review and information gathering (Objective 1) led by consultant, Dr. George Rothschild;
    - Work package 3 (WP3): Situational analysis of pest status, pest management methods and pesticide trade (Objective 2) jointly led by consultants, Drs K.L. Heong and Monina Escalada
    - Work package 4 (WP4): Develop improved practices and pilot field trials (Objective 2) led by national partners Drs. Nwe Nwe Yin and Myanmar CABI Associates, Dr. Myint Thaung / Dr. Loke Wai Hong and Dr. Sivapragasam of CABI-SEA;
    - Work package 5 (WP5): Project implementation and completion led by Dr. Sivapragasam and Chan Fook Wing of CABI-SEA.

2. **Devising participatory step-wise work plan:** The work plan was drawn up based on the project objectives and, related activities were agreed via participatory discussions with the WP leader, stakeholders in the government, international agencies, NGOs and private sectors during the inception meeting. The work plan also included planning and review workshops to select potential cropping systems and locations; identify key questions for the survey pre-test; review the practicalities of activities; coordinating the implementing organizations and members of the project team etc. To do this, some aspects of Outcome Mapping (OM) principles were used by the project team. OM principles were also used to define realistic objectives with milestones and indicators against which progress was monitored. The overall framework included extension pathways (e.g. training and awareness initiatives) to help ensure that the research outputs and potential outcomes would lead to verifiable changes in practice in Myanmar with regards to IPM uptake and reduction in pesticide use and misuse.

    The summary of the activities, outputs and milestones reached, completion dates and additional comments attributed to each activity are provided in the Table as follows:

Objective 1: Identify and address gaps in knowledge necessary to develop sustainable integrated management of pests in rice and vegetables – including the challenge of pesticide use and misuse in Myanmar.

No.	Activity	Outputs/ milestones	Completion dates	Comments
1.1	Project initiation	Agreement on schedule of activities and timing	Mid-May 2019	Preliminary inception meeting of project personnel and stakeholders well accomplished
1.2	Comprehensive 'desktop' review of published and unpublished ('grey') literature on each of the issues (i-viii) listed in Section 3.1 Objective 2	Report and open-access dataset based on results of review and feedback from communications – see 2.3 below	March to June 2019	Undertook review of each of the issues (i-viii) listed in Section 3.1 of the Project Document (PD); Objective 2 successfully
1.3	Gather additional information through interviews with sources of literature in 1.2 above	Updated report based on outcomes of additional interviews	July 2019	Communicated (email etc) and/or meet with these individuals/agencies succinctly
Objective 2: To understand the current situation regarding pest incidence, losses incurred and practices to manage these pests in major rice and vegetable production areas in Myanmar.				
2.1.	Assess status of pest abundance and damage in rice and vegetables	Completed review report on status of pests /damage in rice and vegetables	May to Oct 2019	Effectively conducted using well-established and proven behavioural/ statistically valid techniques, conducting structured interviews with farmers, agro-dealers, and key contacts at MoALI, YAU, and others
2.2.	Assess control methods presently used against these pests	Completed review report on current control methods	May to Sept 2019	Method as in 2.I. above. Structured interviews with farmers (accepted minimum of 300/sample), agrodealers, representatives from MoALI (PPD), Min. of Commerce

				and others carried out as well.
2.3.	Assess current status of pesticide importation and distribution/marketing systems, both legal and illegal (especially cross-border)	Completed review report on pesticide imports, marketing, distribution (some details are also provided in Appendix 1 and 2)	May to Sept 2019	Method as 2.I. above. Structured interviews with farmers (accepted minimum of 300/sample), agrodealers, representatives from MoALI (PPD), Min. of Commerce and others carried out as well.
2.4.	Identify roles of public and private sectors (agro-dealerships etc) in extension on IPM and appropriate pesticide use for rice and vegetable production	Completed review report on extension approaches for IPM and pesticide use	November, 2019	Met and communicated remotely with those involved in extension /communication – MoALI (Ag. Extension Div.; PPD), local Universities, local and international NGOs, agro-dealers and others
2.5.	Assess capacity (numbers/skills/gender) of individuals /agencies with knowledge of IPM and pesticide use/misuse in public and private sectors, and of farmers and rural communities	Completed review report on level of knowledge of IPM, pesticide use across all stakeholder groups	Oct 2019	Collated and analysed outputs from tasks 2.1-2.2 & 2.4-2.5; conducted additional interviews with others as required
2.6.	Identify current training and other capacity-building programs on IPM and pesticide use, and use of digital tools (Apps)	Completed review report on status of capacity-building programs on IPM and pesticides, and use of digital tools	May to October 2019	Compiled clearly information acquired in tasks 2.4-2.5
2.7.	Analysis and synthesis of all outputs from base-line surveys	Completed first draft of analysis and synthesis of	Feb 2020	Undertook analysis and synthesis of all

		all findings from base-line surveys		outputs from tasks 2.1-2.6
2.8.	Consultations with focus groups from each stakeholder category on survey outputs to develop recommendations for improved practices	Completed report on outputs from focus group meetings and combined consultations with agreed recommendations for improved farmers’ practices	Mar 2020	Arranged and conducted workshops/focus group consultations with each stakeholder group, followed by a final consultation for all groups together
2.9.	Pilot field trials by PPD-MoALI on bio-based ‘green’ IPM options in vegetables and in summer and monsoon rice	Comprehensive analyses and report with tentative recommendations for farmers’ best practices.	Nov. 2019 to Nov 2020	Designed pilot trials to assess options for cauliflower and rice (summer and monsoon) crops comparing IPM with farmer conventional practices
3.0	Final International Meeting and Regional Workshop	Complete Final Meeting and Workshop Report with recommendations for follow-up project activities for Phase 2	Nov. 2020	International workshop effectively held via Zoom to share information and experiences on project activities and pesticide use/misuse with regional countries such as Thailand, Vietnam, Cambodia, Laos, Philippines and south China.

3. **Collaborating with in-country partners:** CABI through its SE Asia Regional Office led the project and had overall responsibility for ensuring that deadlines for specific activities are met and reports completed and delivered well. On the ground, the project initially engaged with Dr Tin Htut, the former Permanent Secretary of MOALI and his NGO, The Myanmar Alliance for Agricultural Research, Rural Development & Advisory Service (AARRDAS), which was envisaged to be a strategic engagement to leverage on Dr. Tin Htut’s overseas networks and access to other relevant Ministries including Ministry of Commerce, Ministry of Health and Ministry of Natural Resources and Environment, as well as with national universities especially YAU. However, this arrangement did not materialize as there were issues with the registration of AARDAS. Following this development, the project enhanced its engagement with MOALI’s Department of Agricultural Research (DAR), the Plant Protection Division (PPD) under

the Department of Agriculture Department (DOA), the Department of Agricultural Extension (DOAE) and Department of Planning (DoP) to play significant roles in the SRA in organising the baseline surveys with farmers, farmer associations, and other Myanmar contacts, as well as providing data from their very extensive knowledge base, and providing crucial in-country support for the WP4 pilot trials especially under the existing COVID-19 scenario. Given their background expertise, PPME (DoP) and DAR also helped coordinate and organise the focus group meetings and other consultations and workshops that were crucial to the SRA to achieve its objectives. DAR and DOA (PPD), with their respective extension arms, were also the main channel for translating the SRA's outputs and outcomes into practical actions for farmers and other stakeholders to implement best practices in integrated pest management to reduce pesticide misuse in rice and vegetable production.

In addition to the national public sector partners, the project had links and support of two key private sector inputs (e.g. pesticides and biopesticides) suppliers, namely, AWBA Group based in Yangon and Marlarmyaing Public Company Ltd Pesticide (Stewardship program) based in Nay Pyi Taw. The project also linked and shared experiences with U Than Aye who is a consultant with International Rice Research Institute (IRRI) and WorldFish which are jointly implementing the ACIAR project FIS-2016-135 on Rice-Fish systems that is exploring fish toxicity issues related to pesticides used in rice cropping.

4. **Communicating project outputs:** Project based discussions were done mainly via regular Zoom meetings amongst project partners, especially due to the current Covid-19 scenario whereby inter-country and inter-regional travel within countries are not allowed. As indicated earlier, CABI also developed a dedicated project website for communication amongst project partners (http://www.planthealthmyanmar.org). This website holds reports and documentation for all project activities (password-protected section) and provides updates and highlights of all activities (public access). The website features a blogging mini-site as well for project partners to provide writeups of themes and topics of interest from the project. The blog website address is: http://planthealthmyanmar.org/blog.asp. The website and backend were developed using Microsoft Active Server Pages (ASP) technologies.

8 Key results and discussions

8.1 Comprehensive literature review and information gathering (WP2)

In work package 2, to provide the background to the baseline surveys and other activities in WP3 and WP4 and to undertake the analysis of the project's findings, a total of 129 past and current published and 'grey' literature were reviewed. This was complemented by a total of 74 information gathering (direct and indirect) initiatives with various stakeholders in Myanmar and with 22 international players including donors, private sectors and non-governmental organizations.

The key findings:

Based on literature search, out of the 16 categories of information available, the four highest were: (i) Current use/misuse - pesticides in Myanmar rice and vegetable production (45 items); (ii) Pesticide impacts on human health, non-targets and the environment (44); (iii) Regulatory systems and policies on pesticides in Myanmar, and compliance (39); (iv) Current understanding of pesticide use and misuse by Myanmar farmers, agrochemical dealers and others in the private sector, NGOs and civil society/ consumers etc (37).

The four lowest categories of available information were on: (i) Organic agriculture and horticulture in Myanmar (7); (ii) Losses due to pests in Myanmar rice and vegetables production, effectiveness and costs of pesticides to address losses (5) (information was highly skewed towards rice with little information on vegetables); (iii) pesticide residues in food crops produced for domestic and export markets (4) and (iv) Current methods of disposal of waste pesticides and containers (3). **The study underscored the serious lack of published information on pesticide residues in food crops in Myanmar**.

The study also revealed a **high number of pesticides approved for use in Myanmar are currently banned in the European Union (EU)**. For insecticides, these include acetamiprid, acephate, carbaryl, carbofuran, carbosulfan, dimethoate, imidachloprid, profenofos, propapargite, temephos and thiamethoxam. For fungicides, the list includes benomyl, carbendazim, chlorfenapyr, chlorothalonil, hexaconazole, kasugamycin, mancozeb, propiconazole and thiophanate-methyl. Overall, almost 60% of the fungicides registered are banned in the EU. For herbicides, the list includes imazethapyr and overall almost 17% of the registered herbicides are banned for use in the EU. Kasugamycin (an aminoglycoside antibiotic) is used as a fungicide for rice disease (false smut; blast) control. It was noted that >50% of the registered pesticides are banned in the EU and that cheap unregistered products, including illegal imports and counterfeits are widely used.

The findings were examined from four aspects: (i) Pesticide status; (ii) Markets, (iii) Farmer knowledge and (iv) Education and training. Several recommendations were suggested: (a) Need for appropriate investments to ensure compliance through enforcement, penalties, licensing of pesticide dealers, etc.; (b) Increased participation of pesticide suppliers involving responsible stewardship, price incentives and local community stakeholder platforms; (c) Cognisance of consumer preference, especially with the burgeoning middle class, for healthy residue-free quality produce; (d) Enabling policy environment for enhanced availability and use of selective chemical pesticides and biopesticides. In this context, greater investment in DoA and other public extension services are needed and (e) Participatory community approach with sustainable support including from agri-dealers.

Key messages emerging from WP2 include the under-resourced public extension and crop extension services leading to **farmers obtaining plant health advice from untrained and often unlicensed shop keepers and small agri-dealers**. To counter this, there is a need to deploy more well-trained extension staff, ensure licensing and proper training of agri-dealers regarding selling of pesticides and giving advice on use, coupled with much stricter enforcement by the authorities. A "carrot and stick" approach to enforcement is proposed where failure to follow regulations is punished, but incentives are given for compliance. Alternatives to synthetic chemical pesticides must be strongly promoted based on the principles of integrated pest management (IPM) which includes the use of resistant crops, cultural controls, biopesticides and biological control. However, for this to happen, the government must introduce enabling policies that include proper training and the provision of incentives to persuade farmers to reduce pesticide usage and explore alternative methods for pest control. Data collection on legal and illegal pesticide imports, marketing and use by farmers undertaken in WP2 and WP3 must be further enhanced in order for robust regulatory policies to be developed and enforced. Particular emphasis has to be given to prevention of illegal cross-border trade in pesticides. Similarly, policies that address pesticide misuse from application to container disposal should be developed.

Another major element of WP2 has been the interacting with key stakeholders in Myanmar, especially decision makers to assist with the development of enabling policies to manage pesticide use in Myanmar, and to develop widespread acceptance of IPM in accordance with the National Plant Health Strategy and other national strategies. Those interviewed so far have included selected Union Ministers, Deputy Union Ministers, regional ministers and senior advisers, permanent secretaries, departmental directors, agriculture/trade counsellors, development partners, NGOs, and representatives from the private sector, including industry groups and chambers of commerce and commodity associations.

In conclusion, it can be asserted that the review of information gathered to date reaffirms the rationale for the SRA project, which is to try to maintain the historically relatively low rate of pesticide use in Myanmar compared to other countries in Asia and to avoid the often-catastrophic impacts of misuse. Concomitantly, if the current pesticide levels can be capped and then reduced, there is scope for Myanmar in future to exploit exports of GAP-related and potentially organic food produce that represent a rapidly growing global market. Additionally, non-organic produce is also accepted by EU and other developed country markets but with strict controls on levels of pesticide residues. Thus, Myanmar's relatively low usage of pesticides also provides favourable access opportunities to these markets.

The full report for this work package can be found on the project website link below:
http://www.planthealthmyanmar.org/docs/FinalReport/WP2LitReviewInfoGathering.pdf

8.2 Situational analysis of pest status, pest management methods and pesticide trade (WP3)

The two main activities conducted in work package 3 and their key findings were:

8.2.1 Assessments of insecticide susceptibilities of the Rice Brown Plant Hopper (BPH) and the Diamond Back Moth (DBM).

In this activity, the training of local scientists in toxicological research methods and conducting insecticide susceptibility assessments was successfully conducted. The course entailed the following: (i) Principles of toxicological research and analyses; (ii) Importance of chemical dilutions; (iii) Insecticide mode of actions (iv) Topical application - Importance of precise lab techniques; (v) Insect and insecticide preparations, dosages, observations; (vi) Probit analysis and interpretation of results and (vii) Lab practices. The course involved 1 PhD and 6 M.Sc. students.

The key outputs were:

(i) **Capacity development:** A toxicology training course to standardize precision procedures and methods on toxicological techniques, probit analysis and interpretation of the data was conducted with 7 post graduate students and a professor of YAU.

(ii) **Determining baselines for resistance**: We established a baseline for insect pests BPH and DBM susceptibilities to acephate, imidacloprid, chlorpyrifos and cypermethrin expressed in ug/g insect weight in Myanmar at stability points. Compared to some published data, there is little evidence to suggest insecticide resistance problems occur in Myanmar. Resistance of DBM larvae to chlorpyrifos compared to the Japanese susceptible strain was 403- to 552-fold in Tatkon and 403-fold in Pindaya. For acephate, the estimated resistance was 859- to 919- fold. However, the susceptible strain used had been reared in a laboratory for many generations and may be abnormally susceptible compared to field isolates. The results remain consistent with the conclusion of insecticides effectiveness in Myanmar. This work is providing a baseline for the 2 pests, useful for future research. In BPH, resistance stability point was reached after 3 generations. However, for DBM the larvae were more susceptible after being reared in the lab for a few generations. This observation is not normal and we could not explain this reversal. More investigations would be needed to better understand if this phenomenon was real or due to procedural errors.

Based on these findings, resistance monitoring might be useful in helping to develop management strategies of DBM as the use of insecticides remains the farmers' main control tactic. However, there is need for a plant protection system that can respond to and implement resistance management strategies such as switching insecticide active ingredients when resistance is detected. In order to do this Myanmar's Plant Protection Department needs to be restructured and be provided with the appropriate training to be able to meet future challenges. In the case of BPH, a secondary pest, monitoring and studying insecticide resistance is not required for management. The BPH pest is primarily induced by insecticide use and thus the main strategy for BPH management is to avoid insecticide use as much as possible, especially in the early crop stages. Conversely, future investments in increasing farmers' ecological literacy would be more beneficial.

The full details of the above study are found on the project website link below:
http://www.planthealthmyanmar.org/docs/FinalReport/AssessingInsecticideSusceptibility.pdf

8.2.2 The second activity was on the assessment of rice and vegetable farmers' knowledge, attitude and practices (KAP), key beliefs and factors driving their practices.

The key findings/outputs of the baseline survey that was conducted with 474 rice farmers and vegetable growers in Nay Pyi Taw, Shan State and Yangon regions in Myanmar are:

(i) The average age of respondents was 49, with less than 6 years education. Nearly two-fifths (39.9%) of the respondents were between 35 and 50 years old, followed by more than a third (36.5%) in the 51-66 bracket. About 10% were in the 67-82 age range. Respondents have been growing rice for an average of 26.6 years.

(ii) Farmers cultivated average rice areas ranging from 1.54 ha to 3.62 ha and reported yields ranged from 1.12 to 4.32 t/ha for both the summer and monsoon crops in 2018-2019. The yields were however not related to the number insecticide sprays farmers used. Farmers planted mostly introduced *indica* varieties in both summer and monsoon rice. More respondents used direct seeding than transplanting in crop establishment and relied mainly on rain for irrigation. Vegetable growers mostly relied on underground water using water pumps to irrigate their vegetable crops.

(iii) Farmers generally planted brassica, salad crops and solanaceous vegetables. Insect pests and diseases were farmers’ key constraints in vegetable production. Fungi, boll worm and army worm larvae, leaf-eating beetles were the worst pests in vegetables. Vegetable growers applied an average of 7.8 sprays per farmer per season. Insecticides were applied more often than fungicides. More than half of the respondents across the three regions (52.7%) reported that they had no pest damage in the 2018-2019 rice crop seasons.

(iv) The mean number of all pesticide sprays per farmer/season was 2.2; the lowest number of sprays was zero and the highest 8. Insecticide use had remained low with an average of 0.54 sprays/season compared to that from a 2012 survey (unpublished data) when the average was 0.62. Insecticides were first applied about 18 days after planting, with rice farmers groups withholding their first insecticide spray until about 21 days after planting and the rice and vegetable growers at 15 days after planting. At seedling and tillering stages, weeds were the main spray target of rice growers; at booting, it was stem borers, and at heading, rice ear bugs. Imidacloprid was applied at the seedling stage, and cypermethrin at tillering, booting and heading stages. Average cost of insecticides used for rice was USD35/ha/season, for vegetables, it was USD100/ha/season, significantly more than those who planted both rice and vegetables. By cross tabulating the insecticides that farmers used, and their intended targets and the timing of rice farmers’ sprays, we found that 90% of the insecticides were misuses.

(v) The index, Cronbach's alpha, used to assess the reliability of the belief index (0.710), was high. This indicates that the 12 items in the composite measure or belief index had a high internal consistency or reliability. Farmers’ numbers of insecticide sprays were positively related to the belief index and using Pratt’s index of importance, we found that the two belief items with highest importance driving farmers’ spray attitudes were that, the rice crops at the younger stages needed insecticide protection‘ and, during the first 40 days after sowing, pesticides should be used to prevent pests and diseases‘.

(vi) Insecticide misuse was found to be extremely high (90%). Farm yields and insecticide inputs were not related implying that productivity gain of Myanmar farmers from insecticide use is negligible or negative. A survey done in 2012 (Heong., pers. comm.) also showed that farmers’ insecticide applications had no significant effects on yields. Heavy use of secondary pest inducing insecticides such as cypermethrin, emamectin, chlorpyrifos and imidacloprid, would make Myanmar rice production vulnerable to brown planthopper outbreaks and a threat to future rice production. When we factor in externality costs such as human health, environmental damages and risks of getting secondary brown planthopper outbreaks, **Myanmar farmers would be much**

better off not using any insecticide at all in rice production and they will gain an extra profit of about USD 35 per ha per season.

(vii) Farmers' ecological illiteracy has deepened their dependency on insecticides. Important interventions to help wean rice farmers from insecticide use in rice production will need to include innovative training courses focusing on ecological principles such as plant compensation, secondary pest developments, naturally occurring biological control mechanisms and the impact of insecticides on them. It was stressed that ecology may be hard to teach, and for farmers to appreciate the principles, training courses need to be redesigned incorporating cognitive games, visuals, participatory approaches and methods for farmers to assess their benefits. This means that training should instead focus on modifying farmers' anchored beliefs and practices rather than merely imparting pest and pesticide knowledge. A list of ecological knowledge gaps and techniques to be used to enhance ecological literacy is provided in the report to be used to redesign farmer training (Wyckhuys *et al,* 2019).

(viii) In conclusion, it was cautioned that pesticides continue to be marketed as Fast Moving Consumer Goods (FMCGs) (Heong *et al*., 2013). Thus, there is a need to re-examine pesticide marketing regulations and supply chains and not just focusing on pesticide registrations. In that context, MoALI should ensure the stricter compliance to the FAO/WHO International Code of Conduct on the Distribution and Use of Pesticides by all signatory parties, including government, development agencies and the pesticide industry.

The full survey report can be found on the project website link below:
http://www.planthealthmyanmar.org/docs/2ndProgressReport/ReportPestMgtRiceVegFarmersWP3.pdf

8.3 Develop improved practices and conduct pilot field trials for vegetables and rice (WP4)

The objectives of this work package 4 are:

1. To develop recommendations on improved/best practices for rice and vegetable production after consultation with focus groups and stakeholders, and
2. To demonstrate feasibility of 'green' and IPM approaches based on pilot field trials in rice and vegetables

8.3.1 Objective 1 - To develop recommendations on improved/best practices for rice and vegetable production after consultation with focus groups and stakeholders

Baseline surveys

(i) Two baseline surveys were completed with a total of 21 farmers who grew cabbage and cauliflower and 17 farmers who grew okra in Nwe Yit Village and Yenan Chaung Village, respectively. Demographic and other socio-economic data were collected to have a better understanding of the farmers' background and situation before implementing the IPM trials (Appendix 3).

(ii) Pest and disease incidence ranked as the highest constraint posing serious challenges to the two groups of farmers. Other constraints cited were salinity, poor soil fertility, high temperature, flooding, high input costs, seed quality, lack of investment and unstable markets.

(iii) The major insect pests affecting cabbage and cauliflower were similar. These were diamondback moth, cabbage white butterfly, aphids and flea beetles. For okra, the main pests were armyworms, jassids and whiteflies. To control these pests, farmers resorted to spraying pesticides intensively (10 – 15 rounds in okra, 8 in cabbage and 10 in cauliflower). Early crop season and calendar spraying were practised. Farmers used a wide range of chemicals that were often used alternately and issues that were noted include spraying of inappropriate chemicals, wrong dosages, excessive application, inappropriate timing, and wrong combinations of chemicals.

(iv) A high proportion of cabbage and cauliflower farmers used other control measures such as tobacco leaf powder, yellow sticky traps, handpicking and neem products. Some okra farmers (about 40%) also used non-chemical methods similar to the cabbage growers and lime, ash and smoking as well

Key informant interviews

In the study to fulfil the 1st objective, the 4 key findings, based largely on Key Informant Interviews (KIIs) of key stakeholders in the private and public sectors, were:

(i) There is a need to rationalize tactical use of pesticides within the context of the GAP framework promoted by governments;

(ii) Use of biopesticides or so called 'green' technologies is not an option but a strategic imperative towards quality, safe and sustainable production practices for rice and vegetables;

(iii) Focus on the fundamental understanding and matching of farmer heuristic behaviour, perceptions and challenges faced relevant to production issues and use of pesticides; and

(iv) Strengthen government's role in terms of product registration, governance and policy-based incentives to encourage less use of pesticides and increase the use of 'green' technologies promoted by the government and private sectors.

8.3.2 Objective 2 - To demonstrate feasibility of 'green' and IPM approaches based on pilot field trials in rice and vegetables

Vegetables (cauliflower)

(i) The key insect pests recorded in both the IPM and non IPM (NIPM) plots were the diamondback moth (*Plutella xylostella*), aphid (*Myzus persicae*), flea beetle (*Phyllotreta cruciferae*) and white fly (*Bemisia tabaci*). Generally, higher populations of insects were seen for each key pest in the NIPM plot compared to the IPM plot.

(ii) On a trial plot of 0.2 acres each, the IPM plot received fewer insecticide sprays, i.e. 2 times against 5 times in the NIPM plot which contributed to the higher pest control costs in the NIPM (19.1%) compared to the IPM (8.2%) plot in terms of the total production costs.

(iii) The IPM plot was also superior (USD168.0 per 0.2 acre) compared to the NIPM plot (USD33.8 per 0.2 acre) in terms of overall profit.

(iv) Negligible residues were seen in the harvested produce in the IPM cauliflower compared to the NIPM cauliflower which exceeded (i.e. 0.75ppm) the MRL for cypermethrin (i.e. 0.5 ppm).

(v) This study provided encouraging evidence on the feasibility of the 'green'-based IPM approach in managing pests on cauliflower. However, for the scaling up and adoption of the IPM approach, there are certain obstacles and challenges that need to be addressed.

The IPM trial report for cauliflower can be found on the project website link below: http://www.planthealthmyanmar.org/docs/FinalReport/WP4IPMCauliflowerPests.pdf

Rice (Summer) (results based on per acre):

(i) In Seinsarpin, the key insect pests recorded were the brown planthopper (BPH) (*Nilaparvata lugens)*, green leafhopper (GLH) (*Nephotettix* spp) and yellow stem borer (YSB) (*Scirpophaga incertulas*). Some minor pests such as rice leaf folder, (*Cnaphalocrocis medinalis)*, gall midge (*Orseolia oryzae*), rice whorl maggot (*Hydrellia philippina*), stink bug (*Scotinophara* sp.) and white-back planthopper (*Sogatella furcivera*) were also observed. In Hmwabi, the key insect pests found were also BPH, GLH, the rice stem borer and thrips *(Baliothrips biformis*). However, their numbers, especially for BPH, were relatively lower compared to those in Seinsarpin.

(ii) In both locations, the natural enemies were generally low and comprised largely of predators (lady bird beetles, earwigs and spiders).

(iii) In the IPM trial, chemical insecticides were used 2x (against BPH) by one of the farmers (Daw Sein Htay in Seinsarpin) whereas each of the NIPM farmers in Seinsarpin and Hmawbi used pesticides only once (against BPH) over the summer crop season. The mean total pesticide costs for the two IPM farmers in each trial were USD8.25 (i.e. mean costs based on two farmers; IPM farmer 1: USD 0 costs (no insecticide use) and IPM 2 farmer with 2 sprays of insecticides which cost USDS16.5) and the NIPM farmers was USD9.75 (each incurred USD9.75 per acre) , and this translated to only 3.4% and 4.02% of the total costs of production in the IPM and NIPM trials, respectively. In terms of the bio-based products used, the % costs over the Gross Expenditure was 3.9% and 1.2%, respectively.

(iv) The average Gross Revenue (GR) was higher in the IPM trial (USD545.62) against NIPM (USD420.00), the Gross Expenditure (GE) (direct costs) was almost similar in the IPM trial (USD241.93) versus USD242.25 in the NIPM trial. The Net Revenue (NR) of USD274.16 was also 1.54x higher in the IPM trial compared to USD177.75 for the NIPM trial.

Rice (Monsoon) (results based on per acre basis)

(i) In the monsoon rice trial, the key insect pests were brown planthoppers, stemborers and leaf folders (at the vegetative phase) in both the IPM and non-IPM plots. False smut (*Ustilaginoidea virens*) incidence was low in the IPM plot but was severe in the NIPM plot.

(ii) Based on yellow trap catches, natural enemies recorded were mostly predators and there was not much difference in terms of their diversity in the IPM (mean: 10.0 different species) and NIPM (mean: 10.5 different species) plots.

(iii) In terms of the overall pesticide and non-pesticide costs, gross expenditure and gross net returns, on average, the NIPM crop was sprayed 8x with pesticides compared to the IPM crop over the crop season. The total costs of pesticides were US0.95 and USD27.9 for the IPM and NIPM, respectively.

(iv) About 7.5% of the Gross Expenditure (GE) was attributed to the cost of pesticides in NIPM (USD372). The costs of bio-based products (e.g. *Trichogramma japonicum*, neem seed cake (NSC); yellow sticky traps) and implementing eco-rational approaches (i.e. ecological engineering) were about 13% of total production costs (USD52.91 over USD394.5). Almost 78% of the costs of bio-based products in the IPM plot are attributed to the NSC application.

(v) The average Gross Revenue (GR) was only marginally higher in the IPM (USD741) against NIPM (USD729); the Gross Expenditure (direct costs) was USD394.5 (IPM) and USD372 (NIPM) and Net Revenue (NR) of USD346.5 and USD357.00 for IPM and NIPM, respectively. The slightly reduced mean Net Revenue (NR) in IPM was largely due to the high costs of NSC.

(vi) The study suggested that chemical pesticide applications in rice can be significantly reduced whilst keeping pests at tolerable levels and sustaining farmers' incomes. It also indicated the potential for the use of bio-based products such as the egg parasitic wasp of rice stemborers and leaffolders - *Trichogramma japonicum*, neem seed cake (NSC) and eco-rational approaches (ecological engineering). However, the uptake of bio-based products is currently very low (< 20% of farmers) in rice.

(vii) To expand the use of bio-based interventions, it is important to increase awareness amongst farmers and there is a need to implement larger scale trials to derive clear conclusions based on convincing experimental work and established facts. It is also anticipated that the current promising pilot-level bio-based IPM tactics should be further refined, packaged and scaled-up at the community level within the appropriate sustainable rice/vegetable platform or framework.

The full IPM trial report for rice can be found on the project website link below:
http://www.planthealthmyanmar.org/docs/FinalReport/WP4IPMRiceSeinsarpinHmawbiTownship.pdf

Communication and Awareness: In WP4, the following training and communication and awareness activities were conducted to support the eventual adoption of the various bio-based technologies and approaches used in the IPM pilot trial: (i) Awareness on IPM and related components: targeting mostly farmers and extension agents engaged with the project; (ii) Basics of IPM and its use plus conservation of natural enemies in rice fields; (iii) Use of *Trichogramma japonicum* against rice stemborers and leaf-folders; (iv) Ecological engineering to encourage agro-biodiversity and reduce pesticide use in rice fields; (v) Use of neem and other bio-based products and their benefits for rice and vegetable production (courtesy of Marlarmyaing Public Co., Ltd. Nay Pyi Taw, a member of the project team); (vi) Integration of rice-fish-pesticide use in the field as conducted by the IRRI- RiceFish Project with support from Mr. Than Aye, a member of the project team (ACIAR Project No. FIS/2016/135) and (vii) Scientific Communication for scientists and extension workers viz. producing online versions and web-based tools on Pest and Disease management – collaboration between PPD-DoA and CABI (Plantwise). For each training, about 20 -25 farmers usually participated with less than 20% making up female farmers.

8.4 Project implementation and completion (WP5)

8.4.1 Periodic progress reports

Two progress reports outlining progress made for all work packages have been finalised and submitted to ACIAR for review as per deliverables outlined in the project Gantt Chart

8.4.2 Mid-Term Review Workshop

The mid-term meeting was held from 10 – 11 February 2020 in Nay Pyi Taw, Myanmar.

The meeting report can be found at the following link:
http://www.planthealthmyanmar.org/docs/MidTermMtg/SRAMidtermReport.pdf

Key details and outcomes of the meeting were:

(i) The mid-term meeting was attended by 20 participants comprising international and local partner organisations, private sector suppliers, consultants, and the Program Manager for ACIAR; (ii) The meeting was held to assess, review and update the current findings of the various work packages with presentations on progress by work package leaders; (iii) Discussions were held around pesticide misuse and the need for research and evidence to support the current fragmented data that misuse is harmful both to human health and the environment, reduces crop yield, sustainability, and efficacy of alternatives to pesticides and other negative effects on farmers' livelihoods; (iv) Statements on pesticide related matters by national partners and collaborators on topics ranging from poisoning cases to legislation and regulation of highly hazardous pesticides; (v) Group discussions on current and future works plans using the 'World Cafe' approach under three thematic areas and (vi) Reporting on field visits to demonstration plots for rice and cauliflower under Work Package 4, YAU and DAR.

The following concluding remarks were underscored:

(i) The success of the project and its scale up will depend on whether the project will have some specific and transforming bio-based interventions to offer. In that context, there is a need for clear conclusions based on experimental work and established facts;

(ii) The data collected in the surveys or field/laboratory studies need to be backed-up with explanations to understand the underlying causes. This will also be a learning experience;

(iii)Need to prioritise what work must be done, for example, imperative to work with government and other influential people to try and restrict and, if possible, ban most, if not all, dangerous chemicals; also identify alternatives and other options; and

(iv) The current pilot phase of the project should produce interesting results for scale-up and present the narrative or the direction for the next larger phase of the project

8.4.3 Final Workshop

The final workshop was held on 11 November 2020 via Zoom teleconference due to the pandemic situation.

The meeting report can be found at the following link:
http://www.planthealthmyanmar.org/docs/FinalMtg/FinalMeeting&WorkshopReport.pdf

The key details and outcomes of the meeting were:

The final workshop was attended by 35 participants comprising international and local partner organisations, private sector, and key regional experts on IPM from various ministries in Myanmar. The meeting was held to deliberate on the findings of the various work packages with presentations on outputs and outcomes by work package leaders. Experiences on pesticide use/misuse, bio-based and 'green' approaches in rice and vegetable growing were shared by regional neighbour countries: Lao PDR, Cambodia, Thailand, Philippines, Vietnam and China with discussions around re-designing Myanmar's pest management strategy for the future.

The outcomes were:

(i) It is recognized that there will be significant challenges in transforming the current paradigm of over-dependence on synthetic pesticides to the 'New Normal' focused on bio-based approaches. The regional experiences presented in the meeting also showed evidence of this in other countries. Nevertheless, there is incentive for rice farmers that in Myanmar, the cultivation of rice is possible with little or no pesticides. The same argument, however, cannot be applied for vegetables, which unlike rice, are short-term in nature, smaller in scale (size-wise) and thus not amenable to the kind of ecological services that contribute to the balance in the rice ecosystem.

(ii) The scale-up of the current trial outputs will depend on whether there will be locally available bio-based interventions, especially those used in the project, will be available for larger scale implementation. Some of the evidence presented in the project experiences from regional experts revealed this to a major challenge.

(iii) With regard to the use of bio-based interventions, it is recognised that there is a need for clear conclusions based on convincing experimental work and established facts. This is based on the study which highlighted some of the challenges for farmers to adopt bio-based solutions in Myanmar. These include: Lack of knowledge amongst farmers (28%); Takes too much time (18%); Lack of supply (14%). Lack of government support (14%), Too expensive (12%; e.g. NSC), Too complicated (6%) Lack of knowledge on product and its application (4%) and Lack of extension materials (2%).

(iv) Recognizing and finding solutions to the challenges will bring Myanmar closer to the sustainable 'green' agriculture ideology expounded in the current study. Moving forward, the meeting agreed that the promising pilot-level bio-based IPM tactics that were trialled in the current phase of the project should be further refined, packaged and scaled-up at the community level within the appropriate Sustainable Rice/Vegetable platforms or frameworks in a next and more extensive phase of the project.

9 Impacts

Considering the relatively short time frame of the project (14th March, 2019 until 15th December, 2020; 20 months duration), and the unprecedented challenges posed by the Covid-19 pandemic during a major portion of the life cycle of the project, we provide the following evidence of outputs that are heading positively along the impact pathway.

9.1 Scientific impacts now and in 5 years

We anticipate at least 4-5 scientific or semi-scientific publications (i.e. Special Report) as outputs from this project. These are:(i) A critical review on the status of pesticide use in Myanmar as an output of WP2; (ii) Baseline survey assessment of rice and vegetable farmers and farmer's behaviour towards pesticide use (WP3); (iii) Resistance assessment for two key pests in rice and vegetable (WP3); (iv) Pilot trials on integrated pest management in Myanmar using cauliflower as a model crop (WP4) and (v) Pilot trials on integrated pest management against insect pests in summer and monsoon rice in Myanmar (WP4). The information from these publications could essentially set the stage for more IPM and bio-based related projects in Myanmar for the next 5 years.

The involvement in the project of an academic institution such as YAU gave opportunities for the staff and students to develop their scientific skills on toxicological and resistance assessment (e.g. probit analysis) and monitoring methodologies using two key agricultural pests as models; one on rice and the other on cauliflower. Evidence indicates that these methodologies are not used or available in Myanmar. Thus, having this skill set will help monitor resistance for the two pests in addition to assisting with determining baseline resistance in other insect pests in Myanmar and potentially helping with resistance management strategies in future. This will be critical and enabling against the backdrop of the current indiscriminate and excessive use of pesticides. Managing resistance will impact positively upon resilient pest management and sustainable crop production.

Project scientist, Dr. K.L. Heong provided training to M.Sc. and PhD students on assessing resistance in insect populations. Dr. Myint Thaung and Dr. Sivapragasam gave briefings and shared their experiences on the scientific concepts and principles on IPM, biological control using *Trichogramma japonicum* and ecological engineering to DAR scientists and extension officers. These were then shared with farmers as part of the participatory research approach.

9.2 Capacity impacts now and in 5 years

The project: (i) Trained 1 staff member (i.e. Dr. Phyu Moe Hnin) who was part of the project, 1 Ph.D student and 6 M.Sc. students enrolled at Yezin Agricultural University on principles of toxicological research and analyses (gender-wise 100% women); (2) Provided refresher training to staff of PPME-DOA on data encoding using the spreadsheet program Microsoft Excel©. They were also exposed to survey designs and non-parametric statistics and introduced to the Theory of Planned Behaviour (TpB) which provides a theoretical background behind farmer surveys and (3) Assisted DAR and DOAE staffs with basic capacity development and awareness who would in turn provide farmers with information in the following areas: (i) Basics of IPM and its use plus conservation of natural enemies in rice fields; (ii) Use of *Trichogramma japonicum* against rice stemborers and leaf-folders; (iii) Ecological engineering to encourage agro-biodiversity and reduce pesticide use in rice fields; (iv) use of neem and other bio-based products and their benefits for rice and vegetable production (courtesy of Marlarmyaing Public Co., Ltd. Nay Pyi Taw, a member of the project team);(v) Integration of rice-fish-pesticide use in the field as conducted by the RiceFish Project with support from Mr. Than Aye, a member of the project team (ACIAR Project No. FIS/2016/135) and (vi) Online version and web-based tools on Pest and Disease Management – collaboration between

PPD-DoA and CABI (Plantwise) and (4) Will potentially train scientists and extension workers in aspects of scientific communication based on a web-based modality in March 2021.

9.3 Community impacts now and in 5 years

The project is community targeted and it is an officially supported project by MoALI. Thus, key officials of DoA, DAR, etc. participated in the meetings and discussions with the project team. At the outset, as part of the Participatory Impact Pathway (PIP) approach, measures were in place to eventually disseminate the outputs of the project to benefit rice and vegetable farmers in the community including other key stakeholders in the value chain such as bio-based input suppliers. Thus, although the project is one of limited scale focusing on pilot activities and a sample of farmers of both genders in a location, it did consider the impact extended or up-scaled eventually beyond the project location to the communities around the project sites. This project has started the process as part of PIP whereby at specific points in the project (e.g. IPM trials in WP4), some progressive farmers in the area were brought together to participate in the briefings and training so that they become aware of the various bio-based technologies and to help with increasing the adoption rates across the selected communities. Funded under the ACIAR Launch Fund, we will also soon provide scientific communication for scientists and extension workers. An appropriate lesson-learning system and an effective communication approach will be pivotal for transformative changes in the mindsets of farmers towards increasing adoption rates of the project outputs (refer section 8.4.4).

9.3.1 Economic impacts

The overall analyses indicated that the bio-based IPM practices for cauliflower and summer/monsoon rice in rice–rice systems reduced pesticide costs, increased yield and net revenue of farmers practising the bio-based IPM approach versus the NIPM. In cauliflower, the IPM plot had fewer insecticide sprays, i.e. 2 times against 5 times in the NIPM plot which contributed to the higher pest control costs in the NIPM (19.1% compared to the IPM (8.2%) plot in terms of the total production costs. The IPM plot was also superior (USD168.0 per 0.2 acre; USD840.0 per acre) compared to the NIPM plot (USD33.8 per 0.2 acre; USD169.0 per acre) in terms of overall profit. This translated to a positive return of USD671.0 for the IPM approach.

In summer rice, a Net Revenue (NR) of USD274.16 in the IPM trial compared to USD177.75 from the NIPM trial which gave a positive difference of USD96.7 per acre. However, in the monsoon rice trial, the Net Revenue (NR) was about USD10.5 higher per acre basis in the NIPM versus the IPM, i.e. USD346.5 and USD357.00 for IPM and NIPM, respectively. The slightly reduced mean Net Revenue (NR) in IPM was largely due to the high costs of neem seed cake (NSC) which could bring a longer-term environmental, social and health benefits overall to the rice ecosystem and its farmers. If the costs of NSC, which represented almost 78% of the bio-based product costs, could be reduced by scaling up production, then the overall costs could be reduced substantially. If the NRs from the two rice seasons were combined, then the averages become USD310.33 in IPM versus USD267.38 in NIPM with a positive return of about **USD43.0 per acre basis (about USD106.0 per ha**) using the IPM approach. If this positive return is scaled out to a township level, even partially, then the returns could indeed be significant for the Township. For example, Hmawbi Township in Yangon (Lower Myanmar), where the summer rice trial was conducted has a total population of about 0.2 million and a total area of about 480 square kilometres. In 2018-2019, about 20,474 ha were cultivated, 18,387 ha as monsoon rice and 2,087 ha as summer rice. About 4,640 ha produced vegetables.

The IPM trial also suggested that the above overall positive NR returns to the farmer could be enhanced by the savings accrued with reduced pesticide sprays and the concomitant costs involved (e.g. inputs, labour and other costs). The results from the survey done in WP3 revealed that insecticide misuse was found to be extremely high (90%). Dr. Heong suggested that if we factor in externality costs such as human health, environmental damages and risks of getting secondary brown planthopper outbreaks, Myanmar farmers will be much better off by not using any insecticide at all in rice production and will gain an extra profit of about USD35 per ha per season. Thus, the overall economic benefits are truly substantial for the farmers. Evidence of this is reflected in the results of our brief post-IPM survey which suggested that almost 75% of the farmers were keen to adopt the IPM approach in their farms in the following season against none before the trials. The other 25% are not sure perhaps being risk averse added to the fact that the costs of insecticides are very low compared to the overall production costs. For examples, in the monsoon rice trial, the total costs of pesticides per acre were US0.95 and USD27.9 for the IPM and NIPM, respectively. and this attributed to about 7.5% of the Gross Expenditure (GE) to the cost of pesticides in NIPM (USD372) plot.

It is important to note that the above benefits are largely accrued from reducing insecticides. The other pesticides e.g. herbicides and to some extent, fungicides and molluscicides, may remain critically important for farmers to use as required by a well-structured management strategy in their rice fields.

9.3.2 Social impacts

The social impacts in the project could be potentially seen in terms of measurable factors such as livelihoods and wealth, education and training to build skills, knowledge, and competencies, health and physical wellbeing and social inclusion.

The economic impacts described above, if realized in these communities could translate into key social impacts e.g. better livelihoods and wealth. In terms of gender inclusion, the project attempted to consider gender balance in the course of the project. Currently, men usually dominated the rice production system and played a lead role in land preparation and the application of pesticides and fertiliser, while women are primarily involved in crop establishment, weeding, harvesting, and postharvest activities. Men also dominated decision making and women participate in social activities that have no influence on community or farming decisions. An exception in this respect was seen in our project. One of the implementors of the summer and monsoon rice IPM trials was a woman, i.e. Daw Sein Htay, who has about 20 years of experience in rice cultivation and is highly mechanized in her operations. Women’s lack of access to extension and information is common in Myanmar where men are mostly invited to meetings or training activities even though women are very interested in joining. Our training, education and awareness activities included a few women to help them build skills and knowledge. It is anticipated that there will be an upward shift in the future for women as decision-makers as this aligns with the national mainstream goals. With regards to employment, another social impact, we anticipate spin-off activities amenable for women to undertake with the higher inclusion of bio-based inputs in the rice and vegetable production systems in future. Bio-based businesses are particularly relevant in the context of long-term health and physical well-being.

9.3.3 Environmental impacts

Results from the survey done in WP3 revealed that insecticide misuse was found to be extremely high (90%). Farm yields and insecticide inputs were not related implying that the productivity gain of Myanmar farmers from insecticide use is negligible or negative. Our recommendations for IPM against insect pests in vegetable (cauliflower) and rice are based on ecological approaches that are consistent with integrated pest management. From an environmental impact point of view, the reduction in the amount of pesticides used (in terms of number of sprays) in all the trials potentially helps with reducing the carbon footprint overall; also helps with improving produce quality (e.g. keeping residue levels below MRL, conserving soil health, agro-biodiversity and water quality. The perceived void left by chemical pesticides can be addressed in part by the use of bio-based inputs such as *Trichogramma*, neem-based products etc as well as selected chemical pesticides with low or no impact on non-targets. The use of Ecological Engineering (EE) helps to restore the ecological functioning of the system and by having, for example, no insecticide treatment during the first 30 days of the rice crop. EE can improve greatly the ecological stability of the rice agro-ecosystem against pest outbreaks in contrast to conventional cropping systems which can create instability in the system due to heavy pesticide use. As indicated earlier, Myanmar farmers will be much better off not using any insecticide at all in rice production and they will gain an extra profit of about USD35 per ha per season.

9.4 Communication and dissemination activities

9.4.1 Project website

For the benefit of project partners and to serve as a communication tool, CABI developed a dedicated project website highlighting project activities, progress updates and for uploads and sharing of project documents between project partners. The website and related activities were undertaken as additions to the project to provide a platform for project partners to collaborate on, communicate updates to the donor and findings to project stakeholders, many of whom are grappling with the issue of pesticide misuse in Myanmar.

9.4.2 DropBox service

CABI provided an additional tool by the creation of a shared space for project files and documents in the form of a Dropbox service for the convenience of project partners although the website provides the same functionality. The Dropbox service was conceived as a convenient way for partners to access and obtain project documents through syncing via the DropBox client on their PCs or mobile phones.

9.4.3 CABI website write-up

(Link: https://www.cabi.org/projects/helping-to-achieve-sustainable-agriculture-in-myanmar/

The project was also highlighted by CABI on its website platform to provide wider visibility to potential donors, partners working on a similar subject in Southeast Asia and other regions, CABI member countries and visitors to CABI's website. The write-up provides information on the project duration, subject matter (pesticide use and misuse), details of the research questions being looked at, expected outputs and results achieved at the time of the write-up.

9.4.4 Awareness on IPM and related components

This is targeted mostly for farmers and extension agents engaged with the project.

- Basics of IPM and use and conservation of natural enemies in the rice field
- Use of *Trichogramma japonicum* against rice stemborers and leaf-folders
- Ecological engineering to reduce pesticide use in the rice field
- Use of neem and other bio-based products and its benefits for rice and vegetable production courtesy of Malarmyiang Company Nay Pyi Taw, a member of the

project team

- Integration of rice-fish-pesticide use practices in the field as conducted by the RiceFish Project with support from Dr. U Than Aye who is a member of the project team (ACIAR Project No. FIS/2016/135)

9.4.5 Scientific Communication for scientists and extension workers (in progress)

Communicating the outputs of the project to the key stakeholders will form an essential component for success of the project. In many pest management studies highlighting and featuring just the benefits of the scientific-based interventions may not be effective towards sustainable practice. In the SRA, a Participatory Impact Pathway (PIP) approach has been adopted which rather than being solely technology-oriented is people-centric (including farmers/farmer associations, extensionists, agro-dealers, researchers, NGOs, decision makers from relevant ministries). The final stage of PIP is to disseminate the project's best practices of 'green' technologies to rice and vegetable farmers and to other key stakeholders in the value chain, including input suppliers. This stage will be largely driven by the DOA, DAR, YAU and the Department of Agriculture Extension (DoAE) having proven linkages with stakeholders at various levels that are also aligned with Myanmar Government policies and regulatory frameworks. Thus, an appropriate lesson-learning system and an effective communication approach will be pivotal for transformative changes in the mindsets of farmers towards increasing adoption rates of the project outputs.

9.4.6 Online version and web-based tools on Pests and Diseases Management

A collaboration between Plant Protection Division (PPD) – DoA and CABI (Plantwise)

CABI has developed a suite of tools (web and mobile) for plant pest and disease management for Plantwise, a programme utilising ground-based plant clinics supported by information resources to manage plant pests and diseases. These tools have been used extensively by PPD when conducting plant clinics to capture and record clinic visits by farmers, identify and diagnose pests and diseases, provide recommendations and control options to farmers, map distribution of pests and diseases in areas of plant clinic operations, and provide PPD staff / extension workers with the necessary information resources during clinic operations.

10 Conclusions and recommendations

10.1 Conclusions

This was a relatively short duration project aimed at addressing the challenges posed by pesticide overuse and misuse on Myanmar’s aspiration to progress towards achieving sustainable ‘green’ agriculture. The SRA project had a wide vision but was modest in terms of its scope so as to focus on a critical problem that cuts across agricultural production, its value chains, the environment and human health. Overall, there were four key areas of findings.

The first area of findings (WP2) concerning literature review and information gathering initiatives revealed interesting scenarios and trends. There was good, valuable and useful information from published and ‘grey’ domains as well as from information gathering initiatives (e-mails, interviews and meetings). However, the information was found to be fragmented and skewed towards certain categories as described earlier. The information was also not well-collated/managed, not easily accessible and not widely utilized by stakeholders leading to a situation whereby farmers often obtain advice from untrained/unreliable/partial sources. This led us to conclude that farmers are not getting appropriate and holistic help in their agricultural endeavours. The information gathered on registered pesticides revealed quite an alarming situation whereby more than 50% of the products are products banned in the EU and this was further exacerbated by the significant amount of illegal/counterfeit imports coming across the borders. From this, we conclude that **if Myanmar is not vigilant and careful in addressing this issue, its agricultural produce may suffer and/or face market access difficulties**.

Outputs from WP3 on insecticide resistance showed a serious lack of personnel, expertise and knowledge in this important pest science topic. From the information gathered, discussions held and training provided, we can infer that the pesticide resistance status of many of Myanmar’s agricultural crop pests are not known or managed. The efficacies of the products in use are also uncertain which can lead to more pesticide overuse and misuse.

The assessment (structured surveys) of rice and vegetable farmers’ KAP, key beliefs and factors driving their practices revealed that **farmers had serious deficiencies, such as ecological illiteracy, misconceptions, negative anchored beliefs and overreliance on chemical control**. Pesticides are still sold and used like FMCGs. This led us to conclude that many farmers are still narrow in their pest management outlook and not practising eco-rational crop production.

Findings from WP4 showed that an IPM/biobased approach for cauliflower and rice production can work and farmers are capable of undertaking such a production regime. Neighbouring farmers observing the demonstration plots seemed to be convinced, interested and enthused. We can conclude that there is good potential to transform the current farmers’ production system to the ‘new normal’ of using IPM/biobased approaches if proper training, guidance and availability of the right agronomic resources are made available to professionalize the plant health system. Further, underpinning the latter, the government must introduce structural reforms and enabling policies that include the provision of incentives to persuade farmers to reduce pesticide usage and explore alternative methods for pest control (Heong et al., 2013). Favourable agri-policies via subsidies and use of plant clinics had led to pesticide reduction in China, a major producer, user and exporter of pesticides (Wei *et al*., 2019). In the case of Myanmar farmers, we can quite confidently say that they can be much better off using less and even no synthetic pesticides, depending on the crop/situation. Their economic expectations and livelihoods would still be intact and their produce can have better chances of accessing wider/more markets.

In future, one important aspect that is an imperative is to exploit the increasing trend of farmers in Myanmar using mobile apps. Most farmers have smartphones and the country's smartphone penetration rate is 80 percent (in 2018) and increasing. Notably, App developers have been quick to create apps for everything. In addition to the CABI-PPD app (mentioned above), there are a number of other game-changer apps used by farmers. These include: the 'Green Way' app which was launched in 2016. The app provides farmers with up-to-date information on everything from weather and climate change to crop prices and advice on pesticides and fertilisers. There is also a chat feature on the app that allows farmers to connect with each other, allowing the exchange of information. There are also tips, as well as the availability of experts on hand to answer additional queries. The other interesting app is Impact Terra's 'Golden Paddy.' The Golden Paddy platform has three channels to connect and engage with farmers across Myanmar - a mobile application, a web application and a Facebook page. This app benefits farmers by providing advice on early identification of pests and diseases and flood and drought warnings. Apart from that, the app connects farmers to potential buyers and provides them with information about market prices, indirectly increasing the bargaining power of the farmers. It is worth mentioning that this Project engaged in preliminary discussions to work with Impact Terra and discussions are still in progress with Dr. Quyen McGrath of Impact Terra who was in fact invited to the SRA project's mid-term workshop to share the company's activities. Overall, it is anticipated that any future phase of the project will be driven by a number of IT-based technological advances, although the challenge still remains in increasing the user-base.

10.2 Recommendations

Considering the timescale of the SRA and the challenges posed by the Covid-19 pandemic, the outputs achieved are significant. This project has revealed many issues, gaps and potential areas for further scientific work. The following are some specific recommendations (not exhaustive) for consideration:

- Tap the existing and new information to develop innovative, pragmatic and useful communication, extension and training knowledge products for the whole range of stakeholders;
- Support government institutions, academia, private entities and international agencies to conduct more work locally and generate more useful information;
- Revamp and realign extension and university curricula to generate well-trained and well-informed cadre of agriculture personnel;
- Re-examine and revise pesticide regulations and laws to adequately address registration, packaging, marketing/supply chain, application, disposal, etc.;
- Mobilise appropriate policies and investments to ensure compliance through better enforcement, penalties & incentives ('carrot and stick' approach), licensing and certification of pesticide dealers, etc.;
- Increase participation of pesticide suppliers involving responsible marketing, proper stewardship, price incentives and local community stakeholder platforms;
- Instil consumer preference for healthy, wholesome, safe/residue-free, quality produce;
- Strengthen enabling policy environment for enhanced availability and use of selective chemical pesticides and biopesticides;
- Encourage participatory community approach with sustainable support including from agri-dealers;
- Re-structure/train PPD and other relevant agencies to develop a crop protection system that can respond to and implement pesticide resistance management strategies;

- Strengthen farmer training to improve their agro-ecological literacy by re-designing farmer training focusing on modifying their anchored beliefs and practices through innovative education means such as cognitive games, visuals, entertainment education, mobile clinics, apps, etc.;
- Refine test IPM packages and adopt a more crop/agro-ecosystem-centric approach;
- Up-scale and out-scale demonstration trials for greater visibility and adoption;
- Shift from supply chain to value chain approach.

In concluding, although rice and cauliflower were the focal crops in terms of piloting the green or bio-based approach, further work needs to cover other economic crops, especially other vegetables when it impacts on consumers and markets. There is also a need that the Myanmar pesticide product list be updated as there are banned products still in use as per the survey results. In that context, there is an imperative to bring the industry together with government agencies for a win-win situation and manage the broad expectations of consumers for unblemished produce through education and awareness.

Moving forward, it is anticipated that the current promising pilot-level bio-based IPM approach should be further refined, packaged and scaled-up at the community level within the appropriate sustainable rice/vegetable frameworks. For a start, an important aspect will be to create awareness of farmers on the various bio-based products and approaches available. This would help change their many negative perceptions on the use of these products. To expand the use of bio-based interventions, it is recognised that there is still a need to implement larger scale trials to derive clear conclusions based on convincing experimental work and well-researched facts. Key drivers for this include: (i) Fostering greater private sector engagement and buy-in which is important for more responsible marketing, stewardship and scaling-up of bio-based inputs usage (e.g. neem, *Trichogramma* production, etc.) and (ii) Assisting to transform, strengthen and sustain Government support (e.g. policies, laws, enforcement, capacity development) for better pesticide regulation and 'green' technology development to mainstream the use of environment-friendly products and help Myanmar achieve sustainable 'green' agriculture.

11 References

11.1 References cited in report

Aung, M.L., Ei, N.N., Lin, N.K. and Hlaing, A.P.P. (2017). The impact of pesticide use on human health: A case study from Myanmar. EEI-LMS Policy Brief: No. 2017-PB3.

Costa, A., Sivapragasam, A and Thaung, M. (2020). CABI Services to strengthen the plant health system in FARM, Myanmar. Final Report (mimeograph); Pp. 49.

Escalada, M. M., Heong, K. L., Sengsoulivong, V., & Schiller, J. M. (2006). Determinants of insecticide-use decisions of lowland rice farmers in Laos. Rice in Laos. International Rice Research Institute, Los Baños, Philippines, 283-290.

Finney, D. J., Ed. (1952). Probit Analysis. Cambridge, England, Cambridge University Press.

Heong, K.L., Wong, L. and Delos Reyes, J.H. (2013). Addressing planthopper threats to Asian rice farming and food security: Fixing Insecticide Misuse. ADB Sustainable Development Working Paper Series. No. 27, August 2013. Pp. 20.

Heong, K.L., Escalada, M.M, Chien, H.V. and Delos Reyes, J.H. (2015). Are there productivity gains from insecticide applications in rice production? Pp 181 – 192. Chapter 9. In Heong, KL, Cheng, JA and Escalada, MM. (eds) ‚Rice Planthoppers: Ecology, Management, Socio Economics and Policy' Zhejiang University Press, Hangzhou and Springer Science+Business Media Dordrecht. DOI 10.1007/978-94-017-9535-7.

Suthep S., Srihabut. T. and Khine, M.T. (2016). Pesticides Use Practice and its Related Factors among Farmers in Pyin Oo Lwin Township, Myanmar International Journal of Health Sciences March 2016, Vol. 4, No. 1, pp. 48-58

Thi, S.K., Ogtrop, F.V., Southam-Rogers, L. and Tan, D.K.Y. (2019). Assessment of pesticide residues in vegetables in the Inle Lake region in Myanmar. Proceedings of the 2019 Agronomy Australia Conference, 25 – 29 August 2019, Wagga Wagga, Australia © 2019. www.agronomyaustralia.org/conference-proceedings

Thein, M. (2012). Public health and chemicals in Myanmar. International workshop to strengthen capabilities for sound chemicals management in South-East Asia Region. Bangkok, Thailand, 24-27 May 2011.

Schreinemachers, P., Afari-Sefa, V., Heng, C.H., Dung, P.T.M., Praneetvatakul, S., Srinivasan, R., (2015). Safe and sustainable crop protection in Southeast Asia: Status, challenges and policy options. Environmental Science & Policy 54, 357-366.

Schreinemachers, P., Chen, H.-p., Loc, N.T.T., Buntong, B., Bouapao, L., Guatam, S., Nhu, T.L., Pinn, T., Vilaysone, P., Srinivasan, R., (2017). Too much to handle? Pesticide dependence of smallholder vegetable farmers in Southeast Asia. Science of The Total Environment 593-594, 470-477.

VSAT (2016). Myanmar vegetable farmers are in business: Accelerating the growth and development of the vegetable sector in Myanmar. Draft white paper developed for the round table meeting on vegetable sector development. Retrieved from https://www.dutchvegsupportmyanmar.com/wpcontent/uploads/2018/01/White-paper-VSAT-31-March-2016.pdf, 27 June 2020.

Wei, X., Zhao, L., Qiao, Y., Wang, B., Wan, M. and Toepfer, S. (2019). Implementing agri-policies on pesticide reduction through subsidies and plant clinics in China. CABI Working Paper 13, 25pp.

Wyckhuys, K.A.G, Heong, K.L., Sanchez-Bayo, F., Bianchi, F.J.J.A. Lundgren, J.G. and Bentley, J.W. (2019). Ecological illiteracy can deepen farmers’ pesticide dependency. Environ. Res. Lett. 14, 093004. https://doi.org/10.1088/17489326/ab34c9.

11.2 List of publications produced by project

Escalada, M., Nilar Aung and Heong, K.L. (2020). Pest management of rice and vegetables farmers in Myanmar: Practices, beliefs and pesticide use. (Report of project “Plant Health – a major challenge to achieving sustainable ‘green’ agriculture in Myanmar” (ACIAR CROP/2019/103); 66 pages.

Phyu, M.H. and Heong, K.L. (2020). Assessing insecticide susceptibility of the brown planthopper and the diamondback moth in Myanmar. Special report of Work Package 3 (Report of project “Plant Health – a major challenge to achieving sustainable ‘green’ agriculture in Myanmar” (ACIAR CROP/2019/103); 18 pages.

Rothschild, G. (2021). Comprehensive literature review and information gathering. Final Special Report 2021. Special report of Work Package 2 (Report of project “Plant Health – a major challenge to achieving sustainable ‘green’ agriculture in Myanmar” (ACIAR CROP/2019/103); 16 pages.

Yin, N.N., Myint T. and A. Sivapragasam, A. (2020). A pilot study to evaluate the use of ‘green’ technologies and IPM approach against insect pests of Cauliflower in Thekawgyi Village, Lewe Township in Myanmar. Report of Work Package 4 (Report of project “Plant Health – a major challenge to achieving sustainable ‘green’ agriculture in Myanmar” (ACIAR CROP/2019/103); 16 pages.

Yin, N.N., Myint T. and A. Sivapragasam, A. (2020). A pilot study to evaluate the use of ‘green’ technologies and IPM approach against insect pests of summer and monsoon rice in Seinsarpin (Zeya Thiri Township) and Hmawbi Townships in Myanmar. Report of Work Package 4 (Report of project “Plant Health – a major challenge to achieving sustainable ‘green’ agriculture in Myanmar” (ACIAR CROP/2019/103); 25 pages.

12 Appendices: links to detailed reports

12.1 Literature review

Information on pesticides in Myanmar

12.2 Pest management practices and farmers beliefs

Reports on farmers growing rice and vegetable in Myanmar

Farmers practices, beliefs, and pesticide use

Pest management practices of farmers growing rice and vegetables

12.3 Susceptibility of pests to insecticides

Brown planthopper and diamondback moth susceptibility to insecticides

12.4 Pest and pesticide management status in Myanmar

Pest and pesticide management status in Myanmar

12.5 Baseline surveys on rice and vegetable pests and their management

Rapid baseline survey on pests and diseases and their management:

Baseline survey for rice

Baseline survey for vegetables

12.6 IPM Trials

IPM trial for Cauliflower

IPM trial for Rice