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Final report

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1 Executive summary

Integrated Crop Management (ICM) to enhance vegetable profitability and food security in the southern Philippines and Australia ACIAR Project HORT/2012/020 improved annual farm income by 50% with farmers participating in project-run farmer field schools (FFS). 2072 farmers participated in FFS, 968 were provided with basic inputs such as seed, fertilizer, seedling trays and bed mulch.

The project team included scientists from six Philippine Universities or institutes, training teams from East West Seeds and Landcare Foundation Philippines, and scientists from two state Departments of Primary Industries and a private research provider.

The project team scientifically evaluated various components of an integrated crop management system for field and protected cropping of key high value vegetables in the southern Philippines with 110 experimental trials conducted.

Five new disease records were made for vegetables in the southern Philippines and two exotic melon viruses were found in Australia as a result of project surveys.

The field and laboratory experiments have generated efficacy data for a range of biological and botanical products for management of key pests and diseases of the focus vegetable crops and are the basis for IPM recommendations for each crop.

Two small (UPLB and BISU) and one commercial scale aeroponic system (NMACLRC) were developed and operating for clean white potato seed production in the Philippines and a small scale unit at Mareeba, Australia. The systems produced 500-800% more seed potatoes than traditional seed production methods. Depending on intra-row spacing, yields of 20 t/ha to 32 t/ha were achieved from aeroponic seed.

A range of protected cropping structure innovations including: high-strength steel, coco-lumber and flexible bamboo framed structures; high and low tunnels roofed with removable plastic or net covers, were evaluated in southern Philippines with focus on typhoon prone areas for the focus vegetable crops.

Key agronomic innovations were compared to local practices for the focus crops including:

- Seedling production methods,
- Grafting onto bacterial wilt tolerant root stock
- Plastic and natural material bed mulches
- Biofumigation and microbial soil amendments
- Fertilizer rates, delivery method and timing
- Drip irrigation

Scientific methods for evaluating crop protection and agronomic practices of vegetables and aeroponics have been shared between team members, colleagues and students. Over 3000 VSU crop protection students used the VSU ICM research block as a living laboratory. Philippine students have written 30 BSc undergraduate, six MSc and two PhD theses based on ICM experiments in the Philippines, and one PhD was completed in Australia. Twenty-three papers and twenty-seven posters were presented with eight and twenty respectively at international conferences. Nineteen papers have been published in refereed journals and up to another nineteen papers to be included in a special edition of the Annals of Tropical Research are in review.

2 Background

Vegetables are an essential component of a balanced diet and their production in smallholder farming systems provide opportunities for improved nutrition and income generation. In the southern Philippines, low vegetable yields, combined with distance from markets, unsophisticated transport and marketing systems, limited access to land in coconut production areas, and dietary preferences for rice/fish/meat, have kept vegetable farmers poor, made vegetables unaffordable for many, and threatened household and regional food security.

Production challenges include more than 2000 mm of rainfall per year and frequent typhoons that cause soil and crop loss , widespread insect pest and disease damage, poor access to modern vegetable varieties and cropping inputs, and low skill levels, combined with poor distribution systems. A key challenge is the development of practices that minimise pesticide residue and contaminant risk to meet consumer demand for safe, high quality fresh produce while fostering compliance with the Government of the Philippines Organic Agriculture Act (2010) stipulation to promote, further develop, and implement the practice of organic agriculture in the Philippines.

In response to these issues, ACIAR funded a program of horticultural projects in the southern Philippines and Australia during 2007–2012 to address research priorities in crop management and protection, soil management, protected cropping, handling and marketing, and value chain interventions in the regions of Leyte (VIII), northern Mindanao/Cagayan de Oro (X) and southern Mindanao/Davao (XI) (HORT/2007/067, HORT/2007/066, each with six separate components (i.e. discrete 12 sub-projects). The research partnerships recognised that:

- inadequacies of local production and transport from distant production areas reduced quality and inflated prices, while
- serious pest and disease pressures and poor soil management also seriously impacted on the food security of the rural poor and the prospects for trade, and
- complementarity and synergies of effort between partner teams in Australia as well as in the Philippines within an overall co-ordination framework would enhance outcomes and progress.

Foundational R & D and collaborative partnerships under the program (2007–2012) showed that, the profitability of selected horticulture value chains could increase from further improvements in:

- horticultural practices and crop protection, selection of better performing vegetable cultivars, innovation in design and use of low cost protective structures,
- quality management and diversification in postharvest handling and marketing of selected vegetables, and mangoes and other fruit crops, and
- additional focused investment in R & D team collaboration and capacity building in horticultural production, crop protection and postharvest physiology and quality management.

With the completion of the initial phase 2007–2012, and discussions with the Philippines Council for Agricultural, Aquatic and Natural Resources Research and Development (PCAARRD) and program partners, the following issues were identified as essential to capitalise on the outcomes and the collaborative partnerships of HORT/2007/066 and deliver significant economic benefits to smallholder vegetable farmers in Leyte (VIII) and southern Mindanao/Davao (XI) within a second phase of program support (Figure 1):

- Improving disease, insect pest and nutrient management strategies for the most common vegetables produced in the Southern Philippines.
- Selecting locally suitable open field and protected cropping agronomic systems to maximise yields and financial returns to smallholder farmers.
- Developing a viable method to reliably supply disease-free seed potatoes to combat a serious bacterial wilt problem.
- Formulating an integrated crop management (ICM) approach incorporating the above techniques into practical and profitable vegetable production systems
- Continuing to enhance and expand partnerships with local government units, the seed sector, land care groups and research agencies, to enhance demonstration and uptake of improved production.

Under this new phase of the ACIAR Southern Philippine Horticulture program there would be a vegetable integrated crop management project with three complementary projects with a component of work on vegetables in the Southern Philippines: the postharvest, soils and value chain projects. These projects and the fruit projects all shared a common goal of improving food security and livelihoods for smallholder farmers.

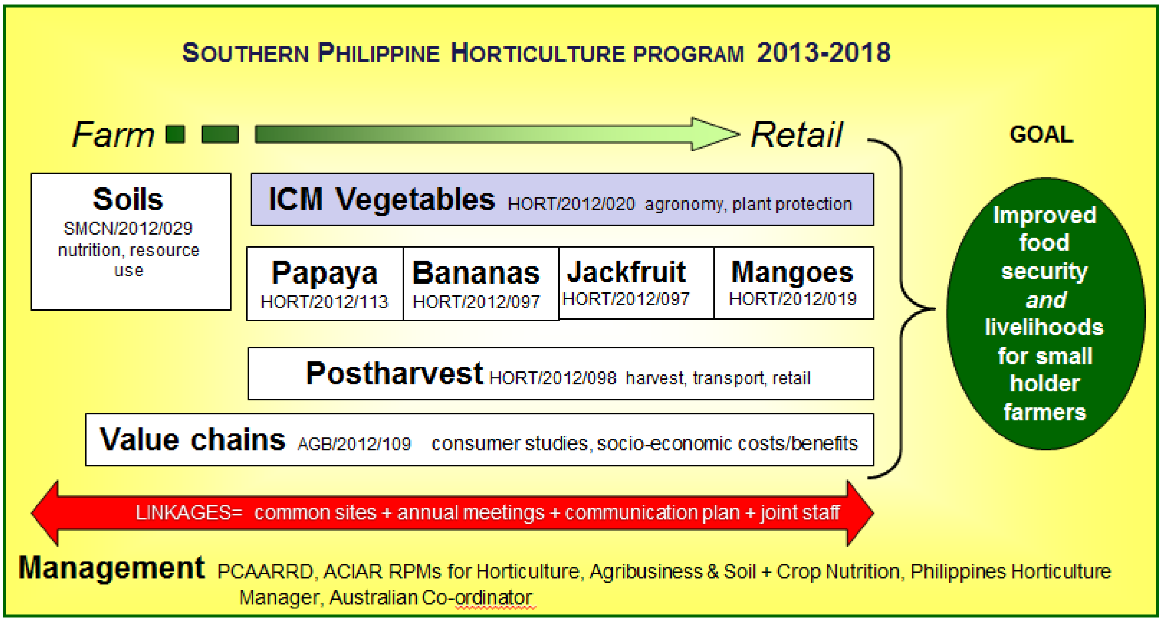

Figure 1. Structure of ACIAR southern Philippines horticultural research program 2013-2018.

The HORT/2012/020 (*Integrated Crop Management (ICM) to enhance vegetable profitability and food security in the southern Philippines and Australia*) project was developed with consultation and collaboration of three Australian research partners and eleven Philippine partners. Its construction was guided by the priorities from the ACIAR Australian-Philippine consultative meetings, PCAARRD Science and Technology agenda for 2011–16, NSW DPI Research and Development priorities and outcomes from the previous project phase (Figure 2). The project was to focus on poverty reduction, food security and sustainable development for Philippine regions 7, 8, 10 and 11 with local research and extension partners (Figure 3). The priority vegetables were identified by PCAARRD as tomato, eggplant, sweet pepper, bitter gourd (ampalaya) and leafy vegetables.

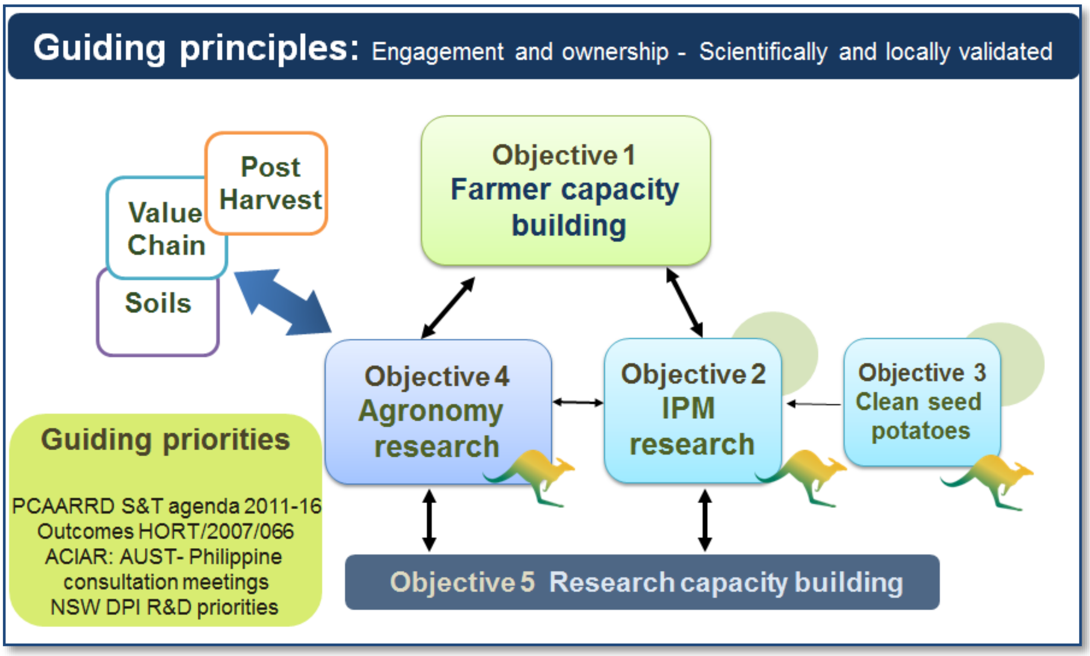

Figure 2. Guiding Principles and Objectives of ACIAR Project HORT/2012020 vegetable ICM in the Philippines and Australia

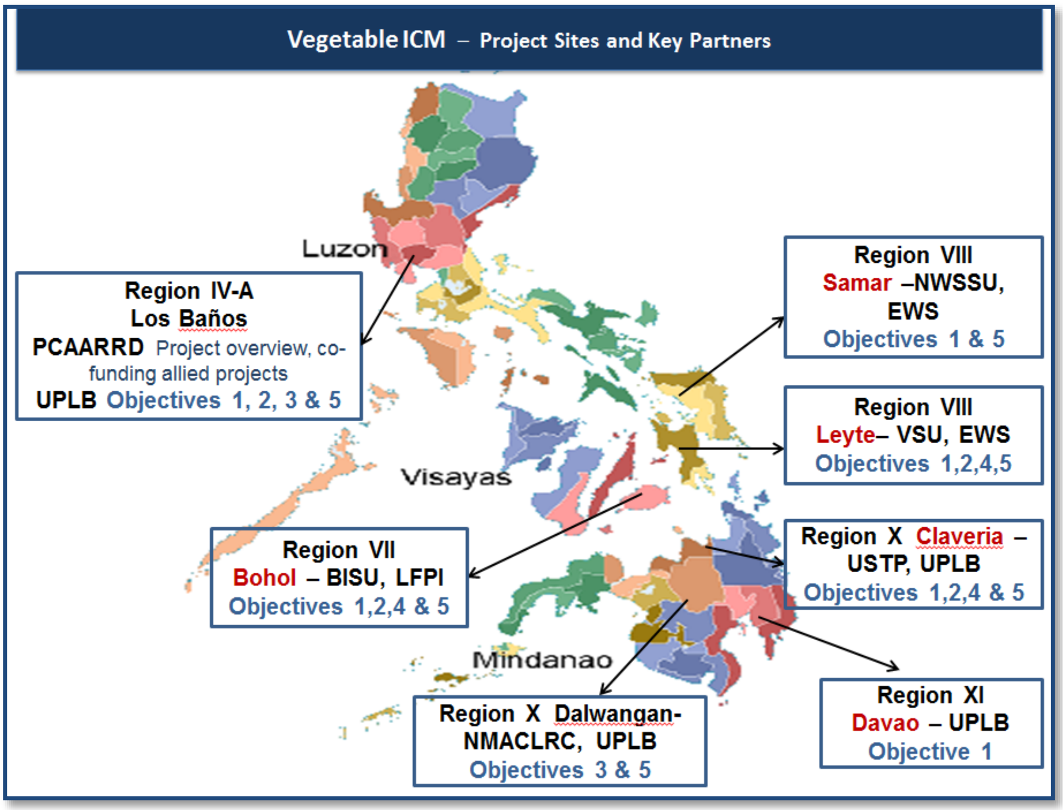

Figure 3. ACIAR Project HORT/2012/020 Vegetable ICM Project Sites and Key partners in the Philippines

3 Objectives

The HORT/2012/020 (*Integrated Crop Management (ICM) to enhance vegetable profitability and food security in the southern Philippines and Australia*) project had the overall goal of helping to improve the livelihoods and food security of smallholder vegetable farmers in the southern Philippines (Figure 2).

The project objectives were:

1. To increase vegetable farmer profitability through integrated crop management (ICM) in Leyte, Bohol, Samar and Mindanao.
2. To develop component technologies for management of key insect pests and diseases in Leyte, Bohol, Samar and Mindanao, and Australia.
3. To develop a commercial clean seed potato production system in the Philippines and Australia.
4. To develop component technologies for management of key agronomic constraints for each target site in Leyte, Bohol, Samar and Mindanao.
5. To build capacity in ICM skills and research capacity with collaborative Philippine organisations.

Key outputs proposed were:

- Integrated crop management systems for open field and protected cropping over 4 regions in the Southern Philippines to help farmers profitably produce tomatoes, sweet pepper, eggplant, bitter gourd (ampalaya) and leafy vegetables.
- An inventory of Philippine vegetable pests with appropriate best practice recommendations for the regions
- At least 1100 farmers over 4 regions (5 sites) trained in integrated crop management in farmer field schools and demonstration plots
- Development of improved protocols for aeroponic systems for producing disease free seed potatoes in the Philippines and Australia and base line data of cost benefit analysis for its future commercialization, and
- Recommendations for the use of plant growth promoting rhizobacteria in aquaponics systems in Australia.

Key sites for the project are shown in Figure 3.

The component research in Australia focused on biosecure and innovative vegetable production through gaining a better understanding of *Fusarium oxysporum* races and diagnostics on melons, fungal entomopathogens, aeroponic seed potato production and aquaponics.

The project was a component of the ACIAR-Philippine horticulture program, and was co-ordinated with and complemented by projects on horticulture value chains, soils and crop nutrition, fruit cropping and postharvest quality management. A management component, including a Philippine based horticulture manager and Australian co-ordinator aimed to ensure that cross linkages and synergies were made.

4 Methodology

To achieve the objectives of the project HORT/2012/020 (*Integrated Crop Management (ICM) to enhance vegetable profitability and food security in the southern Philippines and Australia*) a diverse project team was assembled with three Australian partners with technical expertise in vegetable integrated pest and disease management, protected cropping, vegetable agronomy, and aeroponics. The Philippine partners were selected based on capability and regional proximity. The Visayas State University (VSU) was the primary research partner with expertise contracted from University of the Philippines, Los Baños (UPLB) and local, primarily teaching universities, in Bohol (Bohol Island State University BISU), Samar (North west Samar State University NwSSU) and Claveria (University of Science and Technology of southern Philippines USTP formally MOSCAT). The farmer engagement was primarily through the East West Seeds (EWS) farmer training team and Landcare Foundation of the Philippines Inc. (LFPI). And for the aeroponic seed potato component UPLB and Northern Mindanao Agricultural Crops and Livestock Research Center (NMACLRC formally NOMIARC) partnered with Queensland Department of Agriculture and Forestry (DAF).

Four of the five project objectives of the HORT/2012/020 (*Integrated Crop Management (ICM) to enhance vegetable profitability and food security in the southern Philippines and Australia*) project were highly integrated (Figure 2) and were focused on ICM of tomato, eggplant, sweet pepper, amapalaya and leafy vegetables. The objective to develop a commercial clean seed potato production system in the Philippines and Australia was run somewhat independently of the other four objectives. The Philippine aeroponic component was developed within this project but funded as a complementary PCAARRD project led by UPLB and commenced officially in October 2014.

Increasing vegetable farmer profitability through integrated crop management (ICM), Objective 1, was the overarching objective that engaged with the small holder farmers through farmer field school (FFS) training, farmer field days (FFD) and via interaction with demonstration sites set up with key local vegetable farmers. This objective involved all but the Objective 3 partners.

Develop component technologies for management of key insect pests and diseases in Leyte, Bohol, Samar and Mindanao, and Australia, Objective 2, was informed by the engagement with the vegetable farmers in Objective 1 and led by crop protection researchers at VSU and collaborating scientists from NSW Department of Primary Industries (NSW DPI). It conducted targeted research to evaluate invertebrate pest management options primarily providing efficacy trials for “Organic”, botanical or biologically derived products to control key pests in the targeted vegetable crops. Bacterial wilt, *Ralstonia solanacearum,* was the primary focus of the disease management component research at VSU given it’s severity at the site and that it was found on all but the leafy vegetable crops. Tomato fusarium wilt, *Fusarium oxysporum f.sp.lycopersici*, was the targeted disease for research at the USTP site.

Develop component technologies for management of key agronomic constraints for each target site in Leyte, Bohol, Samar and Mindanao, Objective 4, was led by VSU and collaborating scientists from Australian Horticulture Research (AHR). This objective evaluated protected cropping structures, seedling production methods, bed mulch and some soil amendments as well as irrigation systems and grafting root stock. There was strong interaction between Objectives 2 and 4 with the primary sites being at VSU with the agronomy group managing the trial site and the crop protection teams monitoring the crop protection trials but also evaluating agronomy practice on pest or disease status. Research at BISU and, for a short while, research at NwSSU was focused on protective cropping. BISU and USTP also ran experimental evaluation of bed mulch. BISU ran seedling raising experiments and some crop protection product evaluation, and USTP ran variety evaluations, fertilizer experiments, protected cropping and irrigation experiments.

Building capacity in ICM skills and research capacity with collaborative Philippine organisations, Objective 5, was the mechanism to facilitate team training, provision of equipment and extension materials. The team identified priority equipment and training at the inception meeting and was followed up by an audit of the collaborating Universities facilities. An initial week-long ICM training workshop was held in August 2013 used the team, including collaborative farmers, to present to each other on their specialist areas to build the broader teams' skills across ICM. It established a baseline of existing knowledge and skills for delivering integrated crop management to small holder farmers as well as identifying research, skills and resource gaps. A series of training workshops using both Australian and Philippine expertise in agronomy and crop protection were conducted with farmer groups and the local ICM project teams across the southern Philippines in July 2014 and February 2015. Another week-long "ICM Master" class was held in January 2016 to consolidate the teams' broader ICM knowledge again including key collaborative farmers. Biometric and scientific writing workshops were held for the research staff to build skills specifically in these areas.

Developing and testing a soil-less production system, or 'aeroponic' system was the focus of Objective 3 and follows a promising area identified in HORT/2007/066 to produce potato seed free of bacterial wilt. This component ran somewhat separately, the Australian lead was by Queensland DAF and the Philippine lead was UPLB. The Philippine component was funded separately by PCAARRD and commenced 18 months later.

A soilless production system; Aeroponic technology was standardized to establish clean seed potato production in the Philippines and in Australia. Low cost, small and commercial aeroponic systems were developed and a small scale system piloted at DAF Mareeba, Australia. Two research collaborators from UPLB and NMACLRC were trained at DAF Mareeba for better understanding of the aeroponic system, growing technology and to design and modify systems for the tropical environment. Three aeroponic units, one each in low (UPLB), mid (NMACLRC) and high-land (BSU) areas of the Philippines were established to evaluate the production potential of the low cost aeroponic system. Series of experiments were conducted at DAF, UPLB, NMACLRC and BSU to optimize the aeroponic technology which included, evaluation of planting material, nutrition, crop husbandry, insect pest management, harvesting, seed storage and yield potential of aeroponically grown seed.

Field and pot trials were conducted at QDAF, BSU and NMACLRC to compare the yield potential of conventional and aeroponically grown seed. Data were recorded and analysed based on mean average values. Production cost was estimated and compared with the conventional method.

Project meetings, reports, power point presentations and onsite visits were made to share and increase knowledge of research and technical staff at each site. On-site and field trials were used to demonstrate the potential of this technology to provide seed to growers, suppliers and researchers. Regular updates were made on the experimental results and potential for the aeroponic technology to operate in a commercial environment to policy makers, Landcare and East West seeds during ACIAR project meetings and workshops.

The training teams (EWS and LFPI) commenced engaging with local government units (LGUs) in areas with small holder vegetable farmers to identify those LGUs that wished to partner in the provision of season-long FFS in Leyte and Bohol. The model was that only those LGUs who contributed financially were likely to have a longer-term commitment to ICM principles. Unlike traditional FFS, the training with LFPI and EWS included provision of basic materials (seed, fertilizer, seedling trays, and plastic mulch) to participants to enable them to 'replicate' their training on their own farms. EWS and LFPI staff worked together with the initial LGU engagement and the running of the first FFS in Leyte and in Bohol, after which EWS focused on FFS training in Leyte and Samar; and LFPI focused on Bohol. Ms Vale Justo, a crop protection specialist from UPLB conducted FFS with three grower groups in Davao, two in collaboration with the ACIAR AGB/2012/109 Value Chain project.

Protected cropping (PC) structures had been erected and refined at VSU under a previous project (HORT/2007/066) and additional structures were built to allow the agronomy, plant pathology and entomology groups to each have at least one high plastic-roofed, open-sided bamboo structure with a neighbouring similar sized open field area to conduct paired experiments. Protected Cropping structures were also erected at NwSSU and at BISU for evaluation. A range of PC structures were already at the USTP site and were utilized for some of the project experiments. Under the previous project PC structures were erected on some key farmer co-operator sites in Leyte and in return the farmers collected some research data and provided training for other farmers. Engagement of these farmers continued from VSU. BISU, NwSSU and USTP were encouraged to actively engage with one or more key local vegetable farmers. Resources were provided to build structures on collaborating farmers' sites in Samar and Bohol as well.

After the passing of the Organic Act (2010) agricultural extension was targeted to providing farmers with information on organic, mostly locally or homemade concoctions, for controlling insect pests and diseases. Farmers were also encouraged to use organic fertilizers. Our component research for crop protection focused on evaluating both locally recommended concoctions as well as formulated products that are generally allowable under the International Federation of Organic Agriculture Movements (IFOAM) standards as well as against locally registered insecticides or fungicides.

The component agronomy research focused on evaluating different PC structures including low tunnels and net tunnels, as well as techniques that had been identified as likely agronomic improvements but needing local validation. Agronomic areas that were identified included: seedlings production, grafting onto more disease resistant root stock, using bed mulch, fertilizers and irrigation under PC.

The process of identifying an experiment's aim, implementing the experiment, then analysing the data, writing a report and presenting to the project team was an integral part of the research capacity building. A number of our university collaborators had very little experience in research, and given they also had full teaching loads, involved their students actively into the project research sites and experiments.

Within most ACIAR projects, particularly those using Australian State agricultural department expertise, there is an Australian research component. In some cases the Australian priority is highly aligned with the Philippine component which was the case for the evaluation of aeroponic seed potato production in Mareeba, Queensland with DAF researchers. The NSW DPI Australian research addressed melon industry priorities of in-crop and post-harvest diseases, and post-harvest microbial contamination. The field surveys of Australian melon (rockmelon, watermelon, and bitter gourd/amapalaya) production areas looking for *Fusarium* *oxysporum* wilt races, also collected samples of other melon diseases for identification. The post-harvest microbial contamination work was driven by a serious *Listeria* food poisoning incident in the USA traced to a rock melon farm pack-house in 2011, and an earlier less lethal outbreak traced to melons sourced from the Riverina in 2010. From the 2010 Riverina incident it was found that the local melon growers were confounding fungicides with sanitisers, and pesticide residue testing with microbial testing. Consultation with the industry and local growers led to an Australian research component focused on melon growers and melon food safety. Melon production and handling practices were reviewed to identify potential contamination pathways, and efficacy testing of their fungicide and sanitation procedures was carried out. After positive detections of harmful microbes at three packing sheds, recommendations were made and followed up with the melon growers and finally a joint safety audit with the NSW Food Authority was undertaken. Another NSW DPI research component complemented the Philippine evaluation of biological pesticides with a series of bioassays to evaluate some *Metarhizium* strains for endophytic and biopesticidal activity on sucking insect pests.

AHR was involved in Australian based research through co-PhD supervision of a Philippine researcher who had been part of HORT/2007/066. The PhD research evaluated the use of plant growth promoting rhizobacteria (PGPR) within an aquaponic vegetable production system.

5 Achievements against activities and outputs/milestones

Objective 1: To increase vegetable farmer profitability through integrated crop management (ICM)

no.	Activity/Achievements/ comments
1.1	*Coordinator appointed*
	Dr Zenaida Gonzaga was appointed to this role to coordinate with the project collaborators. There was an intention to also collaborate with other external institutions and organisations beyond engagement for the farmer field school training, but proved to be beyond our capacity and was overly ambitious
1.2	*Identify and support a focal group of farmers in 4 target areas*
	Groups of farmers were engaged with in a variety of ways in Bohol, Leyte, Claveria, Davao and in Samar. **Bohol:** EWS jointly ran with LFPI the initial FFS in Bohol. Landcare continued to engage with this site to the completion of the project and worked with 10 other sites from 6 municipalities to run season long FFS. A total of 452 farmers were trained, 75% were provided with inputs and 49% were women farmers. 82% of the total farmers trained replicated the training on their own farms. Ten farmer groups were set up with accredited legal status and five have successfully set up their own community revolving fund. The revolving funds are based on farmers paying into the fund the cost of the inputs provided by the project after harvest and thereby having finance available for farm inputs for succeeding cropping seasons or new farmers. BISU-Bilar was involved in the conduct of FFS with 27 farmers farmers graduated at Cabacnitan, 25 farmers at Rosariohan, and 20 at Cambacay, all in the municipality of Batuan, Bohol and accommodated the farmers and LGU technicians or Local Extension Facilitators visiting the ICM demonstration site at BISU-Bilar. BISU was able to hold a field day at the same site with 45 local farmers, 6 LGU Technicians, 20 Agriculture faculty and 180 Crop Protection Students and 15 Thesis Students. **Leyte:** VSU worked with 3 farmer-teacher cooperators with protected cropping structures - Albert Rosillo in Baybay, Noel Morales in Cabintan and Boie Gerona in Bontoc. Albert is a new cooperator. All actively led local farmer groups, and hosted FFDs. EWS and LFPI jointly ran the initial FFS in Leyte and EWS took on the followup engagement with the farmers in this group. EWS then subsequently engaged with five other farmer groups to run FFS. 1006 farmers were trained, 35% were provided inputs, 48% were female. **Samar:** NWSSU initially engaged with a respected fruit grower who was keen to expand into vegetables but the poor crops led to a new demonstration site with Raphael Payod, in Santa Margarita which has become a focal point for local farmers and site for FFD for the region. EWS ran seven short FFS involving 394 farmers with four groups having inputs provided (totaling 74% of total farmers provided with inputs), 37% were female farmers. Farmers were engaged individually by the trainers to support adoption and implementation of training. **Biliran** EWS had an opportunity towards the end of the project to run five FFS with farmer groups in the province/island neighbouring Leyte and Samar. They trained 155 farmers with 43% being provided with inputs. **Claveria:** USTSP initially engaged with local farmers for to conduct the baseline survey and understand their issues. They then ran collaborative trials with three local farmers, and held an annual field day for ~120 local farmers at the University.
1.3	*Local cropping system summary*
	At the inception meeting each project Philippine collaborator contributed to developing a local cropping system summary for the each region based on their knowledge. This was augmented with surveys of farmers participating in FFS

	Leyte – VSU, EWS, 56 farmers interviewed Bohol – LFPI, BISU, EWS, 77 farmers interviewed Samar – NWSSU, EWS, 56 farmers interviewed Claveria – MOSCAT/USTP, UPLB Davao – UPLB conducted the socio-economic survey in Sitio Pamuhatan and Upper New Sabang Marilog District , Davao City and submitted to VSU.
1.4	*Establish four farm demonstration support sites for participatory (grower directed) action research with an appropriate technical focus for each site*
	In Leyte, Bohol and Samar, FFS training has principally formed the basis for grower engagement. The FFS model that was adopted by EWS and LFPI provided basic inputs and materials to an initial group of farmers to create their own individual “demonstration” ICM vegetable production sites. There were, however, some sites that were separate from the FFS training groups that were engaged. **Leyte** – VSU had two farmer cooperator sites: Albert Rosillo (Baybay), Boie Gerona (Bontoc). These farmers were also engaged with the Phase 1 Protected cropping project and were participants in project workshops and training sessions, and are leaders of local farmer groups helping train other farmers. **Bohol** – LFPI and BISU engaged with Raquel Lacar (La Suerte, Pilar), a progressive innovative farmer, who was also active in a local farmer group to set up a demonstration site. **Samar** – NwSSU and VSU engaged with Raphael Payod (Sta. Margarita), a retired engineer, who took up vegetable production and was identified as a local farmer leader, to set up a demonstration site with PC structures. **Claveria** – USTP engaged with a number of different farmer co-operators to conduct field experiments rather than a single demonstration. Each experiment was focused on a high priority issue for local vegetable farmers. Each site varied on how it ran the demonstration sites although they all endeavored to follow the basic principles of ICM and adopt best-practice agronomy. **Davao-** Each of the FFSs ran in Davao city by UPLB had a research/demonstration focus, e.g. tomato tolerant to TYLCV, managing Namamarako in ampalaya, high yielding peppers, and pest management strategy for pechay.
1.5	*Collect baseline biophysical data on both grower and ‘best practice’ ICM systems, evaluate changes over time/impacts for open field and protected cropping systems*
	A qualitative snapshot summary of current practices was initially developed by the project team in the first 6 months of the project from visits to potential farmer collaborating or training groups. A baseline survey was developed for farmers participating in the FFSs plus a comparative cohort of farmers from each region but remote to the project engagement sites. 310 vegetable farmers (220 ICM FFS farmers and 90 farmers not in ICM FFS) were asked about the biophysical data on their farm, specific information about the five focus vegetables and other crops they are growing, agronomic and market information (part of Activity 1.7). The survey was conducted among randomly selected farmers in Bohol, Leyte, and Samar. An earlier version of the survey was done with farmers cluster members of Sitio Pamuhatan and Upper New Sabang Marilog District, Davao City prior to FFS training. Soil tests were taken at some farms both independently and in collaboration with the ACIAR Soils project. A follow up survey was conducted targeting 90 FFS participants and 90 non FFS farmers to monitor changes in their farm practices and determine initial financial impact of the ICM system. The survey questionnaire was modified to incorporate gender roles in farming and interviewed 94 farmers.
1.6	*Conduct farmer field schools (FFS) or integrated farm management training on ICM systems involving the private sector and farmer teachers for open field and protected cropping*
	Initially, Landcare and EWS engaged together with LGUs in Leyte and Bohol to identify training groups. They jointly ran a FFS in San Isidro, Leyte and Mayana Jagna in Bohol; after which they engaged

	separately, with Landcare working in Bohol, and EWS in Leyte, Samar and briefly in Biliran. There were 5 project areas instead of originally 4 areas: A total of 2086 farmers were trained in FFS (452 Bohol, 1006 Leyte, 394 Samar, 155 in Biliran and 79 Davao). 1,078 were provided with plastic bed mulch, seeds, seedling trays and fertilizers to 'replicate' in their own blocks (368 Bohol, 353 Leyte, 290 Samar, and 67 in Biliran).
1.7	*Evaluate the economic and technical feasibility of interventions/change of practice or adoption of technology*
	The baseline survey information provided the basis for a profitability analysis of the small holder vegetable farmers. Gross margin analysis was conducted on tomato, sweet pepper, lettuce and pechay subjected to different experimental set-ups exploring several variations in cropping practices. The focus of the analysis was on the experimental set-up in VSU. Investment appraisal and risk assessment of protected cultivation were conducted in VSU and Cabintan project sites. Risk assessment was limited to destructions of the structure brought by strong winds and typhoons.
1.8	*Best practice guides for targeted crops (tomatoes, sweet pepper, eggplant, ampalaya and a leafy vegetable)*
	Best practice guides for tomatoes, sweet pepper, ampalaya, pechay and lettuce for open field and protected cropping, and for cabbage, kangkong and eggplant have been written for farmers. Best practice guides for seedling production and protected cropping were also written. IPM guides were produced for tomato, eggplant, sweet pepper, ampalaya, pechay and kangkong. In addition individual factsheets have been produced for each disease and invertebrate pest. The farmer guides have been translated into Cebuano, Tagalog, and Waray. A workshop with Philippine Department of Agriculture extension officers reviewed the materials. A smart phone or tablet App is being developed with these materials.
1.9	*Conduct basic vegetable production training with farmers in Typhoon Haiyan effected areas*
	Essentially all of the farmers in Leyte, Samar and Bilaran were in typhoon Haiyan affected areas, in total EWS trained 350 farmers and 215 had inputs in the 12 months after the typhoon and 1530 in total were trained since the typhoon.

Objective 2: To develop component technologies for management of key insect pests and disease

no.	Activity/Achievements/ comments
2.1	*Develop an inventory of southern Philippine vegetable pests (including insects, mites, diseases, nematodes and weeds)*
	Dr Borines and Prof. Gerona led surveys on plant pathogens and invertebrate pests and beneficials, respectively. Surveys were conducted in Leyte, Samar, Claveria, Bohol and Davao. Ms Justo surveyed for invertebrate pests and beneficials from trials in Claveria and from the FFSs in Davao. Other project collaborators also forwarded some specimens they were unsure of to VSU for identification. New records for Southern Philippines include: little leaf in ampalaya, *Clavibacter michiganensis* causing bacterial canker of tomato and *Septoria* leafspot in tomato in Cabintan, Ormoc and San Isidro, Leyte. It was found that the bacterial wilt in ampalaya is not caused by *Ewinia tracheiphila* as earlier reported but *Ralstonia solanacearum,* the same species as affecting tomato and other solanaceous plants. There were 16 diseases identified in tomatoes, 11 in sweet peppers, 8 in eggplant, 9 in ampalaya, 5 in pechay, 2 in lettuce and 1 each in kangkong and cabbage. Note: viruses and phytoplasms were identified via a complementary PCAARRD funded project.

	There were 16 invertebrate pests identified in tomatoes, 18 in sweet peppers, 14 in eggplant, 10 in ampalaya, 15 in pechay, 8 in lettuce and 15 in kangkong. Weeds were identified in the two mulch experiments in BISU, and were systematically identified in three trials at VSU, one each in tomato, eggplant and ampalaya. In only one experiment were nematodes sampled and indentified. Without a nematologist collaborating on the project, getting diagnostic support was difficult and needed to be separately resourced.
2.2	*Investigate the effectiveness of grafting for the control of bacterial wilt in tomatoes and sweet pepper*
	Sweet pepper varieties grafted onto a Bacterial Wilt resistant root stock increased survival [field: 35% non-grafted to 93-100% grafted and PC: 55% non-grafted to 100% grafted] and reduced incidence [field: 65% non-grafted to 0% grafted and PC: 45% non-grafted to 0% grafted] of Bacterial Wilt in both field and protected cropping structures over the non-grafted plants. Emperor and Sultan were the only varieties out of the five tested that had significantly increased fruit yield compared to the ungrafted Emperor control. Kamlong or tomato grafted on eggplant rootstock trial evaluated 6 varieties, (2 x determinate, indeterminate and semi determinate), on EG203 rootstock.
2.3	*Undertake efficacy trials of biological and botanical crop protection products or practices for key insect pests and diseases in Australia and the Philippines with a focus on sucking insects and viral diseases*
	A review of literature of botanical and biological insecticides was conducted as well as a more extensive review of Metarhizium as a biopesticide and an endophyte. Three field and protected cropping experiments were conducted on the potential of soil amendments to reduce bacterial wilt or fusarium in tomatoes. Chitosan, acetylsalicylic acid, streptomycin, silicon dioxide, *Bacillus thuringiensis* and *Bacillus subtilis,* potassium salts of phosphorous acid (Phospro), wood vinegar and various combinations were evaluated for control of bacterial wilt (*Ralstonia solanacearum)* in tomato in both field and PC. Cabbage waste as a soil amendment, *Bacillus subtilis* and Phospro were also evaluated for bacterial wilt management in sweet pepper in field and PC. Biofumigation with wild sunflower leaves, *Trichoderma*, and cabbage rotation were compared against cupric hydroxide fungicide for management of Fusarium wilt in tomato over three years. In vitro and in vivo evaluation of wood vinegar from different plant sources was evaluated against *Sclerotium rolfsii* and *Ralstonia solanacearum*. Efficacy trials were conducted with a range of biological or botanical products against invertebrate pests of lettuce, pechay, ampalaya, eggplant, sweet pepper, kangkong and tomato. Biological or botanical products evaluated for insecticide or acaricide activity included: vermitea, wood vinegar, *Bacillus thuringiensis*, *Metarhizium anisopliae*, neem, kakawate extract, garlic, onion, chilli, curry plant extract, lemongrass extract, 7-herb plus (combines extracts from seven plant species: lemongrass (*Cymbopogon citratus* Stapf), buyo (*Piper betle* L.), panyawan (*Tinosphora rumphii* Boerl), garlic (*Allium sativum* L.), bulb onion (*Allium cepa* L.), tobacco (*Nicotiana tabacum* L.) and hot pepper (*Capsicum annuum* L.), to which soap is added). NSW DPI conducted bioassays of various seeds coated with *Metarhizium anisopliae* against a sucking bug pest, and aphids for endophytic activity. Initial results showed promise but subsequent experiments found little insecticide activity. Recommendations were provided for management of all key pests of target crops drawing on relevant trial results and literature.

2.4	*Mitigate microbial and fungal field contamination of melons with washing and sanitation practices postharvest, prior to shipping to market*
	Over two seasons, harvested melons were assessed for microbial and fungal pathogens at fortnightly intervals through the harvest period of Mar-May. Over three seasons melon packing lines and melons from the packing lines were sampled for Listeria and Salmonella spp. pathogens. Positive samples were found and follow up meetings, involving the Food Authority in formal audits which resulted in improvements in packing line sanitation. Reports were prepared for the participating growers, results presented at broader melon industry meetings, and a factsheet prepared on food safe practices. Food Safety of Rockmelons - Find and Mind the Gaps poster and best practice guide was published
2.5	*Characterisation of* Fusarium oxysporum *isolates in melons and evaluate integrated disease management strategies*
	Disease surveys of melon crops (including (Australian grown) Asian melon varieties) have been conducted in all major melon producing areas in Australia including production areas of NT, NSW, QLD and WA. Two new diseases in melons in Australia were identified (Cucumber green mottle mosaic virus (CGMMV) and Melon necrotic spot virus (MNSV), and triggered national biosecurity incidence responses. A gene was identified that may explain the host range of some Fusarium strains Very few cases of *Fusarium oxysporum* were observed in melons, phylogenetic relationships between Australian and International reference isolates of *F. oxysporum* have been determined. *Fusarium oxysporum melonis* (Fom) isolates from Queensland & NSW were associated with Fusarium wilt symptoms – from surveys in all mainland states *Macrophomina phaseolina* & *Plectosphaerella cucumerina* were isolated from melons with rapid vine decline in NSW, Qld & NT *Pythium myriotylum* was isolated from wilting melon plants in NSW, Qld & NT *Verticillium dahliae* isolated from melons in Sunraysia district in combination with Melon necrotic spot virus and soil-borne fungal vector, *Olpidium bornovanus* Gummy stem blight has become more important in the past few years.
2.6	*Develop appropriate crop rotations for managing soil borne diseases*
	Recommendations based on literature and derived from major disease threats. Basics included in best practice guides
2.7	*Optimize the IPM systems for the key insect or disease crop pests in Philippines for open field and protected production of tomatoes, sweet pepper, eggplant, ampalaya and a leafy vegetable, and cucurbits in Australia*
	IPM sections have been included in each of the Best Practice Guides for both open field and protected cropping for tomatoes, eggplant, sweet pepper, ampalaya, pechay, kangkong and cabbage. Commodity IPM guides including tables of key invertebrate pests and diseases with information on identification, damage, monitoring and control options, have been developed for tomatoes, eggplant, sweet pepper, ampalaya, pechay, and kangkong. Short individual factsheets for each invertebrate pest (17) and disease/crop combinations (60) are published. IPM guides, and pest or disease factsheets are in translation into Tagalog, Cebuano, and Waray and are planned to be included in an App similar to the Pacific Pest App.

Objective3: To develop a commercial clean seed potato production system

no.	Activity/Achievements/ comments
	PCAARRD funding for the commercial seed potato production system through aeroponics as the Philippine counterpart to the ACIAR project was only approved and funds transferred in the last quarter of 2014**.**
3.1	*Develop and test an aeroponics seed potato production system*
	Low cost aeroponic systems and aeroponic growing techniques were optimized at QDAF. Three aeroponic systems were developed and tested at three geographical locations (UPLB, BSU and NMACLRC) in the Philippines .The system modified in Australia was refined for the Philippines situation at NOMIARC/NMACLRC, UPLB and BSU. **QDAF**- Four parent materials (tissue culture plantlets, stem cuttings, micro tubers and sprouts) tested under aeroponic system showed no significant difference in minituber production. However, plantlets produced maximum minituber (cv Sebago; 58 /plant). Four nutrient formulations tested for minituber production of cultivars Sebago and Nicola. Maximum numbers of mini tubers were produced using Farren's et al solution; for Sebago and Nicola, 700 and 900 per m^2 respectively. Incidence of *Fusarium* and *Pythium* root rot was observed in the aeroponic system. An effective control program was developed through management of temperature and fertigation. Mites, mealybugs and whitefly were managed through timely application of insecticides. **UPLB** - Nutrient solutions developed for hydroponics in Philippines, were compared to published solutions and a formulation optimized for Australian conditions. The Philippine solutions were then adjusted and reassessed to find an optimal solution. Ammonium nitrate in the CIP formulation was replaced, and the nutrient solution developed reduced the solution cost from ₱15 to ₱1 per litre. This also resolved the problem of lack of availability of ammonium nitrate in the Philippines. Root enhancing hormones were tested and proved effective in improving rooting of the plant, when applied at specific growth stages. **NMACLRC** – All types of parent material of cultivar Granola produced more minitubers than conventional production. Minituber parents produced 19 minitubers, micro-tubers 20 and stem cuttings 17, while conventional production only produced 12 minitubers. Simultaneous planting was done in three sites namely UPLB, BSU and NMACLRC using the developed formulation for aeroponics. Morethan 40 tubers/plant were obtained from the trial including mini- and micro-tubers.
3.2	*Evaluate and improve field performance of potatoes grown from aeroponics and facilitate commercial development of clean seed production using aeroponics*
	QDAF - studies revealed that varieties produced on an average of 40-60 minitubers per plant, (Nicola-48, Sebago-55, Atlantic-45, Kipfler-40, Pink Fir Apple-42 and Blue sapphire-60) in the aeroponic system. Each tuber weighed 8-10 g. More uniform sprouting of minitubers was observed in cold stored tubers when compared to diffused light storage at room temperature. Yield of 21 t/ha was achieved from aeroponically grown seed tubers of cv Sebago using standard commercial spacing (20 cm) in a field trial conducted at Atherton Tableland, Queensland, Australia. Yield was increased 30 to 39 t/ha with closer in-row spacings (10 and 15cm). **NMACLRC**–Aeroponic system has been modified for better aeration and cooling inside the facility. Granola and two new varieties Astra and Atlantic were tested in this system and produced 25 minitubers; whereas varieties Atlantic and Granola produced 17 minitubers/ plant. Each tuber weighed 8 g. Pot experiment, results showed that aeroponically grown seed produced larger size and greater number of tubers/plant than conventionally produced seed potatoes and cuttings. **UPLB and BSU** A new unit was developed, housing 48 plants compared with the previously unit housing 12 plants. The new unit also can maintain cool temperatures within the root zone and have increased the minituber production. Cutivars Raniag and Granola produced 10 and 24 minitubers/plant and Similarly Granola and Raniag produced 21 and 15 minitubers /plant. However, cultivar Igorota produced no tubers at either location.

	BSU Results from field trials to compare yield using planting materials derived from aeroponics with that of the conventional method could not achieved owing to frequent flooding of the experiment site and typhoon damage. Economic analysis of the aeroponic seed potato production systems at NMACLRC and QDAF indicated that the aeroponic system requires 2.2 times more initial investment and in turn increases production by 9 times compared to conventional seed production, and thereby it is possible to reduce the seed cost by 30% . In future commercialization of the NMACLRC aeroponic facility will be able to meet 15% seed demand of Mindanao farmers. Research paper (1) fact sheet (1) web article (2) are published and 2-minute video on aeroponic technology is planned for upload on DAF website.

Objective 4: To develop component technologies for management of key agronomic constraints for each target site in Leyte, Bohol, Samar and Mindanao

no.	comments
4.1	*Identify optimal varieties of tomatoes, sweet pepper, eggplant, ampalaya and a leafy vegetable*
	General Head lettuce and *Greenspan* leafy lettuce were identified as superior varieties for Leyte (VSU) *D-Max* was previously identified as a superior tomato variety for Leyte in the Phase 1 Protected Cropping project MOSCAT/USTP identified processing and fresh tomato varieties In one of the Davao FFS they evaluated tomatoes tolerant to TYLCV against the locally preferred susceptible variety. No new trials were planted (Variation 2). 5 x lettuce trials (VSU) 1 paper submitted in Acta publication, 2 x tomato (MOSCAT/USTP).
4.2	*Evaluate net covered low tunnel protected cropping structures in Leyte*
	Leyte: VSU: 6 x trials; Farmers:16 tunnels on 5 farms Samar: 4 x tunnels on farms; Bohol: 3 tunnels (BISU) Recommendations included in commodity best practice guides. Trials were conducted at VSU comparing low tunnel covered with net against open field with methods of raising seedlings (lettuce, kangkong and pechay) and organic soil amendments (lettuce). At BISU a lettuce seedling raising trial was also conducted under low net tunnel compared to field grown and another two trials on pechay in the high/house-type protected structure compared to the open field.. Recommendations are made in the best practice guides
4.3	*Evaluate whether the Leyte protected cropping structure designs (HORT/2007/066) are appropriate for Samar and Bohol*
	Established low and high tunnel in Samar and Bohol. Recommendations are provided in the best practice guides.
4.4	Removed in variation 2
4.5	*Improve overall crop water use efficiency using appropriate water delivery systems and soil moisture management for open field and protected production*

	Water use efficiency trials were carried out on tomato in Leyte and Claveria; on ampalaya, lettuce, pechay and pepper in Leyte, and on lettuce and cabbage in Claveria. A trial was conducted in Leyte to compare different water delivery systems which were manual sprinkler, drip bottle and drip hose methods on tomato, ampalaya, and sweet pepper under house-type strucutre. On pechay and lettuce were rain fed, manual sprinkler, and 2, and 4 drip lines under net tunnel structure. In USTP, 2, 3, 4 drip lines, and manual sprinkler were done on lettuce and cabbage.
4.6	*Compare seedlings produced in cells, bare-rooted seedlings and direct seeding crop establishment for open field and protected production*
	VSU: 4 completed; 1 paper submitted in Acta publication NwSSU: 1 trials using pechay. BISU had 2 trials for pechay in low net protected vs open cultivation aside from the high structure with UV-treated plastic vs open field MOSCAT/USTP: 3 trials completed A trial was conducted at VSU to compare four methods of raising lettuce, pechay and kangkong seedlings and evaluated in the open field and under protected cropping. The seed raising methods included: pricking from the seed box into seedling tray then transplanted to the field; sowing seeds in seedling tray before transplanted to the field bare rooted; sowing seeds in seedling tray then transplanted to the field with soil at the base and direct seeding in the field. The trials were repeated in pechay and lettuce for confirmation of results. The trial on methods of raising seedlings was replicated in BISU using pechay and lettuce as test crop.
4.7	*Evaluate plastic mulch, organic mulch and soil organic amendments on weed control, water use efficiency and crop performance for open field and protected production*
	VSU: 7 completed using organic, plastic amendments and biofumigation; 1 paper submitted in Acta publication Video complete, Grafting: tomato and sweet pepper, Ampalaya, tomato, sweet pepper (organic, plastic), Lettuce, pechay (organic). Bohol: 3 trials. Claveria: 3 trials Mulch trials were conducted with ampalaya, pepper and tomato crops at VSU. One trial compared 4 organic mulches and another compared 6 different coloured plastic mulches. Each trial was conducted simultaneously under protected cultivation and in the open field. BISU conducted a natural mulch trial for ampalaya, eggplant and tomato. The VSU plastic mulch trial was replicated at BISU on ampalaya and eggplant, and a subset of the natural and plastic mulches was conducted at MOSCAT/USTP on cabbage and tomato. Soil amendment trials were conducted at VSU with lettuce, pechay, tomato and kangkong. Growth promotants were also evaluated in lettuce and tomato.
4.8	*Investigate the use of aquaponics for growing leafy vegetable crops in Australia*
	PGPR x aquaponics: 8 papers published,1 x PhD thesis Determined an inoculation method (4 papers published) Tested using fish effluent as fertilizer (2 papers published - 1 in revision) Conducted inoculation experiment in commercial facility (1 paper published) Constructed an IAA- mutant (1 paper)
4.9	*Evaluate alternative protected cropping structure designs to withstand large typhoons in Leyte*

	Conducted 5 trials with the new structures. One of the five was exposed to strong winds which it resisted. High winds were experienced in January 2016 winds reached between 68-84 km/hour over 5 days, and in February (peak 104 km/hour). The metal hoop and net covered structure survived unexpected high winds in January and February 2017 which destroyed the neighbouring structures at VSU.

Objective 5: To develop sustainable ICM by building research capacity in Leyte, Bohol, Samar and Mindanao

no.	Activity/Achievements/ comments
5.1	Removed in Variation 2
5.2	*Audit and undertake a needs analysis of current laboratory diagnostic facilities and capacity, information and training resources*
	At the inception meeting each group nominated priority equipment and training they needed to deliver on the workplans for the project Objectives that were not already provisioned in the respective budgets. As a team we agreed that funds in the capacity building budget would need to cover more than laboratory equipment and diagnostic capability. In addition Len Tesoriero and Sandra McDougall reviewed the capacity for invertebrate pest and disease diagnostics at the collaborating universities and identified high priority purchases. For the audit, laboratories at VSU, UPLB, BISU, USTP/MOSCAT and NwSSU were visited by either Len Tesoriero and/or Sandra McDougall. UPLB has specialist taxonomists and laboratories for diagnostics. VSU has some basic facilities and routinely did diagnostics based on morphology for entomology, plant pathology, nematology, weed identification. BISU, USTP/MOSCAT and NwSSU have very little laboratory equipment and no significant expertise in diagnostics. A process was agreed by the project team for specimen identification. Specimens were to be sent to VSU for identification and that Lucy or Reny would then contact specialist taxonomists at UPLB if necessary. An equipment and training priority list was completed for each collaborating group. High priority equipment and training has been provided as the need or opportunity has arisen.
5.3	*Provide laboratory equipment and training*
	Within the annual capacity building budget and in consultation with the whole team or at times with the project leaders (Sandra, Gordon & Zenaida) equipment was purchased for and distributed to team members. The initial set-ups included: USB x200 microscopes (x11) for all collaborating groups, stereo microscopes (x5) for the university collaborators A series of field guides for the target crops and a large number of ICM related information resources were provided as PDFs on USB memory sticks. Collection vials, hand lenses and other crop monitoring tools were provided to all collaborators. Other equipment that was required included cameras (NwSSU, BISU, USTP/MOSCAT & LFPI), computers (x7), tablet for LFPI, irrigation monitoring equipment (VSU), Laminator (VSU) and two data projectors (VSU & BISU). [the project budget was unable to fund molecular diagnostic techniques however another complementary project was funded by PCAARRD for the molecular component of the vegetable disease survey]

5.4	*Facilitate train the trainer type workshops* [At least 4 Project proposals submitted to PCAARRD; 5 x training workshops conducted]
	Three proposals were submitted to PCAARRD in 2013 and three more submitted 2017. 1. Potato Seed Production through Aeroponics Phase I: Technology Development [funded] 2. Identification and Transmission Studies on Major Diseases of Vegetables in Eastern Visayas [funded] 3. Inventory of Destructive and Beneficial Arthropods and Alternative Arthropod Pest Management in Vegetables under Protected Cropping in the Philippines [not funded] 4. Bring Pest Management to the Community [funded – yet to commence] 5. Sustainable Organic Vegetable Production under Protected Cultivation in Eastern Visayas, Philippines [in review] 6. Community Based S & T Based Farm on Vegetable Production in Leyte and Southern Leyte [in review] Our project found that we needed to focus on developing the ICM team's skill and hence conducted training workshops primarily for the team. We also ran practical training workshops with farmers, extension workers and including other members of our team in field situations primarily to develop practical understanding of the issues faced by farmers. 1. ICM team training: 2. ICM workshop (August 2013) 3. Biometrics training (June 24-27, 2014) 4. Disease/agronomy training (July 27-August 5, 2014)* 5. IPM training (April 24-30, 2015)* 6. ICM Master class (18-22 Jan 2016) 7. Scientific Writing (6-10 June 2016) * multiple sites with farmer training but including other team members at each site Pesticide residue testing workshop was conducted in Davao with small holder farmers from the FFS training and with the Value Chain team.
5.5	*Establish, review and refine at least one coordinated trial program across multiple sites*
	VSU, USTP/MOSCAT & BISU have conducted both mulch trials and seedling raising trials to the same protocols.
	   Farmer field school training in seedling production, bed mulch and crop growth

6 Key results and discussion

Small holder farmers- farmer field schools

To achieve the objective of increasing vegetable profitability of small holder farmers through integrated crop management a number of different strategies were taken to engage with farmers, with field days, demonstrations and farmer field schools.

In the Philippines agricultural extension is delivered by extension staff who are employed by the Local Government Units (LGUs), with some support of the Agricultural Training Institutes associated with the Department of Agriculture, University based staff and via non-government organisations.

The Farmer Field School (Van den Berg and Jiggins 2007) approach involves a trainer or facilitator meeting weekly with a group of farmers, usually over a cropping cycle. At each weekly session they focus on pre-agreed training topics related to the crop stage and often with a training plot to both practice and demonstrate the new practices they are learning. The intensity of the training requires significant resources that local agricultural offices often do not have. For this project three collaborators conducted farmer field schools: East West Seeds training group, Landcare Foundation Philippines Inc. (LFPI) and Vale Justo, University of Philippines Los Baños.

Initially it was planned that LFPI would use their strengths in social engagement to organize training groups of small holder farmers with the LGUs prepared to co-invest or 'counterpart' and with a commitment to support the training in vegetable ICM. EWS were to conduct the training based on their already developed vegetable production curriculum and a model of providing some basic inputs to ensure each farmer participant can 'replicate' the training on their own plot of land. The training curriculum was to be modified based on results from the agronomy and crop protection research trials. This intensive basic vegetable production FFS was identified as needed in Leyte, Samar and Bohol. In northern Mindanao and Davao vegetable production was more established and the limitations were identified as being more related to crop protection, hence the crop protection specialist, Ms Vale Justo planned to engage local farmers and run a small number of FFS without the need to provide basic inputs.

There was not enough funding allocated for the project to cover the costs of all the inputs for each participant farmer and FFS running costs, so co-investment from LGUs was critical for each FFS. Typhoon Haiyan intervened in the first year of the project requiring an adaptation of the training model in the affected areas to shorter block sessions and use of co-investment from aid organisations rather than the LGUs in some situations. The collaborative approach planned to operate between EWS and LFPI proved difficult largely owing to delays in funds reaching LFPI that caused friction due to organizational cultural differences of a commercial company (EWS) with a training team based in Leyte ready to commence training as soon as they agreed to collaborate on the project, compared to the not for profit organization (LFPI) based in Northern Mindanao, requiring project funds to establish and support an engagement team in Leyte and Bohol. Responsibility for FFS delivery was divided after the first round of joint-run FFS in Leyte and Bohol, with EWS taking Leyte and Samar, and LFPI taking Bohol.

In total 2072 small holder farmers were trained within a FFS across Bohol, Leyte, Samar, Davao and Bilran (Table 1). 968 were provided basic inputs and 47% were women farmers. Bilran, included after insurgency activity in Samar prevented further expansion of training in accessible areas, is an island close to both Leyte and Samar with similar social demographics that was also affected by Typhoon Haiyan. No FFS were conducted in northern Mindanao because most vegetable farmers had participated in basic FFS training previously, new agribusiness opportunities were resulting in large proportions of farmers switching to maize and tobacco production, and the project research did not have extendable results until close to the end of the project.

Table 1. Summary of farmer field school (FFS) training of small holder farmers under vegetable ICM project between 2014–17

Region	No. FFS	inputs	Training only	Total Trained	% female
Bohol	12	368	82	452	49%
Leyte	12	353	653	1006	48%
Samar	7	180	200	380	39%
Bilran	5	67	88	155	55%
Davao	3	0	79	79	51%
TOTAL	**39**	**968**	**1102**	**2072**	**47%**

The form and structure of each FFS varied between the delivery partner, based on their strengths, and through consultation with the regional and local government units on the specific needs of the local farmers. Co-investment from the LGUs was sought to ensure commitment to the training program and improve chances of adoption. Farmer participants needed to commit land and were “validated” for adoption by the training teams, again to improve impact and to reduce risk of attendance at training for ‘free food’ or purely the social aspect.

The East West Seeds training model had a small group of trainers, all with university agricultural, horticulture or crop protection degrees, who ran the practical training sessions and then a trainer who visited the participant farmers weekly at their farm plot to check and mentor the farmers with their vegetable production. Once a crop cycle was completed they moved to a new group of farmers with some in-frequent followup to previously trained farmers.

East West Seeds successfully implemented 24 FFS involving 1573 farmers over three Provinces. 632 were provided basic inputs and they leveraged an additional ₱3,455,455 (approximately $115,182) from LGUs or aid agencies for the training. The first farmer field school in each Leyte and Bohol was jointly organized and trained by both EWS and Landcare.

Landcare (LFPI) used the project budget and co-investment from LGUs totaling ₱2,641,393 (approximately $88,046) to provide training in a communal learning area and inputs for an agreed number of small holder farmers, and included other farmers in the training without inputs. Each farm group participated in a season long FFS with weekly training sessions, and weekly or fortnightly visits and mentoring sessions to the end of the project or for at least a year. Some cross-site visits were organized between farmer groups to learn from each other. Some of the earlier formed farmer groups also participated in farmer business school training.

Landcare successfully implemented 12 FFS involving 482 farmers in the 7 municipalities (Table 1), 393 with inputs. Because of the inputs provided, the rate of individual adoption is considered high at 81.41% and thereby provided additional income for farmers.

Landcare's strength lay in social engagement and 'embedding' practice change within the local decision making structures. To this end LFPI worked with the Municipal Agriculture office to allocate an extension staff member to the ICM project with additional funding to support the ICM project activities of themselves and to six other local extension staff to engage with 12 farmer groups, from seven municipalities in the Province of Bohol. Through participation in the project they were enabled to develop their technical and social skills and capacity (Table 2). At the end of the project these staff have returned to their substantive positions and are involved in further roll-out of ICM mentoring and training under separate Philippine government funding. Two co-funded LFPI ICM facilitators and the LFPI Director developed their technical vegetable production skills by participating in the ICM project training as well as the co-running of the initial FFS with EWS staff. Bohol Island State University staff also provided technical assistance with many of the Bohol FFS. The whole team participated in all the training in Bohol as part of the ICM project. The LFPI ICM facilitators also utilized their skills with extending ICM training the conflict areas of western Mindanao under the ASEM/2012/063 project.

Table 2. Perceived competencies developed by LGU Extension Facilitators

Competencies developed with ICM	Impact to delivery of extension services
Recommended agronomic and horticultural practices	Integrated in LGU training modules for farmers
Pest and diseases identification and management	Holistic approach in providing management/control options to give recommendations to farmers
Facilitation skills	Gain more confidence and employed innovative training methodologies
Soil and water conservation	Integration of approaches in sustainable upland development programs of LGU

The LFPI facilitators helped facilitate each farmer group to collectively organize; ten became legal entities with agreed organizational policy and manual of operation. Having legal status is an essential requirement in accessing livelihood assistance from the government. With this, access to government extension services and livelihood support programs also improved. Assistance received has been in the form of seeds, farm tools and machinery, and farmer business management training. Five of these groups have successfully set up their own community revolving fund. The revolving funds are based on farmers paying into the fund the cost of the inputs provided by the project after harvest, and thereby having finance available for farm inputs for succeeding cropping seasons or new farmers.

Ms Vale Justo, Crop Protection Specialist from University of the Philippines, Los Baños, with a long history in delivering the traditional IPM FFS consulted with local Davao City agricultural extension and with University of the Philippines Mindanao staff to identify three vegetable farmer groups to conduct FFS training with an emphasis on improving crop protection practices. After conducting the baseline survey, the crop and focus invertebrate pests and diseases were identified and curriculum agreed. The FFS focused on pechay, tomato, and ampalaya (bitter melon) and eggplant respectively. Training topics covered crop protection strategies from variety choice (disease resistant varieties), monitoring and identification of pests, diseases and beneficials, cultural control, use of pesticides and biologicals as well as good basic soil management, nutrition and watering practices, sanitation, harvest and business management practices for vegetable production. Over three season-long FFS 79 small holder farmers were trained and conducted small research experiments to compare the new practices they were learning about against their current practices. The last two groups were also focus groups for the Value Chain project (AGB/2012/109) and received farmer business school training and were working as a cluster to supply Davao City markets.

Demonstration farms

Demonstration farms were established on farmer sites that were situated in strategic locations at each of the regions in the southern Philippines. These farms were found in Baybay, Leyte; Tacloban, Leyte; Bontoc, southern Leyte; Sta. Margarita, Samar; Pilar, Bohol; and Claveria, Misamis Oriental. Each farm was provided with some inputs like seeds, fertilizers and protective structure/s, and technical services such as pest and disease consultations and horticultural techniques. Farmer's field days (FFDs) were conducted in conjunction with some of the project team at each farm to showcase the technologies and practices. These farms also served as learning sites for farmer visitors and other local entrepreneurs interested in vegetable production.

The farmer-cooperators actively participated in the activities of the project like training and seminars, and a few of the more experienced farmer-cooperators became farmer-trainers and a focal point for local vegetable farmers. These farmer-cooperators were happy being involved in the project as it enhanced their productivity, income, and improved their farm activities.

Demonstration farmers: Rafael Payod (Samar), Albert Rosilio, Boie Gerona and Wilson Dupa (Leyte)

Small holder farmers- baseline information

The top eight major vegetable crops planted by both non-FFS and FFS farmers include: eggplant, bitter gourd, beans, sweet pepper, pechay, squash, tomato and okra (lady finger). The methods of raising seedlings vary according to the crops planted. Most of the farmers till their land as part of the land preparation with draft-animals. Most farmers use inorganic fertilizers in their vegetable production. Some farmers practise pruning and trellising on selected plants and the main reasons for pruning are to increase yield, and to control pest and disease infestation. The average distance of farms to market for both non-FFS and FFS respondents is close to 10 kilometers with an estimated travelling time of around 26 minutes. The vegetable products are mostly delivered to the buyer.

More than half of the non-FFS farmers are satisfied with their production output while only 32% of FFS are satisfied with their current output. More FFS farmers than non-FFS farmers believe that in the next five years their production output will considerably improve. Many farmers are aware and willing to adopt protected cultivation but only very few actually adopted the technology mainly because of the added cost and uncertainty in its financial gains. For the follow-up survey, there is a noticeable increase in level of satisfaction in vegetable production among the FFS group. This suggests that the project was able to encourage vegetable production among farmers trained under the farmer field school compared to the non-FFS group.

Assessing gender roles in farming, the respondents reported that men mostly focused on labour intensive activities in vegetable farming such as land preparation, irrigation, trellising and taking products to the market. The role of women in vegetable farming mostly focused on record keeping and monitoring the sales of the vegetable enterprise. Both men and women participate with harvest. Results also point out that it is usually men who decide on which crop to plant.

In terms of farm income, the FFS group had a relatively low average income compared to the non-FFS group from the baseline survey. However, the situation changed in the follow up survey. The FFS group had higher income from vegetable production compared to the non-FFS group. The change in household farm income among FFS group is an increase of around 50%. This is a positive indication that the FFS training improved small holder farm profitability. In terms of impact, the method of difference shows that the impact of the ICM FFS generates an increase in farm income of ₱ 4,346.43. Given that the followup was less than two years post training, the change in income can be considered as a short term impact of the project. It is recommended to do another impact assessment two or three years post project completion. Aside from the economic impact, social and environmental impacts should be assessed.

Small holder farmers- gross margins/ profitability analysis

Gross margin analysis has been conducted to investigate whether it is profitable to grow vegetable crops under protected structure as compared to the conventional open field method of growing vegetables. Gross margin analysis was made of selected vegetable crops experimented under different protected cropping structures compared to open field production. With the gross margin as a measure of profitability, we only take into account the variable costs incurred in the production. This analysis excludes the cost of the structure. The focus of the analysis was mainly on the experimental set-up in Visayas State University. Results showed that vegetables grown under protected cultivation had higher yields translating into higher profit as compared to open field cultivation. Tomato, sweet pepper, lettuce and pechay cultivated under protected structures had higher gross margins as compared to open field cultivation.

For the non-experimental sites, we utilized the data from the baseline survey to assess the factors affecting profitability of small scale vegetable production in the Visayas region. The study focused on the four main vegetables: tomato, sweet pepper, eggplant and bitter gourd. These vegetables are commonly planted in Bohol, Leyte and Samar. Profitability of vegetable production was assessed using gross margin analysis while regression analysis was used to determine the factors that influence profitability of vegetable production in Bohol, Leyte and Samar.

The profitability of vegetable farming is dependent on the right balance of cropping, marketing and management practices. Results of the analysis shows that among the three areas considered, Bohol farmers had the highest gross margin among the four vegetable crops. To reduce the variability in farm gate price, the official price of vegetables published in the Bureau of Agricultural Statistics was used. Samar consistently showed that its gross margin is relatively lower compared to Leyte and Bohol. This suggests that more has to be done in Samar to increase its profitability.

Results from correlation analysis shows that area planted is positively associated with the gross income of farmers. Increasing profitability of vegetable farming is possible with a larger farm area. Growing more than one high value vegetable crop also significantly affected profitability, growing both eggplant and sweet pepper was highly profitable although this may not be the case if farmers grow both these solanaceous crops for multiple years given they share some common pests and diseases. Another factor that significant influenced productivity was the market outlet. Farmers can get higher prices and hence higher profit if they sell directly to the market rather than using an intermediary.

These results are complemented with the regression analysis suggesting that farm area, cropping practices and market outlets are the significant factors affecting profitability. Results suggest that holding other factors constant, increase in farm area translates to higher profitability of vegetable production. However since the analysis focused on small-scale vegetable production, increasing farm area is not the immediate solution to increase profitability.

Results show that aside from farm area, cropping practice such as intercropping or growing a number of different crops can help increase profitability. The challenge is to identify which vegetables would perform better in an intercropping set-up. With intercropping, farmers can maximize the yield from their small farms. In addition to cropping practices, market outlet also significantly affects profitability. This suggests that if farmers can have better access to market, this will positively affect profitability. As would be expected, the further the farm was from the market, and the poorer the quality of the road, the greater the negative impact on vegetable quality. The descriptive analysis shows that on average vegetable farmers are relatively far from market. Hence, improving road infrastructure is something the government can do to help boost the profitability of vegetable farmers.

Protected cropping technology has been introduced for year-round production of vegetables, to increase production and quality during the rainy season when field production tends to fail or have both poor quality and low yields. However, small scale farmers are reluctant to adopt this technology due to the relatively large investment cost and the risk associated with extreme weather conditions, such as typhoons. Hence, a study to evaluate protected cropping was conducted in Leyte, to evaluate the profitability and assess the relative risk of protected and open-field cultivation to extreme weather conditions such as tropical cyclones, El Niño, La Niña, and strong winds.

Results show that protected cultivation generates higher yields compared to open field cultivation. At the Baybay site, steel-type high strength tunnel covered with polyethylene plastic is the most viable investment as it attained the highest net present value (NPVs), benefit-cost ratios (BCRs) and internal rate of return (IRRs). It also had the earliest payback period across different climatic scenarios. At the Cabintan site, the low tunnel structure was the most viable when a high-end market was established. Market outlet is one of the critical factors affecting profitability and pricing. Given the potential of protected cultivation in minimizing crop failures, it is recommended that the government and private sector shall extend financial and technical assistance to farmers to assist them in getting access to capital to invest in protected cropping structures. Investors should be covered with crop and structure insurance as risk of crop failure and loss of capital is high during inclement weather conditions, which are relatively common in Leyte.

Philippine insect and disease inventory

Regular monitoring of invertebrate pests and plant diseases was conducted at the vegetable trial site at the Visayas State University in Baybay City. Nearby towns like Hilongos, Hindang and Bato and Ormoc City; Bontoc, Southern Leyte, Ormoc City and the ACIAR-ICM trial sites in Bohol and Calbayog were also surveyed. The related PCAARRD-funded “Identification and Transmission studies of vegetable diseases in Eastern Visayas” conducted additional surveys for diseases and potential insect vectors in other municipalities and cities in Eastern Visayas. Additional surveys targeting detection of phytoplasma diseases and a few viruses were conducted.

Invertebrate pest and beneficial specimens were returned to the laboratory for identification if not recognised in the field. Disease specimens were collected and brought back to the laboratory for examination and isolation of the pathogen. Symptoms were characterised, described and recorded. The associated pathogens were also documented and described. Diagnosis for some obligate fungal pathogens such as downy mildew was based only on symptoms and signs of the pathogen. Pathogenicity tests were conducted for most isolates. Tomato, eggplant and pepper seedlings were maintained in the screenhouse for pathogenicity testing. Immuno-diagnostic strips for *Ralstonia solanacearum* and viruses attacking tomato and pepper were obtained from Pocket Diagnostics and AGDIA. Only a few viruses of tomato and pepper were observed occurring at the VSU experimental site, and were diagnosed based on symptoms and the use of immunostrips. Table 3 summarises all the diseases found on vegetables in the central and southern Philippines.

The major diseases affecting tomato in Eastern Visayas are bacterial wilt, bacterial spot and leaf mould while fusarium wilt more frequently occurred in Claveria. Among these diseases, bacterial canker, target spot, septoria leaf spot and tomato stunt/little leaf are emerging ones.

The diseases observed in pepper include: frogeye or Cercospora leafspot, fusarium wilt, bacterial wilt, bacterial spot, damping off, anthracnose, leaf blight and leaf mosaic. Six fungal pathogens (*Cercospora capsici*, two *Fusarium* species, *Pythium* sp., *Choanephora cucurbitarum*, and *Colletotrichum* sp.), two bacterial pathogens (*Ralstonia solanacearum* and *Xanthmonas euvesicatoria*) and cucumber mosaic virus were so far monitored from pepper.

Nine diseases were monitored from eggplant which included shoot blight and fruit rot due to *Phytophthora* sp., bacterial wilt due to *Ralstonia solanacearum*, leaf blight due to *Choanephora cucurbitarum* and two kinds of wilts due to *Fusarium* sp and *Sclerotium rolfsii,* powdery mildew caused by *Erysiphe cichoracearum* and Cercospora leaf spot caused by *Cercospora melong*enae. Choanephora blight was recorded only in Pilar Bohol, but all the plants in that surveyed farm were infected and the disease was quite serious. The Phytophthora species affecting eggplant was confirmed to be *Phytophthora nicotianae* and *Phytophtora parasitica* based on PCR and RFLP analysis. Eggplant yellows was newly documented and is suspected to be due to *Phytoplasma*. Confirmation of the pathogen through molecular methods still needs to be conducted.

Nine diseases were monitored from bittergourd which included damping off caused by *Pythium* sp., Fusarium wilt caused by *Fusarium oxysporum f. sp. momordicae*, bacterial wilt caused by *Ralstonia solanacearum*, sclerotium wilt caused by *Sclerotium rolfsii*, downy

Table 3. Summary of diseases by vegetable found in central and southern Philippines

Group	Common name	Scientific name	Tomato	Sweet pepper	Eggplant	Ampalaya	Pechay	Lettuce	Kangkong
Bacteria	Bacterial Canker	*Clavibacter michigenensis subsp. michiganensis*	☑						
Bacteria	Soft rot	*Pectobacterium carotovorum*					☑		
Bacteria	Tomato pith necrosis	*Pseudomonas spp*	☑						
Bacteria	Bacterial wilt	*Ralstonia solanacearum*	☑	☑	☑	☑			
Bacteria	Bacterial spot	*Xanthomonas axonopodis pv vesicatoria/*	☑	☑					
Bacteria	Bacterial spot	*or Xanthomonas euvesicatoria*	☐	☐					
Bacteria	Bacterial spot	*(old name: X. campestris pv. vesicatoria)*							
Fungal	Damping off	*Pythium*		☑		☑			
Fungal	Blight	*Phytophthora sp.*		☐		☑	☑		
Fungal	Late blight, stem and leaf blight	*Phytophthora infestans*	☑						
Fungal	Phytophthora blight and fruit rot	*Phytophthora nicotianae* and *Phytophtora parasitica*			☑				
Fungal	Basal stem rot/ fruit rot	*Phytophthora capsici*		☑			☑		
Fungal	Stem rot	*Rhizoctonia solani*	☑						
Fungal	Fusarium wilt	*Fusarium oxysporum f.sp. momordicae*	☐		☐	☑			
Fungal	Fusarium crown & root rot	*Fusarium oxysporum f.sp. radices-lycopersici*	☑		☐	☐			
Fungal	Fusarium wilt	*Fusarium oxysporum f.sp. lycopersici*	☑	☑	☑	☐			
Fungal	Fusarium wilt	*Fusarium oxysporum f.sp. melongenae*			☑				
Fungal	Fusarium wilt	*Fusarium solani*	☑		☐				
Fungal	Sclerotium wilt/ Southern blight	*Sclerotium rolfsii*	☑	☑	☑	☑	☑	☑	
Fungal	Sooty mould	*Capnodium spp.*		☑					

Group	Common name	Scientific name	Tomato	Sweet pepper	Eggplant	Ampalaya	Pechay	Lettuce	Kangkong
Fungal	Pechay Cercospora Leaf spot	*Cercospora brassicicola*		☐			☑		
Fungal	Frog-eye spot/ Cercospera leaf spot	*Cercospora capsici*		☑	☑				
Fungal	Cercospora Leaf spot	*Cercospora melongenae*		☐	☑	☐			
Fungal	Leaf and fruit spot	*Cercospora citrullina*		☐	☐	☑			
Fungal	Lettuce leaf spot	*Cercospora sp.*		☐	☐	☐		☑	
Fungal	Leaf mould	*Pseudocercospora fuligena*	☑		☐	☐			
Fungal	Septoria (leaf) spot	*Septoria lycopersici*	☑						
Fungal	Phomopsis blight	*Phomopsis vexans*			☑				
Fungal	Powdery mildew	*Leveillula taurica*		☑					
Fungal	Powdery mildew	*Oidium neolycopersici*	☑	☐	☐				
Fungal	Powdery mildew	*Erysiphe cichoracearum*	☐	☐	☑				
Fungal	Chonaephora/Leaf Blight	*Choanephora cucurbitarum*		☑	☑		☑		
Fungal-like	White rust/White Blister	*Albugo ipomoeae-panduratae*							☑
Fungal-like	Downy mildew	*Pseudoperonospora sp.*				☐	☑		
Fungal-like	Downy mildew	*Pseudoperonospora cubensis*				☑	☐		
Fungal	Target f spot	*Corynespora cassiicola*	☑			☑			
Fungal	Early blight	*Alternaria tomatophil** (inventory has *solani)*	☑						
Fungal	Leaf spot	*Curvularia lunata*					☑		
Fungal	Anthracnose	*Colletotrichum capsici*		☑					
Fungal	Anthracnose	*Colletotrichum coccodes*	☑	☐					
Fungal	Clubroot	*Plasmodiophora brassicae*							☑

Group	Common name	Scientific name	Tomato	Sweet pepper	Eggplant	Ampalaya	Pechay	Lettuce	Kangkong
Viral	CMV	*Cucumber mosaic virus*	☑	☑					
Viral	TSWV	*Tomato spotted wilt virus*	☑						
Viral	TYLCV	*Tomato yellow leaf curl virus*	☑						
Viral	TMV	*Tomato mosaic virus, Tobacco mosaic virus*	☑						
Viral	Namamarako	CABYV				☑			
Mollicutes - bacteria	Tomato stunt/little leaf	*Phytoplasma*	☑						
Mollicutes - bacteria	Eggplant Yellows	*suspected Phytoplasma*			☑				
Mollicutes - bacteria	Little leaf/witches' broom	*Phytoplasma*				☑			
Nematode	Root knot	*Meloidogyne incognita* and other *Meloidogyne species*	☑						

mildew caused by *Pseudoperonospora cubensis*, Cercospora leaf spot caused by *Cercospora citrullina*, target spot caused by *Corynespora cassiicola*, “Namamarako” disease or cucurbit aphid-borne yellow virus (CABYV) and little leaf/witches broom caused by *Phytoplasma*. High incident diseases were associated with the pathogens *Fusarium sp., Ralstonia solanacearum* and *Pseudoperonospora cubensis*.

Kangkong was affected by white rust caused by *Albugo ipomoeae panduratae*, pechay by *Sclerotium rolfsii* fungus, bacterial soft rot caused by *Pectobacterium carotovorum pv. Carotovorum,* Choanephora blight, basal stem rot caused by *Phytophthora* sp., and downy mildew caused by *Peronospora parasitica*. Three diseases were found infecting cabbage, namely, clubroot caused by *Plasmodiophora brassicae*, black rot caused by *Xanthomonas campestris* and Alternaria leaf spot caused by *Alternaria brassicae*. Three diseases were monitored from lettuce, namely: Sclerotium rot, target spot and surprisingly, a wilt disease which turned positive to *Ralstonia solanacearum* using an immunodiagnostic strip of the pathogen and which is considered to be an emerging disease.

Invertebrate survey

Invertebrate pests surveyed from research, demonstration and farmers’ fields were collected and when the species was not readily recognized in the field, returned to the laboratory for identification. Table 4 shows the arthropod pests surveyed on the target vegetables: tomato, sweet pepper, ampalaya/bittergourd, eggplant, pechay, lettuce, and kangkong respectively.

In tomato, sixteen invertebrate pest species were recorded, the most common and damaging were: 12-spotted beetle (*Epilachna sp.*), fruit fly ((*Bactrocera cucurbitae* (Coq.)), fruitworm (*Helicoverpa armigera* (Hubner)), green tobacco capsid (*Nisiodiocoris tenius* Reuter) which is also recorded as generalist predator, Common cutworm (*Spodoptera litura* F.) and cotton aphid (*Aphis gossypii* Glover). High infestations of fruitworm (*Helicoverpa armigera* (Hubner)) were commonly observed in all the places surveyed while the fruit fly (*Bactrocera cucurbitae* (Coq.)) was high in Bohol only.

In sweet pepper eighteen invertebrate pest species were observed. The most common and damaging were: broad mite (*Polyphagotarsonemus latus* (Banks)), fruit fly (*Bactrocera cucurbitae* (Coq.) and in Claveria *B. dorsalis* was also found), aphids (*Aphis gossypii* Glover) and the mirid or capsid bug (*Helopeltis collaris* Stal.). Mealybugs, scale and whitefly (*Bemisia tabaci* and *Aleurodicus disperses*) were locally serious. In Claveria whitefly vector Tomato Yellow Leaf Curl virus (TYLCV) which is asymptomatic in sweet pepper. In Claveria cutworm (*Spodoptera litura)*, earworm (*Helicoverpa armigera*) and red spider mites (*Tetranychus kanzawai)* were other common invertebrate pests of sweet pepper.

In eggplant sixteen invertebrate pest species were observed. The eggplant fruit and shoot borer (EFSB *Leuconoides orbonalis* Guenee) was common and usually the most serious pest in all places visited given it attacks the fruit. Other common leaf feeding pests were: the cotton leafhopper (*Amrasca devestans*), the 12-spotted beetle (*Epilachna tridecimpunctata*), and aphids (*Aphis gossypii* Glover). In Bohol mealybugs and scale were sporadically seen in high numbers.

In ampalaya of the twelve invertebrate pests surveyed the fruit fly (*Bactrocera cucurbitae* (Coq.)) was the most consistently serious fruit damaging pest. Cucumber moth (*Diaphania indica* (Saunders)) could cause significant defoliation. Aphids (*Aphis gossypii* Glover) could infest ampalaya causing significant leaf distortion and sooty mould.

Table 4. Summary of invertebrate pests by vegetable found in central and southern Philippines

Common group name	Order	Family	Common name	Scientific name	Tomato	Sweet pepper	Eggplant	Ampalaya	Pechay	Lettuce	Kangkong
Mites	Acari	Tetranychidae	Red spider mite	*Tetranychus kanzawai*		☑	☑				☑
Mites	Acari	Tarsonemidae	Broad mite	*Polyphagotarsonemus latus*		☑					
Thrips	Thysanoptera	Thripidae	Tobacco thrips	*Thrips tabaci*	☑	☑	☑				
Thrips	Thysanoptera	Thripidae	Melon thrips	*Thrips palmi*			☑				
Aphid	Hemiptera	Aphidae	Cotton aphid	*Aphis gossypii*	☑	☑	☑	☑	☑		
Aphid	Hemiptera	Aphidae	Green peach aphid	*Myzus persicae*				☑		☑	
Leafhopper	Hemiptera	Cicadellidae	Cotton leafhopper	*Amrasca devestans =biguttula*			☑	☑			
Leafhopper	Hemiptera	Cicadellidae	Patola leafhopper	*Ricania speculum*			☐	☑			
Whitefly	Hemiptera	Aleyrodidae	Spiraling whitefly	*Aleurodicus dispersus*	☑	☑	☑				
Whitefly	Hemiptera	Aleyrodidae	Silverleaf whitefly	*Bemisia tabaci biotype B*	☑	☑	☑	☑			
Mealybugs	Hemiptera	Pseudococcidae	mealy bug			☑	☑				
Scale	Hemiptera	Coccididae	scale			☑	☑				
Bugs	Hemiptera	Miridae	Mirid/ Capsid bug	*Helopeltis collaris*	☑	☑	☑				
Bugs	Hemiptera	Miridae	Green tobacco capsid	*Nisiodiocoris tenius*	☑	☐	☐				
Bugs	Hemiptera	Pentatomidae	Green stink bug	*Nezara viridula*	☑	☑					
Bugs	Hemiptera	Alydidae	Stink bug/ Rice bug	*Leptocorisa oratorius*	☑	☑	☑				
Bugs	Hemiptera	Coreidae	Sweet potato bug/ Leaf-footed bug	*Physomerus grossipes*				☑			
Caterpillars	Lepidoptera	Noctuidae	Common cutworm	*Spodoptera litura*	☑	☑	☑	☑	☑	☑	☑
Caterpillars	Lepidoptera	Noctuidae	Green looper	*Chrysodeixis chalcites*	☑				☑		
Caterpillars	Lepidoptera	Noctuidae	Corn earworm or Tomato budworm	*Helicoverpa armigera*	☑	☑					
Caterpillars	Lepidoptera	Pyralidae/Crambidae	Eggplant fruit and shoot borer	*Leucinodes orbonalis*			☑				
Caterpillars	Lepidoptera	Pyralidae	Cabbage webworm	*Crocidolomia parvonana =*					☑	☐	

Common group name	Order	Family	Common name	Scientific name	Tomato	Sweet pepper	Eggplant	Ampalaya	Pechay	Lettuce	Kangkong
				binotalis							
Caterpillars	Lepidoptera	Crambidae	Melon worm/Cucumber moth	*Diaphania indica*				☑			
Caterpillars	Lepidoptera	Totricidae	Leafroller	*Adoxophyes privatana*		☑					
Caterpillars	Lepidoptera	Plutellidae	Diamondback moth	*Plutella xylostella*				☐	☑		
Caterpillars	Lepidoptera	Lymantriidae	Tussock moth	*Orgyia spp.*		☑	☑	☐	☐		
Fruit fly	Diptera	Tephritidae	Melon fruit fly	*Bactrocera cucurbitae*	☑	☑		☑			
Leafminer	Diptera	Agromyzidae	Leaf miner	*Liriomyza sativae*	☑	☑		☑	☑	☑	☑
Lady beetles	Coleoptera	Coccinellidae	Tomato lady beetle/ 12 spotted beetle	*Epilachna tridecimpunctata*	☑		☑				
Flea beetles	Coleoptera	Chrysomelidae	Flea beetles	*Psylloides spp.*	☑	☑	☑				
Flea beetles	Coleoptera	Chrysomelidae	Striped flea beetle	*Phyllotreta striolata*		☐	☐		☑		
Flea beetles	Coleoptera	Chrysomelidae	Flea beetles	*Phyllotreta spp.*			☐		☑	☑	☑
Squash beetles	Coleoptera	Chrysomelidae	Squash beetles	*Aulacophora similis*				☑			
Squash beetles	Coleoptera	Chrysomelidae	chrysomelids	*Aulacophora spp.*				☑			☑
Tortoise beetle	Coleoptera	Chrysomelidae	Green tortoise beetle	*Cassida circumdata*					☑	☑	
Tortoise beetle	Coleoptera	Chrysomelidae	Orange tortoise beetle	*Aspidomorpha miliaris*					☐	☐	☑
Katydid	Orthoptera	Tettigoniidae	Philippine katydid/ Long-horned grasshopper	*Phaneroptera furcifera*	☑				☑		☑
Grasshopper	Orthoptera	Pyrgomorphidae	Slant faced grasshopper	*Atractomorpha psittacina*	☐				☑	☑	☑

In pechay, of the eleven invertebrate pests surveyed, cabbage web worm (*Crocidolomia binotalis*), diamondback moth (*Plutella xylostella*) and the striped fleabeetles (*Phyllotreta striolata*) could completely devastate the plantings. Aphids (*Aphis gossypii* Glover) and common cutworm (*Spodoptera litura* F.) were generally minor pests.

Lettuce rarely had major damage from the six invertebrate pests surveyed. Aphids (*Aphis gossypii* Glover) and common cutworm (*Spodoptera litura* F.) were generally minor but most serious pests of lettuce.

Kangkong similarly rarely had major invertebrate pest damage from any of the nine invertebrate pests surveyed.

Beneficial invertebrates were only periodically sampled in the vegetable field trials and would have been more extensive than represented in Table 5. The generalist predators, particularly the coccinellid ladybeetles and spiders were the most conspicuous. Other generalist predators include preying mantids, earwigs (Dermaptera), carabid beetles and a range of spiders, including the Lynx spider *Oxyopes javanus*. Syrphids and neuropterans were observed amongst aphid colonies. Vespid wasps predated caterpillars. Hymenoptera parasitoids were reared from caterpillars (*Spodoptera litura, Diaphania indica, Chysodeixis chalcites* and *Helicoverpa armigera*), aphids (*Aphis gossypii*), whitefly and eggs (*Spodoptera litura*).

Table 5 Benefical invertebrates surveyed in vegetables in southern Philippines

Order	Family	Scientific name	host or prey
Hymenoptera	Braconidae	*Microplitis* sp.	Lepidoptera larval parasitoid (*Spodoptera litura)*
Hymenoptera	Braconidae	*Copidosomopsis truncatella*	Lepidoptera larval parasitoid (*Chrysodeixis chalcites)*
Hymenoptera	Braconidae	*Cotesia* sp.	Lepidoptera larval parasitoid (*Helicoverpa armigera*)
Hymenoptera	Braconidae	*Cotesia* sp.	Lepidoptera larval parasitoid (*Diaphania indica)*
Hymenoptera	Braconidae		Lepidoptera larval parasitoid *(Helicoverpa armigera)*
Hymenoptera	Braconidae	*Aphidius* sp.	Aphid parasitoid (*Aphis gossypii*)
Hymenoptera	Aphenilidae		Whitefly parasitoid
Hymenoptera	Encyrtidae		Whitefly parasitoid
Hymenoptera	Platygastridae		Whitefly parasitoid
Hymenoptera	Eurytomidae		Whitefly parasitoid
Hymenoptera	Scelionidae		Whitefly parasitoid
Hymenoptera	Scelionidae		Egg parasitoid (*Spodoptera litura*)
Hymenoptera	Vespidae		Lepidopterous larvae
Coleoptera	Coccinellidae	*Micraspis crosea*	Generalist predator: aphids, whiteflies
Coleoptera	Coccinellidae	*Menochilus sexmaculatus*	Generalist predator: aphids, whiteflies
Coleoptera	Carabidae	*Carabid spp.*	Generalist predators- soil active
Diptera	Syrphidae		Aphids
Araneae	Oxyopidae	*Oxyopes javanus*	Generalist predator
Neuroptera	Chrysopidae	*Chrysoperla sp.*	Generalist predator: aphids, whitefly
Mantodea	Mantidae		Generalist predator
Dermaptera			Generalist predator

Weed surveys

Weeds were surveyed at VSU as part of each of the first entomology experiments per crop, as part of the mulch experiments in Bohol and Claveria (Table 6). Weeds were more of a significant problem in the field grown and unmulched crops.

Table 6. Weeds surveyed from vegetable crops grown in three sites in the Philippines: VSU (Leyte), MOSCAT/USTP (Claveria) and BISU (Bohol)

Family	Scientific name	Leyte	Claveria	Bohol
Aizoaceae	*Trianthema portulacastrum*		y	
Amaranthaceae	*Amaranthus spinosus*	y	y	
Asteraceae	*Ageratum conyzoides*		y	y
Asteraceae	*Bidens pilosa*			y
Asteraceae	*Chromolaena odorata*		y	y
Asteraceae	*Vernonia cineria*	y		
Capparidaceae	*Cleome rutidosperma*	y	y	y
Commelinaceae	*Commelina benghalensis*	y		
Commelinaceae	*Commelina diffusa*	y		y
Convolvulaceae	*Ipomoea triloba*		y	y
Euphorbiaceae	*Euphorbia hirta*	y	y	y
Euphorbiaceae	*Euphorbia prostata*	y		
Euphorbiaceae	*Phyllanthus amarus*	y		y
Euphorbiaceae	*Phyllanthus niruri*			
Fabaceae	*Calpogonium mucunoides*			y
Fabaceae	*Cassia tora*			y
Fabaceae	*Desmodium triflorum*			y
Fabaceae	*Mimosa pudica*		y	y
Malvaceae	*Corchorus olitorius*			y
Nyctaginaceae	*Boerhavia erecta*	y	y	
Onagraceae	*Ludwigia octovalvis*	y		
Portulacaceae	*Portulaca oleracea*	y	y	
Rubiaceae	*Borreria laevis*		y	y
Rubiaceae	*Borreria ocymoides*			y
Rubiaceae	*Hedyotis corymbusa*	y		
Verbenaceae	*Stachytapheta jamaicensis*			y
Poaceae	*Brachiaria humidicula*			y
Poaceae	*Cynodon dactylon*	y	y	
Poaceae	*Digitaria ciliaris*	y	y	
Poaceae	*Echinicloa colona*	y		
Poaceae	*Echinicloa crusgalli*		y	
Poaceae	*Echinicloa glabrescens*	y		
Poaceae	*Eleusine indica*	y	y	
Poaceae	*Rottboelia cochinchinensis*		y	
Cyperaceae	*Cyperus iria*	y	y	
Cyperaceae	*Cyperus kyllingia*			y
Cyperaceae	*Cyperus rotundus*	y	y	y

Efficacy of biological and botanical crop protection products

The 2010 Organic Act mandated the provision of research and recommendations for organic agriculture. Information available to small holder vegetable farmers is not always based on scientific data. Experiments testing biological and botanical crop protection products were conducted for key diseases and invertebrate pests in each of the focus crops.

Disease management

A total of 14 efficacy trials related to plant disease management were conducted in Leyte focusing more on the control of bacterial wilt disease of solanaceous vegetables, the major constraint in vegetable production in Eastern Visayas due to the high annual rainfall. The different disease management trials are listed in Table 7. Trials marked with an asterisk **(*)** were mainly aimed for bacterial wilt management. Among the bacterial wilt management trials conducted, all were conducted on tomato, except for Trial 6 which was using sweet pepper.

A range of disease management approaches were evaluated against bacterial wilt of solanaceous vegetables that include: soil amendment with organic materials such as cabbage residues, *Chromolaena odorata* and forest leaf litter (Trial 2), evaluation of resistance elicitors such as chitosan, acetylsalicylic acid (Trial 3) and even the raw source of chitosan (i.e., crab and shrimp exoskeleton, Trial 1), silicon dioxide (Trial 4), evaluation of crop protection products such as Serenade® (*Bacillus subtilis*), PhosPro and *Bacillus thuringiensis* (Trial 6 and 7), lactic acid bacterium and Bio-N from UPLB BIOTECH (Trial 7), and wood vinegar trials (Trial 12 and 14) all coupled with protected cultivation. Trial 10 is a pH trial which tried to establish the effect of pH on bacterial wilt incidence. Trial 5 and 8 were intended for the management of pechay and lettuce diseases while Trial 11 was a wood vinegar efficacy trial against *Sclerotium rolfsii* conducted in the laboratory and screenhouse of the Department of Pest Management. One trial (Trial 13) was conducted by an MS Plant Pathology student which was the evaluation of different *Solanum pimpinellifolium* accessions from East West for their susceptibility to bacterial wilt and bacterial spot of tomato conducted in the screenhouse and field.

Table 7. Trials conducted by the Plant Pathology component research:

No.	Trial location	Report title	Year
1	VSU	Evaluation of Crab and Shrimp Exoskeleton Against Two Major Diseases of Tomato (*Lycopersicum esculentum* Mill)*	Nov-Feb, 2013
2	VSU	Effects of selected Organic Soil Amendments on the Performance of Tomato Grown Under Protective and Open Field Cultivation*	June-Sept. 2014
3	VSU	Field Evaluation of Chitosan, Aspirin and Streptomycin against Tomato Bacterial Wilt Caused by *Ralstonia solanacearum* Under Open and Protected Cultivation*	March-June 2014
4	VSU	In-Vitro and Field evaluation of Silicon Dioxide for the Control of Bacterial Wilt of Tomato*	Oct. 2014-Jan. 2015
5	VSU	Performance of *Brassica rapa* (Pechay) and Lettuce (*Lactuca sativa*) as Affected by Serenade and Wood Vinegar Under Open and Protected Cultivation	Feb-March, 2015
6	VSU	Disease Incidence and Yield of Sweet Pepper as Influenced by Cabbage Amendment and Bacillus subtilis (Serenade) and PhosPro	Apr.-August

		Treatments*	2015
7	VSU	Effects of *Bacillus thuringiensis* (Aztron), Silicon Dioxide and Chitosan + Acetyl Salicylic Acid Treatments on Disease and Yield of tomato under protective and open cultivation*	Sept. -Dec. 2015
8	VSU	Performance of Pechay (*Brassica napus var chinensis*) and Lettuce (*Lactuca sativa*) as Affected by Different Rates of Fertilizer Application and Wood vinegar under Protected and Open field cultivation	Dec-Jan. 2016
9	VSU	Evaluation of Potential Biological Control Agents for the Management of Diseases of Tomato (*Solanum lycopersicum* L.) grown under Protective and Open field cultivation. *	March-June 2016
10	VSU	Evaluation of different pH levels for Bacterial wilt Management in Tomato (*Solanum lycopersicum*) grown in pots under Protective cultivation*	Aug-Nov, 2016
11	VSU	Evaluation of Wood Vinegar from Different Plant Sources Against *Sclerotium rolfsii* Affecting Tomato	Sept-Dec, 2016
12	VSU	In vitro Evaluation of Wood Vinegar from Different Sources Against *Ralstonia solanacearum**	Jan-March, 2017
13	VSU	Evaluation of Currant Tomato (*Solanum pimpinellifolium*) Accessions to Major Diseases of Cultivated Tomato (*Solanum lycopersicon*). *	Oct. 2016-April, 2017
14	VSU	Field Evaluation of Different Wood Vinegar Against Naturally Occurring Diseases of Tomato Under Open and Protected Cultivation*	June-Sept,2017
15	Claveria	Management of Fusarium Wilt in Tomato with biofumigation, *Trichoderma hazaianum* and crop rotation	2 crops

The low cost protective structure consistently reduced bacterial wilt incidence in almost all the Plant Pathology component trials conducted. Bacterial leaf spot and leaf mould were also reduced in few trials which further highlights the importance of protected cultivation in the Eastern Visayas region where annual rainfall is very high (Baybay annual rainfall averages 2830 mm with average temperature of 27°C Climate-data.org).

The first trial conducted was just an open field experiment that evaluated the effect of the raw sources of chitosan (i.e. pulverized shrimp and crab exoskeleton, together with water, chitosan and streptomycin as checks) against naturally occurring diseases of tomato, conducted by an undergraduate thesis student, Wences Rey de la Peña. The seedlings were sown the week before typhoon Haiyan in 2013 and were transplanted after the typhoon in a stressed condition; the bacterial wilt incidence was high (from 79.69 – 87.50%) and the treatments showed no impact on bacterial wilt incidence and yield of tomato. The treatments, however significantly reduced the leaf mould incidence. Plants applied with chitosan, streptomycin, and chitosan with streptomycin had significantly lower percent infection at five and six weeks after transplanting compared to the control and the rest of the treatments including crab and shrimp exoskeletons and water. All treatments however had significantly lower disease severity rating compared to the control.

In the second trial, organic soil amendments using cabbage residues, *Chromolaena odorata* and forest leaf litter had significantly reduced bacterial wilt incidence in tomato. In the same trial, bacterial spot incidence was significantly reduced by *C. odorata* and forest leaf litter amendment. Bacterial wilt and bacterial spot incidence, as well as rot knot nematode rating was lower in the tomatoes grown under the protective structure than in the open field. The most cost-effective control based on gross margin analysis was cabbage amendment applied to the soil under protected cultivation.

In the third trial, chitosan and acetylsalicylic acid (which are reported as resistance elicitors in several research papers), when applied as spray, were effective in reducing bacterial wilt incidence in tomatoes grown under protective structure only, but not in the open field. Chitosan and acetylsalicylic acid individually or in combination also increased the tomato yield grown under protected cultivation. The combination of chitosan + acetylsalicylic acid plus protected cultivation produced the highest yields of tomato.

Silicon dioxide (SiO_2) in the fourth trial did not reduce bacterial wilt incidence either under open or protective cultivation but it did reduce the nematode counts particularly *Rotylenchulus* sp. when applied as a drench, and drench plus spray but not when applied as a spray-only. A combination of SiO_2 application plus protected cropping increased the tomato yield.

In the sixth trial, Serenade® (*Bacillus subtilis* strain QST713) and Liquid PhosPro (phosphate plus calcium; 0-16-0-4) treatments had significantly lowered bacterial wilt incidence but showed no significant effect on the yield of sweet pepper. Cabbage amendment had slightly reduced bacterial wilt incidence and Serenade® and PhosPro had significantly reduced bacterial wilt incidence but none showed a significant effect on yield. Bacterial wilt incidence in this experiment was not high, which may have masked treatment effects on yield.

In the seventh trial, chitosan+acetylsalicylic acid, and SiO_2 were re-evaluated together with *Bacillus thuringiensis var aizawai* (Aztron®) against bacterial wilt of tomato under protected and open field cultivation. Only protected cultivation reduced the disease incidence and thereby increased the yield of tomato. In this trial chitosan+acetyl salicylic acid, which was the most effective in reducing bacterial wilt in the previous trial, did not reduce the disease most probably because in the first trial it was applied as a spray while in this trial it was applied as a drench. It's mode of action was reported to be as inducer of resistance. Reduced contact with the host plant may have been the cause for its ineffectiveness in this trial.

All microbial agents in Trial 9 (Serenade®, lactic acid bacterium and Bio-N®) were not effective in reducing the incidence of bacterial wilt and on the yield of tomato. The treatments in this trial were applied as drench. It is suggested that in future experiments, these potential biocontrol agents may be tried again using different application methods, such as foliar spray application.

In the pH trial (Trial 10), pH was adjusted to pH 5.5–7.5 in pots filled with the highly bacterial wilt infested soil from the field experimental area, however there was no bacterial wilt infection on the tomatoes grown in the pots.

In the efficacy of wood vinegar to control *S. rolfsii* in tomato (Trial 10), 17 wood vinegars were evaluated, 11 were inhibitory at 2% concentration (i.e., bamboo, banaba, cacao, caimito, Ipil-ipil, lumboy, madre de cacao, malunggay, mango, panyawan and rice hull). All of the wood vinegars increased their *in vitro* inhibitory property against *S. rolfsii* when the concentration was increased. Wood vinegar from Ipil-ipil, which is the most inhibitory to *S. rolfsii* in vitro, was also the most toxic to tomato seedlings. At 0.5% it was toxic to tomato seedlings. There are wood vinegars however that inhibited the fungus at 2% in the *in vitro* trial but were not phytotoxic at 2% at 72 hours, noteably: banaba, lomboy and madre de cacao. Lomboy, was inhibitory at 1% and showed no phytotoxic effects at 2% concentration.

bamboo, cacao and tigbao were also not toxic at 2% after 72 hours. All the wood vinegars, except cacao were highly phytotoxic at 20%.

In the *in vitro* evaluation of wood vinegar against *Ralstonia solanacearum* (Trial 12), eight out of the 17 wood vinegars showed inhibition to the bacterium but only at a much higher concentration (20%) which is already phytotoxic to tomato seedlings. These were wood vinegars from: banaba, Ipil-Ipil, lomboy, madre de cacao, panyawan, malunggay, ricehull, and tigbao. At 10%, lomboy produced a little inhibition to *R. solanacearum* and at 15%, Ipil-ipil, lomboy, madre de cacao and rice hull also showed zones of inhibition to the bacterium. Lomboy wood vinegar was the most inhibitory at 20%.

Six of the wood vinegars were evaluated against *R. solanacearum* in a field experiment, i.e., banaba, Ipil-ipil, rice hull, malunggay, tigbao and lomboy (Trial 14). Wood vinegar (5%) were applied to tomato plants either as spray or drench together with Kocide® and water as checks. Results show that rice hull and madre de cacao were effective in reducing bacterial wilt rating when used as a drench while, lomboy was effective when used as a foliar spray. Out of these three wood vinegars, lomboy was found the most effective.

Ten of the wood vinegars (bamboo, banaba, ipil-ipil, lomboy, madre de cacao, malunggay, mango, rice hull and panyawan) were evaluated against *S. rolfsii in vitro* and in seedling experiment in the screenhouse. The *in vitro* trial evaluated the wood vinegars at four concentrations (i.e. 0.2%, 0.5%, 1.0% and 2.0%). All four concentrations slowed progress of the disease relative to untreated plants. Wood vinegar at 0.2 and 0.5% showed no inhibitory effect to *S. rolfsii in vitro* but when used on plants, the lowest concentration, i.e. 0.2% produced the lowest disease severity rating and the slowest rate of disease progression. Wood vinegar at 0.2%, even if it has no direct effect on the pathogen had protected the plants against infection. It is possible therefore that aside from the direct antifungal effect of wood vinegar to *S. rolfsii* at higher concentrations, it had possibly induced plant defenses against the pathogen. The higher disease severity rating of the plants at higher wood vinegar concentrations is probably due to the combined effect of *S. rolfsii* infection and wood vinegar phytoxicity.

A pechay and lettuce trial (Trial 5) was conducted together using Serenade® (*Bacillus subtilis* strain QST713) and wood vinegar as treatments. Serenade® produced significantly heavier pechay plants compared to wood vinegar and the control. Both Serenade® and wood vinegar produced significantly higher marketable pechay yield compared to the control. In lettuce neither Serenade® nor wood vinegar had any significant effect on yield.

Trial 8 was a bioefficacy trial of wood vinegar from “kakawate’ (*Gliricidia sepium*), commercial SeaCrop foliar fertilizer and the recommended fertilizers for growing pechay (i.e. 16-16-16 plus $CaNO_3$). Wood vinegar produced significantly taller pechay plants when grown under protective cultivation but not in the open field. On the other hand, plants treated with Seacrop foliar fertilizer and combination of Seacrop fertilizer and recommended fertilizers (1:1 ration of RR+ Seacrop or ½: ½ ratio) produced taller plants but showed no significant effect on total weight. In the open field, however, Seacrop and the recommended fertilizers, alone or in combination all produced taller plants. In terms of total weight, only the recommended fertilizers or the combination of Seacrop and recommended fertilizers (either 1:1 or ½: ½) produced heavier plants. Seacrop foliar fertilizer alone did not significantly increase the total weight of pechay. The highest weight was produced by the combination of ½:½recommended fertilizers and SeaCrop fertilizer.

Monocropping, acidic soil, warm conditions, and planting alternate hosts favour high incidence of fusarium wilt, a soil borne fungal disease caused by *Fusarium oxysporum f.sp.lycopersici* which is a major constraint in tomato production at Claveria, Misamis Oriental, Philippines. Three sequential plantings compared biofumigation with wild sunflower residue, *Trichoderma harzianum*, weekly cupric hydroxide fungicide applications and in the 2nd cropping a rotation after sweetpotato and in the 3rd cropping a rotation after cabbage. There were no significant treatment effects in any of the three plantings. The first, second and third plantings had *Fusarium* wilt incidence between 91–93.5%, 39.5–52.5% and 32.8–34.5% respectively. The results suggest that the cultural treatment practices were as effective as the grower practice but without an unsprayed control we can say whether any were effective.

Invertebrate pest management

Efficacy of botanical and biological insecticide or miticide treatments were tested against pesticide and water controls in each of the focus crops against the invertebrate pests present at the time of the experiment in the open field and in most cases also under protected cropping. Sixteen experiments were conducted, fourteen single cropping experiments at VSU and two three cropping cycle trials at USTP.

Table 8. Trials conducted by the Entomology component research

	Location	Year	Trial title
1	VSU	2014	Evaluation of two **vermitea** preparations against **broad mite** *Polyphagotarsonemus latus* (banks) and other arthropods associated with **sweet pepper** *Capsicum annum* L. grown under protected and open field cultivation
2	VSU	2015	Efficacy of **wood vinegar** and **neem** leaf extract against ***Bactocera cucurbitae*** (Coq.) and other insect pests of **amplaya** grown under protected and open-field cultivation.
3	VSU	2015	Biocontrol potential of ***Bacillus thuringiensis*** var. *aizawai* and ***Metarhizium anisopliae*** SPW isolate against insect pests of **pechay** and **lettuce** under protected and open field cultivation
4	VSU	2016	Efficacy of **wood vinegar** and **neem** leaf extract on **fruit and shoot borer** (*Leucinodes orbonalis* Guenee) of **eggplant** grown under protected and open field cultivation.
5	VSU	2016	Efficacy of **vermitea** on insect defoliators of **kangkong** (*Ipomea aquatica* Forsek) grown under protected and open field cultivation
6	VSU	2016	Efficacy of **kakawate** (*Gliricidia sepium* Jacq.) leaf extract on insect defoliators of **lettuce** (*Lactuca sativa* L.) grown under protected and open field cultivation
7	VSU	2016	Efficacy of "**7-Herb Plus**" botanical extract on insect defoliators of **pechay** (*Brassica rapa* L.) grown under protected and open field cultivation.
8	VSU	2016	Efficacy of botanical extracts on the **broad mite** (*Polyphagotarsonemus latus* Banks) of sweet **pepper** grown under protected and open field cultivation
9	VSU	2016	Efficacy of **wood vinegar** and **neem** leaf extract on the fruitworm (*Helicoverpa armigera* Hubner) of **tomato** under protected and open field cultivation
10	USTP	2017	Development of ICM for Cabbage

11	VSU	2017	Efficacy of **7-herb Plus** and **Curry** plant extracts against the **broad mite** (*Polyphagotarsonemus latus* Banks) of sweet **pepper** grown under protected and open field cultivation
12	VSU	2017	Efficacy of **7-herb Plus** against melon **fruit fly** *Bactrocera cucurbitae* Coq. of **ampalaya**
13	VSU		Efficacy of sulfur, kakawate [*Gliricidia sepium*(Jacq.)] leaf extract and *Metarhizium anisopliae* SPW isolate against **broad mite** [*Polyphagotarsonemus latus*] (Banks) of sweet **pepper** (*Capsicum annum* L.)
14	USTP	2017	Management of **broad mites** on sweet **pepper**
15	VSU	2017	Efficacy test of **botanicals** on mite and insect pests of sweet **pepper** (*Capsicum annuum* L.) under conventional and protected cultivation
16	VSU	2017	Efficacy test of **botanical** mixes on insect pests and diseases of **tomato** (*Lycopersicon esculentum* L.) under conventional and protected cultivation

Broadmites (*Polyphagotarsonemus latus* Banks) are a serious pest of sweet pepper causing leaf deformation and five experiments were conducted evaluating vermitea, neem (*Azadirachta indica*), kakawate (*Giricidia sepium*), garlic (*Allium sativum*), garlic and chilli (*Capsicum annuum*), onion (*Allium cepa*), curry plant (*Murraya koenigii*), "7-herb Plus", *Metarhizium anisopliae* SPW isolate, sulfur and abamectin. Four experiments were conducted at VSU under both field and protected cropping, with the field experiments each receiving in excess of 200 mm of rain (Trials 1, 8, 11 & 13). All except kakawate and metarhizium reduced broad mite damage relative to the water control treatment under protected cropping but were not as effective as the abamectin miticide. Sweet pepper grown in the field was subjected to greater than 200 mm for each experiment, nevertheless vermitea, garlic + chilli, onion, curry plant, 7-herb Plus, and sulfur all reduced broadmite damage relative to the water control but again not as well as the abamectin or dinotefuran miticides. Abamectin (Trials 8, 11 &13) and dinotefuran (Trial 1) treated plots consistently had significantly higher yields under protected cropping. There were no differences in field grown sweet pepper yields in the four VSU field experiments.

In the first of two plantings in Claveria at MOSCAT/USTP broadmite pressure was very low and there were no treatment differences (Trial 14). In the second planting abamectin miticide and the sulfur treatments had significantly lower mite damage, and the kakawate and metarhizium treatments were not as effective but better than the water control. In both plantings sulfur had significantly higher yields. *Aphis gossypii* was also present in the second planting and kakawate, metarhizium and abamectin did reduce aphid numbers relative to the sulfur or water treatments.

At VSU there were single experiments on tomato, eggplant, kangkong, and lettuce, and two experiments each for ampalaya and pechay to evaluate biologicals or botanicals against a water and insecticide control (Table 9). At MOSCAT/USTP three farming systems were evaluated on three crops of cabbage: ICM, organic and farmer's practice (Trial 10).

Two biological insecticides, *Bacillus thuringiensis* var. *aizawai* (*Bta*) and *Metarhizium anisopliae* (*Ma*) SPW isolate, were tested on lettuce and pechay grown under protected and open field cultivation for control of lepidopterous pests (Trial 3). Weekly spraying of each treatment was done using the recommended rates (RR) of application: *Ma* at 3 L spore suspension / 13 L water ($1x10^8$ spore concentration); *Bta* at 20 g / 16 L water; cypermethrin 5EC at 30 ml / 16 L water. Insect infestation was monitored weekly based on insect counts

Table 9 Summary of biological and botanical efficacy experiments compared to pesticides and water controls in open field and protected cropping.

OPEN FIELD

Common name	Scientific name	Crop host	Vermitea	Wood vinegar	Neem *Azadirachta indica*	Kakawate *Gliricidia sepium*	Garlic *Allium sativum*	Garlic+chilli *Allium sativum + Capsicum annuum*	Onion *Allium cepa*	Curry plant *Murraya koenigii*	7 herb Plus' Note 1.	FPJ madre cacao	Bta *Bacillus thuringiensis var. aizawai*	Met *Metarhizium anisopliae* SPW isolate	Sulfur	Abamectin	Cypermethrin Synthetic pyrethroid	Dinotefuran Neonicitinoid	Methomyl Carbamate
Broad mite	*Polyphagotarsonemus latus*	SP	☑		☒	☒	☒	☑	☑	☑	☑			☒	☑	☑☑			
Aphid	*Aphis gossypii*	SP				☑								☑	☒	☑			
Whitefly	*Bemisia tabaci*	Cab										☒	☒						☒
Cutworm	*Spodoptera litura*	Let, Pec				☑							☑☑☑☒	☑☑			☑☑		☑☒
Fruitworm	*Helicoverpa armigera*	Tom			☑													☑	
Cucumber moth	*Diaphania indica*																		
EFSB	*Leucinodes orbonalis*	Egg		☒	☒													☑	
DBM	*Plutella xylostella*	Pec, Cab										☒	☑☑☒	☑			☑	☑	☑☒
Webworm	*Crocidolomia binotalis*	Cab										☒	☑ ☒						☑☒
	Hellula undalis	Cab										☒	☒						☒
Fruitfly	*Bactrocera cucurbitae*	Am									☒						☒		
Leafminer	*Liriomyza sp*	Cab										☒							☒
	"defoliators"*	KK* Pec^		☑							☑						☑☑		

PROTECTED CROPPING

Common name	Scientific name	Crop host	Vermitea	Wood vinegar	Neem *Azadirachta indica*	Kakawate *Gliricidia sepium*	Garlic *Allium sativum*	Garlic+ chilli *Allium sativum + Capsicum annuum*	Onion *Allium cepa*	Curry plant *Murraya koenigii*	7 herb Plus' Note 1.	FPJ madre cacao	Bta *Bacillus thuringiensis var. aizawai*	Met *Metarhizium anisopliae* SPW isolate	Sulfur	Abamectin	Cypermethrin Synthetic pyrethroid	Dinotefuran Neonicitinoid	Methomyl Carbamate
Broad mite	*Polyphagotarsonemus latus*	SP	☑		☑	☒	☑	☑	☑	☑	☑			☒	☑	☑ ☑			
Aphid	*Aphis gossypii*	Am		☑	☑													☑ ☑	
Cutworm	*Spodoptera litura*	Let, Pec				☑							☑☑	☑☑			☑☑		
Fruitworm	*Helicoverpa armigera*	*T*			☒													☑	
Cucumber moth	*Diaphania indica*	Am		☒	☑													☑ ☑	
EFSB	*Leucinodes orbonalis*	Egg		☒	☑													☒	
DBM	*Plutella xylostella*	Pec											☑	☑			☑	☑	
Fruitfly	*Bactrocera cucurbitae*	Am									☒						☒		
	"defoliators"*	KK* Pec^		☑							☑						☑☑		

Note 1. "7-Herb Plus" botanical extract (an extract derived from 7 pesticidal plants added with soap: 3 kg makabuhay (*Tinosphora rumphii* Boerl), 2 kg lemon grass (*Cymbopogon citratus* Stapf), ¼ kg hot/chili pepper (*Capsicum annuum* L.), ¼ kg garlic (*Allium sativum* L.), ¼ kg bulb onion (*Allium cepa* L.), 3 tobacco leaves (*Nicotiana tabacum* L.), 1 kg buyo leaves (*Piper betle* L.), and ¼ bar neutral soap)

Note 2. * Chrysomelids & orthoptera ^ *Crocidolomia binotalis* & *Phyllotreta striolata*

Yield difference

SP= sweet pepper; Am= ampalaya; Cab= cabbage; Let= lettuce, Pec=pechay; Tom= tomato; Egg= eggplant; KK= kangkong

☒ cross= no difference compared to water; colour corresponds to crop tested on

☑ tick= reduced numbers or damage of target invertebrate pest compared to water; colour corresponds to crop tested on

☑ bolded= bigger impact than unbolded

☑☒ tick and cross of same colour is when second experiments get different results and damage ratings. Yields were recorded at harvest. Results showed that application of either *Bta, Ma* or cypermethrin significantly reduced populations and damage of *Spodoptera litura* Fabr. and *Plutella xylostella* L. Pechay plants applied with *Bta* and *Ma* showed higher yields than cypermethrin in both types of cultivation. These findings suggested that *Bta* and *Ma* SPW isolate were effective against *S. litura* and *P. xylostella* and can be used as an alternative non-chemical option for their management.

Neem leaf extract at 1:9 dilution and wood vinegar at the rate of 150 ml per 16 L water were not effective against fruit fly in ampalaya, based on damage or yield compared to the insecticide (cypermethrin) (Trial 2). However, they were generally more effective against aphids and larvae of cucumber moth were comparable with the water control treatment and in some weeks as effective as the insecticide (cypermethrin). Highest yields of up to 12 times were observed under protected cultivation largely due to the approximately 180 mm of rain and the high bacterial wilt incidence in the open-field cultivated ampalaya during the period.

A similar study conducted on eggplant for control of eggplant fruit and shoot borer (EFSB) under open and protected cultivation found that application of neem leaf extract at 1 L/ 5 L water and wood vinegar at 300 ml/ 16 L water sprayed twice weekly resulted in lower mean number and weight of borer-damaged fruit in both types of cropping systems but did not differ significantly from the negative water control (Trial 4). Dinotefuran showed the lowest number of damaged fruits in the open field. There were no significant differences in the mean weight and number of marketable fruits between treatments in either type of cropping system although yields were generally higher under protected than in open field cultivation.

A third evaluation of the efficacy of wood vinegar and neem leaf extract was on tomatoes against the fruitworm (*Helicoverpa armigera* Hubner) under protected and open-field cultivation (Trial 9). Results showed that 1 L neem leaf extract/ 5 L water applied twice weekly had significantly lower damage ratings than the control under open field cultivation. However, wood vinegar at 300 mL/ 16 L water applied at the same frequency of application had no significant effects on damage ratings of tomato fruitworm (*Helicoverpa armigera* Hubner) which was comparable with the control. Dinotefuran, a neonicotinoid insecticide, at the recommended rate gave the lowest damage ratings in both types of cultivation. There were no significant differences in yield among treatments and between the two types of cropping system despite the approximately 560 mm of rainfall.

Vermitea or worm tea was evaluated for control of insect defoliators of kangkong (*Ipomea aquatica* Forsek**)** under protected and open field cultivation resulted in lower damage ratings of insect defoliators in both types of cultivation relative to the negative water control but higher damage relative to the positive cypermethrin control (Trial 5). Marketable yields were comparable between treatments in both types of cultivation although yields in the open field were almost twice those under the protective structure.

Kakawate (*Gliricidia sepium*) is used as a natural insect repellant and is promoted as a useful pest management strategy in organic and low-input rice production. Hence it was tested in lettuce for control of insect defoliators, specifically cutworm (*Spodoptera litura*) in both protected and open field cultivation systems (Trial 6). Weekly applications of aqueous kakawate leaf extract to lettuce plants resulted in lower damage ratings relative to the negative water control and higher damage ratings than the positive cypermethrin control. Kakawate treatments had significantly higher marketable yields than plants treated with tap water, and were comparable with those applied with cypermethrin under protective structure cultivation. In contrast kakawate was ineffective against broadmite on sweet pepper in either cultivation situation (Trial 13).

"7-herb Plus" is a botanical concoction using extracts from seven pesticidal plants with added soap (3 kg makabuhay (*Tinosphora rumphii* Boerl), 2 kg lemon grass (*Cymbopogon citratus* Stapf), ¼ kg hot/chili pepper (*Capsicum annuum* L.), ¼ kg garlic (*Allium sativum* L.), ¼ kg bulb onion (*Allium cepa* L.), 3 tobacco leaves (*Nicotiana tabacum* L.), 1 kg buyo leaves (*Piper betle* L.), and ¼ bar neutral soap) that is commercially available and used by farmers as an 'organic' pest management option. Twice weekly sprays were evaluated on pechay (Trial 7) against the insect defoliators, on sweet pepper for broad mite (Trial 11) and for fruit fly in ampalaya (Trial 12) under protected and open field cultivation. In pechay cabbage webworm (*Crocidolomia binotalis* Zeller) and flea beetle (*Phyllotreta striolata* F.) were the defoliators observed in both cropping systems and the 7-herb Plus botanical extract was as effective as cypermethrin based on insect counts and damage ratings, and significantly better than the negative water control in both types of cropping systems. There was no significant marketable yield differences between plants treated with botanical extract and tap water, whereas cypermethrin treated plants had significantly higher yields. There was 50% more pechay yield in protected cropping compared to the open field under approximately 280mm of rainfall.

On sweet pepper 7-herb Plus reduced broad mite damage ratings versus the water control but was not as effective as the abamectin and had no impact on yields. In ampalaya grown under protected cropping or open field neither the 7-herb Plus botanical extract nor cypermethrin were effective in reducing melon fruit fly (*Bactrocera cucurbitae)* numbers or damage. Marketable yields trended to being higher in the cypermethrin treatment and lowest in the water control but the differences were not significant. However under laboratory conditions, the botanical extract "7-Herb Plus" at 22 ml/L water killed 36.67% of treated maggots whereas cypermethrin had 100% mortality in both maggots and adults. Moreover, fruit fly would not oviposit on ampalaya fruit sprayed with the extract or with cypermethrin in both no choice and choice tests. Yield differences among treatments were evident but they were not significant, although in the two types of cultivation, yields were consistently higher under protective structures in all treatments than in the open field but again were not significant.

Over three field plantings of cabbage in Claveria, northern Mindanao at MOSCAT/USTP campus three farming systems were compared for control of key insect pests: diamond back moth (*Plutella xylostela*)[DBM], webworm (*Crocidolomia binotalis*), leafminer (*Liriomyza sp.*), whiteflies (*Bemisia tabaci*), and cutworms (*Spodoptera litura*) (Trial 10). Diamond back moth and cabbage webworms in particular cause significant damage resulting in heavy crop losses. The farming systems compared were: Farmer's Practice, an ICM approach and an organic management approach to pest management. The Farmer's Practice included weekly applications of methomyl (Lannate®); the ICM treatment included weekly *Bacillus thuringiensis* (Aztron®) applications for lepidopterous pests and if monitoring indicated high larval numbers then chlorantraniliprole (Prevathon®) was applied. The organic treatment was fermented plant juice (FPJ) as recommended by the Department of Agriculture and prepared from one kilogram of chopped madre cacao leaves to one kilogram of sugar, put in a jar and buried in shaded area for seven days afterwhich two teaspoons of FPJ to a litre of water was sprayed weekly.

Both methomyl and *Bacillus thuringiensis* (Bt) applications reduced DBM and cutworm larval numbers relative to the FPJ treatment in the first year of the trial but had no impact on the whitefly or leafminer numbers. In the second year the invertebrate pest populations were initially lower than in the first planting, methomyl and Bt had fewer cutworm larvae than FPJ but no significant difference was seen between the treatments on DBM, whitefly or leafminers. In a third cropping DBM and cutworm numbers were low throughout the cropping and no differences between treatments were observed, no leafminers or whitefly were observed and *Hellula undalis* and *Crocidolomia binotalis* larva were initially reduced in numbers by the methomyl and Bt treatments relative to FPJ but there was no significant difference at the end of the crop.

In the first cropping the average marketable yields ranged from 30 tons per hectare for the organic treatment, to about 37 tons for the Farmer's Practice and 43.5 tons for the ICM treatment but the differences were not significant. In the second and third cropping the organic treatments were significantly lower than the other treatments, with yields of about 12 tons in organic plots versus between 43–63 tons per hectare. The differences in marketable yields between the treatments in the absence of significant differences in pest numbers suggest the differences between treatments are likely to be more strongly related to the differences in the fertilizer treatments associated with the different farming systems. Application of fermented plant juice in organic plots had no effect on insect populations nor reduced damage.

Metarhizium anisopliae isolates were evaluated as potential endophytes for management of invertebrate plant pests. A series of pot trial experiments were conducted using two isolates from Dr Robert Mensah, NSW DPI at Narrabri that had shown activity against a range of sucking pests in cotton. The initial experiment testing canola and sunflower seeds, as models of small and large seeds, treated with an undiluted suspension of *Metarhizium* and then grown as whole plants before cabbage aphids (*Brevicoryne brassicae*) and Rutherglen bugs (*Nysius viridula*) were introduced onto caged plants found the aphids successfully colonized most of the canola plants and RGB survived on the sunflower plants. Follow up experiments tested different plant leaf parts for toxic or repellant properties without success but did find direct feeding on cucumber seeds treated with one isolate by RGB did cause higher mortality, seemed to reduce insect activity and illicit avoidance. Treating cabbage seedlings with undiluted suspension of *Metarhizium* killed the seedlings. Treating stored grain at 1% dilution of *Metarhizium* reduced numbers of progeny of 4 of 5 stored grain beetle species but had no effect on the adults. Both 25 and 50% dilution increased adult beetle mortality but was not high enough for use as a disinfestant.

Grafting onto disease resistant rootstock

Grafting susceptible crops onto disease resistant rootstock can be an effective way of managing soil borne diseases and was evaluated in both tomato and sweet pepper at VSU, where the incidence of bacterial and fungal wilt is high. Several trials were conducted between the VSU agronomy and plant pathology project teams. Grafting significantly reduced bacterial wilt incidence and increased the yield of both tomato and sweet pepper varieties.

Grafting sweet pepper (cv. Sultan, Red Crest, Kayem, Green Hornet and Emperor) to a resistant chili pepper (BPI-HP-001) variety resulted in higher yield than non-grafted check variety (Emperor). Under protective structure, grafted plants had 100% survival compared to open field. The yield of grafted Emperor was the highest followed by grafted Sultan. Protective structure produced significantly higher marketable fruits and lower non marketable than open field.

On the other hand, tomatoes (cv. Atlas, Agatona, Discovery, Diamante max, Kingkong and Season Red) that were grafted to a resistant eggplant rootstock (EG203) had significantly lower bacterial wilt incidence than non-grafted of the same cultivar both under protective structure and open field. Grafted Agatona and Atlas tomato varieties showed the lowest bacterial wilt incidence in the open field while Agatona, Atlas and Diamante Max varieties had the lowest disease incidence under protective structure.

Australian wilt and vine decline in rockmelons and Asian melons

Research based in Australia looked at the causes of wilt and vine decline diseases of rockmelons and Asian melons, including bitter gourd or ampalaya (Table 10). The surveys of all major melon producing areas across Australia confirmed that Fusarium wilt of rockmelons occurs in Australia – *F. oxysporum* f.sp. *melonis* (*Fom*). *Fom* race 1 isolates were collected from Queensland and NSW and were associated with Fusarium wilt symptoms (Figure 4(L). *Macrophomina phaseolina* and *Plectosphaerella cucumerina* were isolated from melons with rapid vine decline in NSW, Queensland and the Northern Territory. Similarly *Pythium myriotylum* was isolated from wilting melon plants in NSW, Queensland and the Northern Territory. *Verticillium dahliae* was isolated from Sunraysia district in combination with *Melon necrotic spot virus.* The surveys also found that gummy stem blight (Figure 4(R) had become more important in the past few years but it is unclear why.

Figure 4. Fusarium wilt affected rock melons (L) and Gummy stem blight (R)

Table 10. Summary of melon disease surveys in Australia

Disease/cause	Occurs in Australia
Fusarium wilt (*Fom*)	+
Pythium root rot – several species	+
Charcoal rot – Macrophomina phaseolina	+
Gummy Stem Blight – *Didymella bryoniae**	+
Plectosphaerella spp. (Sudden vine decline)	+?
Verticillium dahliae - wilt	+
Monosporascus cannonballus (Sudden vine decline)	-
Bacterial wilt (strains of *Ralstonia solanacearum*)	-
Bacterial wilt (*Erwinia tracheiphila*)	-
Phytophthora root & crown rot (*P. capsici*)	-

*now known to be caused by 3 different species; (*Stagonosporopsis citrulli*, *S. cucurbitacearum* & *S. caricae)*

Significantly the melon surveys found the important exotic virus *Cucumber green mottle mosaic virus* (CGMMV) in the Northern Territory and triggered a national biosecurity response that, although painful for the Northern Territorial melon growers, did mean that quarantine and monitoring significantly reduced the impact on the industry compared to if it had not be identified through this project.

Field surveys conducted under this project also detected the exotic virus *Melon necrotic spot virus* (MNSV) and soil-borne fungal vector, *Olpidium bornovanus* in the Sunraysia and the Riverina areas of Victoria and NSW.

Significantly, national field melon surveys did not detect *formae speciales* of the cucurbit wilt pathogen *Fusarium oxysporum* which occurs overseas on Asian Melons and did not detect other exotic fungal, bacterial & oomycete pathogens on melons.

Australian melon food safety

This Australian component aimed to mitigate microbial and fungal field contamination of melons with washing and sanitation practices postharvest, prior to shipping to market (Figure 5).

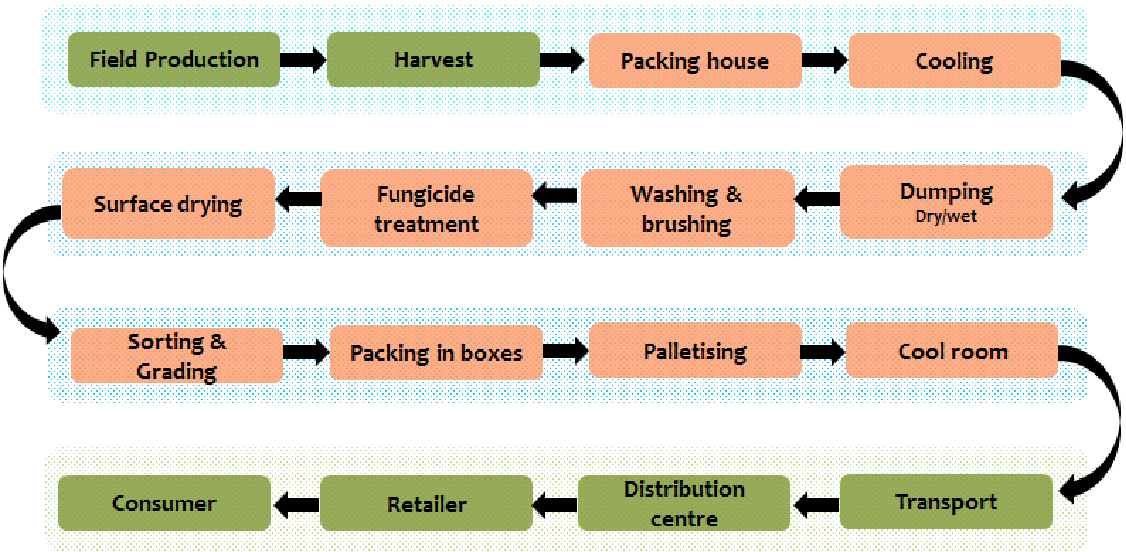

Figure 5. Diagram of activities in a typical Australian melon pack house from harvest prior to transporting to market.

Four melon pack houses were assessed for food safety risks and found concerns in:

- Quality of wash water
- Levels of sanitiser/disinfectant in wash water
- Recirculation of wash water without treatment
- Non-uniform application of fungicides
- Unacceptable packing house hygiene

Good practices resulted in reduction of microbial load of food safety concerning organisms on fruit surface and extended storage potential.

Gaps in good practices were linked to getting positive tests for the foodborne pathogens, *Salmonella* spp. and *Listeria* spp.

Efficacy of different types of sanitisers was demonstrated through laboratory experiments to offer more options for melon packers.

After initial pack house assessments, taking fruit samples for testing at intervals through a season, the assessment the following season found improved practices, few positive tests of foodborne pathogens but still areas of concern. Improvements found were that water recirculation was stopped, there was an increase in sanitiser concentration used but still sub optimal concentration and general packing house hygiene remained poor. After an outbreak of salmonella linked to contaminated rockmelons in the Northern Territory a joint rockmelon food safety exercise was conducted with the NSW Food Authority. Workshop- inspections, qualitative and quantitative risk assessments were made, with many samples taken. Improvement notices were issued to each pack house and a reinspection was made four weeks later. A followup impact inspection was made twelve months later.

A factsheet and best practice guide was published for melon growers.

Agronomy

Vegetable Varieties

To help identify suitable varieties by location, varietal trials were conducted in Leyte and Claveria on tomato, lettuce, cabbage and sweet pepper.

Sweet pepper varieties were successfully grafted on to resistant chilli pepper rootstock at Leyte in an area with high bacterial wilt inoculum. 'Emperor' and 'Sultan' were by far the most productive varieties, with yields 85% and 45% higher respectively than the next best variety ('Kayem'). The importance of grafting was demonstrated, with ungrafted 'Emperor' yielding half that of a grafted plant as a result of severe bacterial wilt infection.

Tomato varieties evaluated included the AVRDC fresh market tomato lines 'AVTO 1173, 1007 and 1004' (Figure 6 (R)). These AVRDC lines performed as well as 'Check' variety that farmers are currently reliant on. The AVRDC lines therefore provide a cheaper alternative to 'Check' that is often in short supply. All varieties were similarly susceptible to tomato yellow leaf curl virus (TYLCV), although pruning plants did reduce incidence and severity of the virus.

Figure 6. Leafy lettuce variety trial (VSU) and tomato variety trial (USTP)

Assessment of tomato varieties in Leyte suggested that under high levels of bacterial wilt inoculum, the variety 'Agatona' ungrafted has some tolerance to bacterial wilt. Only 20% of 'Agatona' plants were infected, whereas most other varieties had 100% infection. Even so, grafting 'Agatona' to eggplant rootstock increased yield by ninefold. Other varieties which were highly susceptible to bacterial wilt performed well when grafted, with 'Season Red' and 'Diamante Max' producing the highest yields, and consequently the best net return.

Both head and leaf-type lettuces were successfully grown in lowland Leyte. Yield differences between five head-type varieties were not significantly different due to high variability within treatment reps. The number of days to harvest was similar between varieties. Yield of three leaf-type lettuce varieties, 'Grand Rapid', 'Green Span', and 'Green Tower' were the highest in Leyte, due to the larger plant size (Figure 6 (L)).

Table 11. List of varietal trials conducted

Trial location	Year	Report title
MOSCAT/USTP	2015	Influence of pruning in the performance of selected fresh market tomato lines
VSU	2015	Growth and yield of different head-type lettuce varieties grown under protected and open field cultivation
MOSCAT/USTP	2015	Performance evaluation of promising AVRDC processing tomato lines in response to pruning
MOSCAT/USTP	2016	Growth and yield performance of tomato genotypes under protected and conventional cultivation
MOSCAT/USTP	2016	Performance of lettuce as influenced by different irrigation systems under conventional and protected cultivation
VSU	2016	Growth and yield performance of different sweet pepper varieties grafted to chilli pepper grown under protected and conventional cultivation
MOSCAT/USTP	2017	Growth and yield performance of lettuce grown under different levels of drip irrigation system

Protected cropping and net tunnels in Bohol & Samar

Low covered netted tunnels increased survival of lettuce seedlings by 10% compared to the open field during hot weather. Tunnels benefited seedling establishment at an early stage, although final yield was unaffected.

In contrast, lettuce and pechay seedlings planted during more favourable weather had similar survival rates regardless of the netting cover (Figure 7 (R) and 8 (L)). Yield was also unaffected. These results suggest that benefits of low covered netted tunnels are probably limited to helping seedling establishment during particularly hot weather.

House-type protected cropping structures first setup in Leyte were evaluated in Samar, Bohol (Figure 7) and Claveria. In Bohol and Claveria, tomato yields were increased under the protected structure. Yields under protected cropping and open field were similar in Samar as a result of severe bacterial wilt infection. Regardless of cropping method, the low yields in Bohol, Samar and Claveria suggest that growing practices can be improved in order to reach yields achieved in Leyte (Table 12).

Figure 7. Protected cropping structure and net tunnel in Bohol

Table 12. Tomato yields achieved under protected cropping house-type structures compared to the open field

Location	Protected cropping – Yield (t/ha)	Open field – Yield (t/ha)
Bohol	4.8	1.8
Samar	12.3	14.9
Claveria	17.3	11.3
Leyte*	45.0	22.0

*Average tomato yields reported in Hort/2007/066/2 Final Report.

Table 11. List of protected cropping and tunnel trials conducted

Trial location	Year	Report title
BISU	2014	Field versus protected cropping of tomato in Billar, Bohol
VSU	2015	Influence of different methods of raising seedlings on the growth and yield of lettuce grown under tunnel type structures and the open field
VSU	2015	Growth and yield of pechay grown under tunnel-type structure and open field as influenced by different methods of raising seeds
MOSCAT/USTP	2015	Growth and yield performance of tomato genotypes under protected and conventional cultivation

Figure 8. High net tunnels (L) and (R) light framed high tunnel with detachable plastic roof

Irrigation

The benefits of drip irrigation were demonstrated in most trials with lettuce, tomato, sweet pepper and ampalaya, under protected structures and in the open field. For example in two trials, each with two crops of lettuce grown in Claveria, had between 17–27% higher yields when drip irrigation was used compared to manual or overhead irrigation.

During times of frequent rainfall, there was little benefit gained from drip irrigation in the open field. For example during the wet season in Claveria, lettuce yields were similar under manual and drip irrigation. In contrast, during the dry season, yields were 27% higher using drip irrigation. Similarly, in Leyte, there were no differences in yield of tomato grown in the open field using drip or conventional irrigation when rainfall was regular. Whereas in the same trial, under protected cropping, yields were 25% higher using drip irrigation.

Hand-sprinkler, drip bottles and drip hose irrigation were compared in another trial. Water use efficiency and yield were highest for drip bottles across tomato, sweet pepper and ampalaya. It was recognised that improvements needed to be made to the drip irrigation rate and scheduling, which would most likely result in higher yields from this system. Despite the additional labour costs using drip bottles over drip hose, the net return was still highest using drip bottles (Table 14). Drip bottles could be a cheaper initial alternative for farmers, prior to investing in a well scheduled drip irrigation system.

Table 12. Net return per hectare of vegetables grown with different water delivery systems in a house-type protected structure (prices in Philippine Peso)

	Water delivery system		
Crop	**Sprinkler (hand watering)**	**Drip bottle**	**Drip hose**
Tomato	-5,695	25,818	4,473
Sweet pepper	28,000	94,629	77,571
Ampalaya	61,075	82,484	42,707

In some trials, drip irrigation increased plant survival rates where soil-borne pathogens were present. This was most likely due to the reduction in inoculum levels and spread, by eliminating soil splash that occurs in conventional irrigation, and allowing alternate wetting and drying of soil. For example, death of sweet pepper from fusarium wilt infection was eliminated using drip hose, while plants grown under drip bottles had 97% survival, and hand sprinkler irrigated plants only 73% survival.

Table 13. List of irrigation trials conducted

Trial location	Year	Report title
VSU	2017	Growth and yield of ampalaya as influenced by method of water delivery system grown under protected cultivation
VSU	2017	Growth and yield of ampalaya as influenced by method of water delivery system grown under protected cultivation
VSU	2017	Growth and yield of lettuce as influenced by method of water delivery system grown under protected cultivation
VSU	2017	Growth and yield of pechay as influenced by method of water delivery system grown under protected cultivation
VSU	2017	Growth and yield of sweet pepper as influenced by method of water delivery system grown under protected cultivation
VSU-Cabintan	2016	Growth and yield performance of tomato (*Solanum lycopersicum* L.) as influenced by irrigation, mulching and type of cultivation
VSU	2017	Growth and yield of tomato as influenced by method of water delivery system grown under protected cultivation

Seedlings

Pechay

The most consistently superior seedling raising method in Leyte, Samar and Bohol was seedling trays which were then transplanted to the field. They were superior to direct seeding or the traditional farmer method of bare rooted seedlings.

However performance of the different methods varied by trial and location. In Samar, direct seeding had very low survival rates due to heavy rains soon after sowing which washed soil and seed away. In Bohol, lower yields from the seed box were due to transplant shock when moving bare-rooted seedlings into the field during hot weather. In contrast, yields were similar between the three methods in Leyte, as weather conditions were favourable after sowing and transplanting (Table 16).

Aside from seedling raising method, the major effect on yield was the location, where yields in Leyte were higher than Samar and Bohol. This is likely a result of poor soil fertility in the trial sites of the latter regions.

Table 14. Total yield of pechay from three provinces of the Southern Philippines grown with different seedling raising methods

Method of raising seedlings	Total yield (t/ha)		
	Bohol	Leyte	Samar
Direct seeding	16.28a	21.75a	4.81b
Seed box	8.90b	21.49a	12.04a
Seedling tray	11.19ab	24.05a	16.16a

Lettuce

Across the three trials, sowing lettuce into seedling trays was at least as effective, if not more so than using a seed box or direct seeding. In the Leyte trial, seedling trays (Figure 9) increased final lettuce head weight and yield by at least 53% compared to other treatments.

Similar to Pechay, direct seeding was ineffective during the rainy season for lettuce, with final yield reduced using this method in Bohol. However in Leyte, direct seeding produced similar results to using the seed box.

One trial in Leyte showed that sowing seeds into seed boxes, and then directly transplanting to the field bare-rooted, reduced yields compared to other methods. This suggests that root structure development was poor in seed boxes compared to seed trays, resulting in seedlings more prone to transplant shock.

Figure 9. Lettuce seedlings grown in seedling trays

Table 15. Total yield of lettuce from trials in two provinces of the Southern Philippines grown with different seedling raising methods

	Total yield (t/ha)		
Method of raising seedlings	Lettuce - Bohol	Lettuce – Leyte	Lettuce - Leyte
Seed box to tray	12a	27.1a	18.5b
Seed box to field	11.7a	14.3b	20.3b
Seedling tray - with soil	12.3a	21.4ab	31.1a
Seedling tray - bare root		20.2ab	
Direct seeding	5.7b		18.1b

Kangkong

Direct seeding kangkong or using seedling trays resulted in similar final yields. This suggests that there is no benefit to be gained using the more expensive seedling tray method for kangkong. However like pechay, if heavy rain was to occur after sowing, then seedling trays may be a better option.

Protected cropping versus open field

Under protected cropping, the relative performance of seedling raising methods was similar to that of the open field. Generally, seed raising methods that produced the highest yields in the open field also did so under protected cropping. However when severe rain events occurred soon after direct seeding, seeds were washed away in the open field, but not protected cropping, thus reducing the performance of open field direct seeded plants relative to those under protected cropping.

Table 16. List of seedling production trials conducted

Trial location	Year	Report title
VSU	2017	Growth and yield of kangkong as influenced by method of raising transplants grown under protected and open field cultivation
VSU	2014	Growth and yield performance of selected leafy vegetables grown under protective structure and open field as affected by different methods of raising seedlings
BISU	2016	Influence of different methods of raising seedlings on the growth and yield of lettuce (*Lactuca sativa* L.) under open and protected cultivation systems.
VSU	2014	Growth and yield performance of selected leafy vegetables grown under protective structure and open field as affected by different methods of raising seedlings
BISU	2016	Yield Performance of Pechay Grown in Different Methods of Raising Seedlings under Open and Protected Cultivation Systems
VSU	2014	Growth and yield performance of selected leafy vegetables grown under protective structure and open field as affected by different methods of raising seedlings
BISU	2017	Influence of Different Methods of Raising Seedlings on the Growth and Yield of Pechay (*Brassica rapa* L.) Under Open and Protected Cultivation Systems

Mulches

Organic and plastic mulches eliminated most weed growth in open field and protected structure trials across Leyte and Bohol. However less densely laid mulches like coconut palm fronds failed to control some weeds.

Mulches tended to increase yield of lower lying crops such as cabbage and eggplant. Whereas there was less benefit to taller growing crops like tomato and ampalaya, which tend to quickly grow above weed growth (Table 19).

Mulching was beneficial in the open field and under protected structure. However in some cases mulches were more beneficial in the open field, most likely due to higher weed pressure in the rain-exposed open field.

Table 17. Summary of effects of mulches on vegetable yields

Crop/location	Result
Ampalaya – Leyte	No effect from plastic or organic mulches
Bohol	No significant effect from organic mulches, although trend towards higher yields
Eggplant – Bohol	Significantly increased yields (open field) under plastic and organic mulches
Sweet pepper – Leyte	A trend (not significant) towards higher yields under black and silver plastic in the open field.
– Leyte	Only hagonoy increased yield under protected structures, while rice straw or rice hull, and kakawate had no effect.
Cabbage – Claveria	Coloured plastic mulches and rice straw all increased head weight and yield.
Tomato - Leyte	Plastic and organic mulches had no effect on yield
Bohol	Coconut fronds and plastic mulch had no effect on yield.
Claveria	Black, silver and red plastic mulch increased yield.

Some mulches tended to attract or repel pest insects, including whitefly and mirid bug. For example, less whitefly was recorded on tomato plants grown in silver mulch, as well as cabbage grown in silver, red and rice straw mulches. Numbers and damage caused by the spotted ladybeetle (*Epilachna* sp.) larvae was reduced in tomato by mulching with coconut fronds or black plastic. However in general, pest insects were still above levels requiring control, though the aforementioned mulches could play a role in an IPM program.

Overall, plastic mulches more reliably excluded weed growth, and benefited yield slightly more than organic mulches. However organic mulches have the added benefit of providing organic matter that can improve soil fertility for the following crop. Furthermore, organic mulches are widely available for free or little cost, and do not have the issue of disposal like plastic mulches.

Figure 10. Natural and plastic mulch trials were conducted at BISU, USTP and VSU.

Table 8. List of mulching trials conducted

Trial location	Year	Report title
VSU-Cabintan	2016	Growth and yield performance of tomato (*Solanum lycopersicum* L.) as influenced by irrigation, mulching and type of cultivation
BISU	2015	Effects of different mulches on bitter gourd under protected and open field cultivation systems.
VSU	2014	Influence of different mulching materials on the growth and yield of ampalaya (*Momordica charantia* L.) under two types of cultivation system in Leyte, Philippines
VSU	2014	Influence of different mulching materials on the growth and yield of ampalaya (*Momordica charantia* L.) under two types of cultivation system in Leyte, Philippines
MOSCAT/USTP	2016	Mulching of rice straw and different colored polyethylene for enhancing productivity of cabbage
BISU	2015	Effects of different mulches on eggplant under protected and open field cultivation
VSU	2015	Influence of organic mulches on sweet pepper (*Capsicum annuum* L.) grown in two cultivation systems.

Amendments/biofumigants

The benefits of soil amendments in the open field was demonstrated across lettuce, pechay and tomato crops. Whereas under protected structures, yield was generally similar despite application of soil amendments. For example, without any soil amendments, lettuce and pechay growth was severely stunted in the open field, resulting in a major yield increase when any amendment was applied. In the same trial, under protected cropping, no benefit was gained from applying amendments to lettuce, and only slight benefit for pechay (Table 21). This suggests that amendments are less necessary under protected structures which tend to have higher soil fertility than the open field.

Growth promoting products including Wokozim™ and BioGreen™ were shown to be as effective as soil amendments like fertiliser, vermicast and dung.

Table 9. Yield of lettuce and pechay in the open field and protected cultivation as effected by soil amendments.

	Total yield (t/ha)			
Treatment	Lettuce - open field	Lettuce - protected cultivation	Pechay - open field	Pechay - protected cultivation
Control	0.2b	19.9a	3.3b	12.5b
Inorganic fertiliser	15.2a	24.9a	15.9a	17.4ab
Vermicast	17.3a	23.6a	18.5a	18.9a
Dung	19.1a	19.9a	17.3a	18.3a
Wokozim™	17.8a	18.8a	18.5a	18.9a
Bio Green™	17.9a	24.8a	19.1a	19.6a

Growing tomatoes with biofumigants such as wedelia, hagonoy, chicken dung, carbonized rice hull, cabbage waste and wild sunflower slightly improved survival from bacterial wilt.

Yield was increased and 10-15% more plants survived in biofumigant plots. Even so, a maximum of only 58% of plants survived in biofumigant plots, suggesting these biofumigants are not a commercial solution to bacterial wilt.

In a tomato trial in Claveria, granular fertiliser increased yield by 39%, whereas fertigation, inorganic and organic foliar application did not significantly increase yield.

Table 10. List of amendment trials conducted

Trial location	Year	Report title
VSU	2017	Growth and yield of kangkong applied with different organic amendments grown under protected and open cultivation
VSU	2015	Growth and yield of lettuce (*Lactuca sativa* L.) grown under tunnel-type structure and open field as influenced by different organic soil amendments
VSU	2016	Growth and yield performance of tomato (*Solanum lycopersicum* L.) amended with biofumigants grown under protected and conventional cultivation
VSU	2017	Growth and yield of two-grafted tomato cultivars applied with different soil amendments grown under protected and open field cultivation
VSU	2016	Growth and yield of Lettuce (*Lactuca sativa* L.) as influenced by organic amendments under protected and conventional cultivation

Grafting and pruning

A novel trial conducted within the agronomy program was evaluating growing lateral tomato branches grafted onto eggplant rootstocks and pruning experiments. The grafting of tomato onto eggplant rootstock is a technique for managing bacteria wilt but was assessed and was modified by growing lateral branch on rootstock to determine its effect on performance and yield of tomato in Leyte. The treatments compared were non-grafted, grafted plant without lateral branch and grafted plant with one lateral growing on rootstock. Results showed grafted tomato without lateral branch had the highest yield which almost doubled than non-grafted plants. However, grafted tomato with lateral branch gave the highest net return due to additional income from the eggplant fruits.

In Claveria, a participatory evaluation of pruning of tomato accompanied with fertilization practices was conducted in both on and off station trials. Results showed that pruning had minor influence on the parameters in farmer’s field due to nutrient overloading and less reliance of the standard soil analysis as guidelines exist among tomato growers in the area that masked the effects of pruning.

On the other hand, an on station trial (USTP area) with the same treatments using the different fresh market and processing tomato lines from AVRDC, revealed that pruned fresh market tomato exhibited bigger stem diameter and higher percent fruit set hence significantly increased the number of marketable fruits harvested per plant, yield in terms of total fruit weight, and yield per area regardless of difference in line than unpruned plants. Similarly, the pruned processing tomato line AVTO 1007 exhibited commendable growth with significantly taller plants and bigger stem. The yield was increased as a consequence of a greater number of fruits that were harvested. The occurrence of tomato yellow leaf curl virus (TYLCV) showed that pruned plants exhibited lower incidence and severity of the leaf curl virus.

Aquaponics

The growth of vegetable seedlings fertilised with fish effluent was increased by inoculation of seedlings with the plant growth promoting bacterium, *Azospirillum brasilense.* Strains of *A. brasilense* survived and colonized roots of 35-day old seedlings. Inoculated vegetable seeds generally germinated faster and had better early seedling growth than uninoculated controls (Table 23, Figure 11). For example, the strains promoted the growth of tomato and cucumber seedlings, increasing endogenous plant IAA, phosphorous and protein content by inoculation. *A. brasilense* is a promising agent to maximise the usefulness of fish effluent for plant production in aquaponics.

Table 11. Growth response of cucumber seedlings growing in fish effluent to inoculation with different strains of *A. brasilense*

Treatment	Leaf number	Plant height (cm)	Root length (cm)	Dry weight (g)
Control – fish effluent only	1.60b	7.20b	360.90b	1.21b
Sp7 + fish effluent	2.00a	9.07a	450.60a	1.39ab
Sp7-S +fish effluent	2.05a	8.93a	427.10a	1.49a
Sp245 + fish effluent	1.21b	1.39ab	450.40a	1.45a

Figure 11. Growth response of cucumber seedlings growing in fish effluent to inoculation with different strains of *A. brasilense*

List of aquaponic trials conducted

1. Mangmang, J. S. Deaker, R. ; Rogers, G (2016) Response of cucumber seedlings fertilized with fish effluent to *Azospirillum brasilense*. International Journal of Vegetable Science 22:2 129-140
2. Mangmang, J. S. Deaker, R.; Rogers, G (2016) Inoculation effect of *Azospirillum brasilense* on basil grown under aquaponics production system. Organic Agriculture 6:1 65-74
3. Mangmang, J. S. Deaker, R.; Rogers, G. (2016) Germination characteristics of cucumber influenced by plant growth-promoting rhizobacteria. International Journal of Vegetable Science 22:1 66-75
4. Mangmang, J. S., Deaker, R. & Rogers, G. 2015. Early seedling growth response of lettuce, tomato and cucumber to *Azospirillum brasilense* inoculated by soaking and drenching. *Horticultural Science,* 42:1, 37-46

5. Mangmang, J., Deaker, R. & Rogers, G. 2015. Optimal plant growth promoting concentration of *Azospirillum brasilense* inoculated to cucumber, lettuce and tomato seeds varies between bacterial strains. *Israel Journal of Plant Science*. pp. *145-152. http://dx.doi.org/10.1080/07929978.2015.1039290*
6. Mangmang, J., Deaker, R. & Rogers, G. 2015. Response of lettuce seedlings fertilized with fish effluent to *Azospirillum brasilense* inoculation. *Biological Agriculture & Horticulture,* 31:1, 61-71
7. Mangmang, J., Deaker, R. & Rogers, G. 2015. *Azospirillum brasilense* enhances recycling of fish effluent to support growth of tomato seedlings. *Horticulturae*. 1:1, 14-26
8. Mangmang, J., Deaker, R. & Rogers, G. 2014. Effects of plant growth promoting rhizobacteria on seed germination characteristics of tomato and lettuce. *Journal of Tropical Crop Science,* 1:2, 35-40.

Aeroponics

Aeroponic system evaluation for commercial seed potato production

Low cost aeroponic systems tested at QDAF Mareeba were found effective in seed potato production under semi-controlled conditions. The aeroponic units connected to acyclic timer, aquarium chiller and dosetronic system yielded high quality seed potatoes due to the better control over nutrition temperature and moisture management. The root zone cooling (10–15ºC) and longer fertigation intervals (at nighttime) resulted in increasing minituber production and solved root rot problems in the aeroponic system. The use of shade cloth over the roof and overhead misting reduced the temperature by 5ºC in the screen house during summer and allowed year-round crop production. High numbers of seed tubers of cultivar Sebago (630) and Nicola (900) per m^2 were produced. However March–June and July to October has been found ideal for aeroponic seed production in north Queensland

The prototype aeroponic system tested at three geographical regions in the Philippines (NMACLRC, UPLB and BSU) produced 3–5 times more tubers when compared to the conventional method. The low cost system was found more suitable and cost effective at NMACLRC and BSU; due to the favourable environment conditions for potato crop; however, warmer conditions at UPLB showed the need for a fully climatically controlled greenhouse for aeroponic seed production (Figure 12).

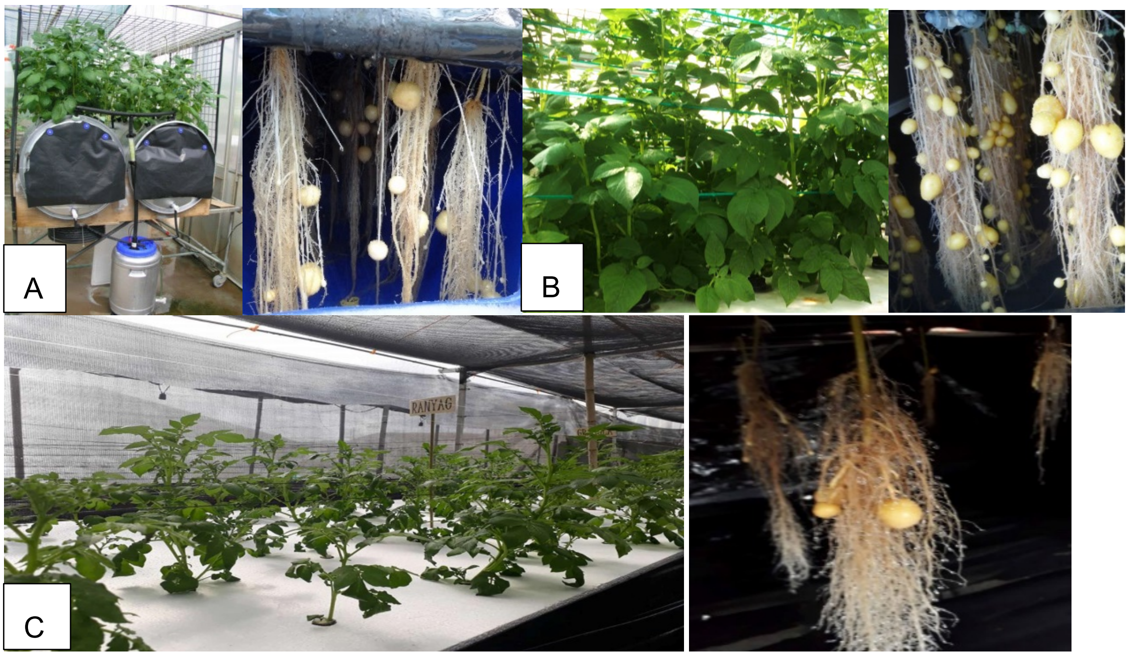

Figure 12: Small and commercial scale production unit A & B; QDAFand C. NMACLRC

This suggests that application of aeroponic technology in Mindanao and in the Luzon area could significantly increase seed production and reduce the production costs of quality potato seed to make it more accessible to growers. In Queensland, seed supplies for early and late planting crops are difficult to obtain, consequently growers often keep their own or purchase the ‘smalls’ from ware crops. This seed can be of variable quality and aeroponics may provide an alternative source.

Optimize nutrient solution for aeroponic seed potato production

Among four tested nutrient formulations (two commercial Flora Grow and Hydroponic solution A & B and two CIP nutrient formulations: Farran et al, 2006 and Otazu et al. 2010), the Farren et al formulation supported maximum minituber production in both the cultivars; Sebago and Nicola (Table 24). This solution was selected to conduct further studies at QDAF, such as the evaluation of different planting materials and responses of different cultivars for minituber production in aeroponic systems.

Table 24 .Effect of nutrient formulation on minituber production

Nutrient Formulation	**Sebago** (number of tubers / plant)	**Nicola** (number of tubers /plant)
Flora Grow series	28	15
Plantastic Hydropnoc solution A&B	12	7
CIP formulation (Farren et al 2006)	50	48
CIP formulation (Otazu et al.2010)	35	42

Average mean values

UPLB identified a potential nutrient solution (CIP nutrient solution, a modified Hoagland’s nutrient solution) for the production of potato tubers. The solution is composed of three nutrient mixes named: Solution A, B and C, the use of the solutions depends on the stage of development of the potato crop. Primarily, Solution A and B are used during the vegetative phase while solution B and C are used during the formation of tubers. In UPLB, using the modified solution, tuber yield increased from 2 tubers to 13 tubers per plant for Granola while less were obtained from Igorota (2 tuber per plant) and Ranyag (5 tubers plant). Initial trials conducted in BSU were able to generate a maximum of 21 tubers from Granola using the same solution. For NMACLRC, 17 tubers per plant were obtained from both Granola and Atlantic, while 25 tubers per plant were obtained from Astra.

Evaluate yield potential of initial planting material in aeroponic system

In Australia all planting material whether produced from plantlets, aerial stem cuttings, micro tubers or sprouts were found suitable to grow in an aeroponic system. The parent material was rooted in pots and within three weeks had produced sufficient root length 120–150 mm for transplanting into the aeroponic system. Microtubers produced the best plant survival rates (100%) followed by tuber sprouts (98%), plantlets (96%) aerial stem cuttings (85%).

After six weeks of transplanting, all the planting materials had formed stolons. The first harvest of minitubers (10–15 g) was at 56 days after planting and subsequent harvests at 7–10 days intervals. The transplanted plantlets produced the maximum number of minitubers (32–58) followed by micro tubers (30–56), aerial stem cuttings (28–52) and sprouts (28–50).

The minituber production in plants grown from aerial stem cuttings and micro tubers did not produce consistent minituber production and senesced within two weeks. This may be due to use of old stem cuttings and the micro tubers being at a younger physiological age. Generally the potato crops grown from seed with an old physiological age, have a shorter growing period and therefore reduced yield potential, and a similar trend has been observed in the aeroponic system.

At NMACLRC aerial stem cuttings and CIP formulation of cultivar Granola produced 27 minituber tubers per plant using aeroponic technology. This is three times more tubers per plant than their traditional system produces.

Seed production will be further increased by modifications to the aeroponic system which will allow it to regulate irrigation frequency, maintain nutrient concentration and modify root zone temperature for better plant growth and minituber production.

Cultivar response to minituber production in aeroponic system

Two Australian commercial cultivars: Sebago and Nicola showed growth differences over time for stolon initiation, number of minitubers produced and time of crop senescence in the aeroponic system. The stolon formation of Nicola (48 days after transplanting) occurred one week earlier than Sebago. (55 days after transplanting). The stolons of both cultivars formed at each node of the stem, so lowering of plant, at fortnightly intervals is an important technique to increase the number of seed tubers, as it is equivalent to hilling up in the field (Otazu, 2010). By the sixth harvest, minituber production had slowed and all minitubers ranged between 5–15 g were harvested at the eighth harvest which was during the plant senescence stage.

The cumulative count of minitubers production of cultivar Sebago and Nicola for one to eight harvests is presented in Figure 13.

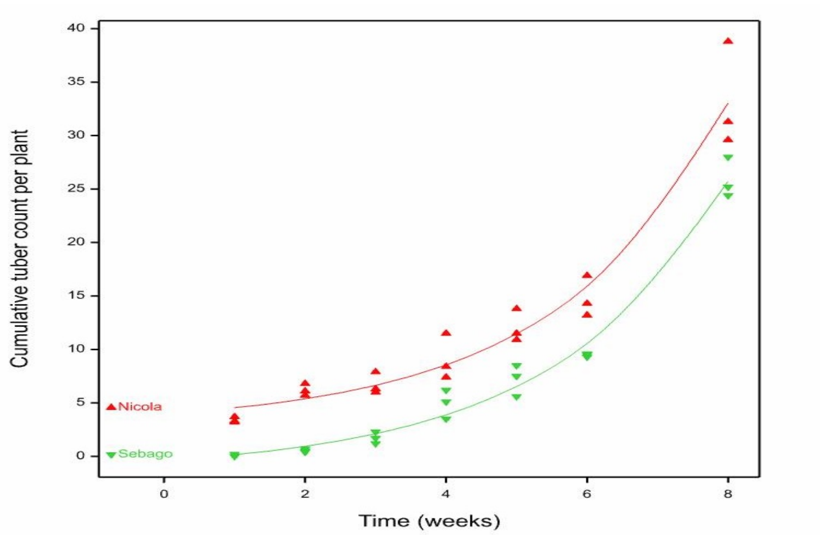

Figure 13. Minituber production of cultivars Sebago and Nicola

Six cultivars Sebago, Nicola, Atlantic Kipfler, Pink Fir Apple and Blue Sapphire (Figure 14) tested in same aeroponic unit showed differences in their growth cycles and minituber production (Table 25). This suggests that three crops of early maturing varieties (Nicola, Kipfler and Pink Fir Apple) and two of standard varieties could be easily produced in a year.

Minituber production could be increased when single cultivars are grown in individual unit, as there are specific nutritional requirements at each growth stage of the plant.

Table 25 Cutivar response to minituber production in aeroponic system

Yield / Growth cycle	Sebago	Nicola	Kipfler	Atlantic	Pink Fir Apple	Blue Sapphire
Minitubers/plant	55	38	40	45	42	60
Crop cycle (days)	120	70	70	120	90	120

Sebago Nicola Kipfler Atlantic Pink Fir Apple Blue Sapphire

Figure 14. Six potato cultivars tested in aeroponic system at QDAF

Similarly four cutivars Granola (25), Astra (25), Allantic (15) Raniag (15) and Igrorota were tested at UPLB, BSU and NMACLRC and with the exception of Igrorota have successfully produced minitubers. Cultivar Igorota may have specific nutrition requirements or is not suited for aeroponic system.

At QDAF, the maximum number of seed tubers was achieved by harvesting of 8–10 g size minitubers at 7-day intervals. 15 and 21 day harvest intervals, produced larger seed size, on average 10–15 tubers of 20^{+}g,which is half the number required for the aeroponic system to be economical. Storage studies revealed that aeroponic seed could be stored for four months in diffused light at 25 ± 2°C and over a year in refrigerator 4 ºC. After the cool storage the minitubers will require 30 days for uniform sprouting for field planting.

Powdery mildew *Fusarium* and *Pythium* root rot has been identified as the major problem in aeroponic production.and it was found to be easily managed by maintaining root zone temperatures between 10–18 °C and adding Pythoff® (chlorine compounds) to nutrient solution.

Regular monitoring and timely application of insecticides Stealth® (abamectin) and Confidor® (Imidacloprid) effectively managed infestation of mites, white fly and mealy bugs.

Evaluate field performance of aeroponic seed

Two field trials conducted on a commercial potato farm in Tolga (May 2013) and Atherton (May 2015) showed minimal yield differences from the different weighted minitubers ranging from 8–40 g and are comparable in yield to the farmer's planted seed (60–80 g). Aeroponic seed showed 99% seed emergence and produced 2–3 stems (stem thickness 11mm). Field spacing of minitubers at 10 and 15 cm spacing produced yields ranging from 30 to 39 t/ha.

Due the early onset and heavy pressure from *Alternaria solani* it is believed that yields could have been even better with lower disease pressure.

A plot experiment at NMACLRC showed that aeroponically grown seed produced a greater number of tubers (20 minitubers/plant) and bigger sized tubers compared to conventionally produced seed (12 minitubers/plant) and stem cuttings (17 minitubers/plant). Field trials at BSU failed due to heavy flooding brought by typhoons. This indicates that the aeroponic system could be effective in maintaining seed supply in the Philippines.

Currently in the Philippines, tubers in the Australian seed size range (35–60 mm) are regularly sold in markets as ware potatoes. Given this situation, Philippine produced aeroponic minitubers could be directly sold to farmers, negating the need for further field multiplication. This is of particular importance to the Philippine potato industry as many of their production zones, particularly those in Mindanao are affected by bacterial wilt. Negation of field multiplication should noticeably improve the quality of seed being provided to farmers.

Cost benefit Analysis aeroponic vs traditional seed potato production system

In Australia, the cost benefit analysis was based on cost of QDAF aeroponic system and average number of minituber production per plant. It was observed that while production did vary with variety in the aeroponic system, production was still 5-8 times higher than that produced by conventional methods. The estimated cost to produce 30 mm seed size minitubers was $US.0.21–0.29. The current retail price for a 20 mm seed size minituber is $US1.33, indicating a direct benefit of $1.04 per aeroponically produced minituber (Appendix 10).

The aeroponic system allows taking 2–3 crops in a year therefore; integration of this system into existing seed production system could increase the production of pre-basic seed and need of fewer field multiplications, lower the risk of contamination, and ensure the seed is free from soil borne and other pests and diseases.

In the Philippines, the cost benefit analysis was based on current NMACLRC aeroponic experience and conventional operations. The analysis showed that initial investment for aeroponic set up is 2.27 times higher than conventional production (Appendix 10), although this initial setup cost for aeroponics is recovered by the second crop. At full production the estimated net gain from the Philippines aeroponic facilities in 1st and 2nd years is $US 25,414 and 74,577 respectively. Two conventional production cycles run during this project showed the negative returns. The probable causes are inconsistent production due to bacterial wilt - contaminated soil, latently infected seed tuber or stem cuttings and government policy to provide subsidised seed to the farmers.

The studies conducted clearly indicated that to build a sustainable potato industry in the Philippines requires change to a more productive seed production system that will minimise the soil borne disease infection rates and if possible reduce subsidies to encourage private sector seed supply development.

Table 26. List of aeroponic trials to develop and test clean seed potato production in the Philippines and Australia

Trial location	Year	Report title
QDAF	2013	Develop low cost aeroponic system for seed potato production for tropical environments
QDAF	2013	Optimize fertigation for plant growth and to increase minituber production in aeroponic system
QDAF	2013	Evaluate yield potential of initial planting material in aeroponic system
QDAF	2013	Evaluate field performance of varying seed sizes of aeroponic seed to traditional size seed potato
QDAF	2014	Test the response of potato varieties for minituber production under aeroponic system
QDAF	2015	Standardize field spacing trial to improve yield potential of aeroponic seed
QDAF	2017	Economic analysis of aeroponic technology for commercial seed potato production
UPLB	2014	Re-designing of greenhouse and aeroponic facility to suit regional environment conditions
UPLB	2014	Develop and test low cost nutrient solution for aeroponic seed potato production
UPLB	2016	Determine best planting material to maximize minituber production
UPLB	2017	Cost benfit analysis of aeroponic seed potato production under low- lands conditions
NMACLRC	2013	Refine aeroponic facility to increase the efficacy of system for commercial seed potato production in the Philippines
NMACLRC	2014	Evaluate the efficacy of UPLB and CIP nutrient formulation for minituber production
NMACLRC	2015	Determine the yield potential of aeroponically grown micro and minituber to convettionally produced seed tubers and cuttings
NMACLRC	2016	Test the respose of potato varieties for minituber production in aeroponics system
NMACLRC	2017	Pot trials to compare the yield potential of aeroponic seed to conventionally grown seed potato
BSU	2015	Evaluate the efficacy of low cost aeroponic system for seed potato production in high-lands of the Philippines
BSU	2017	Determine the field performance of aeroponic seed to conventional seed potato

7 Impacts

7.1 Scientific impacts

The project team have scientifically evaluated various components of an integrated crop management system for field and protected cropping for key high value vegetables in the southern Philippines with 110 experimental trials conducted. Scientific methods for evaluating crop protection and agronomic practices of vegetables and aeroponics have been shared between team members, colleagues and students. Over 3000 VSU crop protection students used the VSU ICM research block as a living laboratory. Philippine students have written 30 BSc undergraduate, six MSc and two PhD theses based on ICM experiments in the Philippines, and one PhD was completed in Australia. Twenty-three papers and twenty-seven posters were presented with eight and twenty respectively at international conferences. Nineteen papers have been published in refereed journals and up to another nineteen papers to be included in a special edition of the Annals of Tropical Research are in review. The university partners have also gained additional research projects from PCAARRD, CHED and Department of Agriculture as a direct result of their involvement in this project.

More specifically the project team have contributed to scientific knowledge with five new disease records for the southern Philippines:

- Tomato: Bacterial canker (*Clavibacter michiganensis*)
- Tomato: Septoria leaf spot (*Septoria lycopersici*)
- Tomato: Target spot (*Corynespora cassiicola*)
- Ampalaya: little-leaf (Phytoplasma)*
- Ampalaya: Bacteria wilt (caused by Ralstonia, not Erwinia),

and in Australia two exotic melon viruses: *Cucumber green mottle mosaic virus* (CGMMV) and *Melon necrotic spot virus* (MNSV), along with its' soil-borne fungal vector, *Olpidium bornovanus* were discovered.

The field and laboratory experiments have generated efficacy data for a range of biological and botanical products for management of key pests and diseases of the focus vegetable crops and are the basis for IPM recommendations for each crop.

Two small (UPLB and BSU) and one commercial scale aeroponic system (NMACLRC) were developed and operating for clean white potato seed production in the Philippines and a small scale unit at Mareeba, Australia. Research showed benefits of cooling the solution to increase seed production in tropical conditions. The systems in the mid (NMACLRC) and high-land (BSU) areas of the Philippines produced more seed potatoes than the lowland system (UPLB). The system has been adapted to ginger and sweet potato as well.

A range of protected cropping structure innovations including: high-strength steel, coco-lumber and flexible bamboo framed structures; high and low tunnels roofed with removable plastic or net covers, were evaluated in southern Philippines with focus on typhoon prone areas for the focus vegetable crops.

Key agronomic innovations were compared to local practices for the focus crops including:

- Seedling production methods,

- Grafting onto bacterial wilt tolerant root stock
- Plastic and natural material bed mulches
- Biofumigation and microbial soil amendments
- Fertilizer rates, delivery method and timing
- Drip irrigation

Research methods and outcomes from the project have been included into the collaborating university curricula which should continue to have a positive impact on the quality of the science from the graduating students.

7.2 Capacity impacts

Capacity impacts have been substantial for the immediate project team, extended to farmers, extension staff, students and colleagues, but also to other projects and unrelated communities. Mobilizing other resources has allowed the project to increase its capacity impact, such as with PCAARRD funding the Philippine aeroponics component and a survey of vegetable viruses in the southern Philippines. Both EWS and LFPI leveraged ‘counterpart’ support for farmer field school training from a range of government and non-government sources amounting to ₱ 3.45m (~$115K) and ₱ 2.64m (~$88K) respectively.

Protected cropping structures, irrigation systems, stereo and digital microscopes, laptops, digital cameras, printers, insect monitoring equipment, and information resources provided to each of the university collaborators, as well as funds to employ research assistants and labourers has greatly increased the capacity of these universities to conduct research as well as use these resources to enhance their teaching capacity.

Similarly capacity for research and implementing ICM was increased with formal training in ICM, diagnostics, biometrics and scientific writing, but also developed through conducting the 110 experiments written up in trial reports, preparing posters (27) and presentations (23), for national and international conferences, and in preparing the 38 refereed publications.

Both formal training and the informal interactions within the team have broadened the technical skills of the team for vegetable production. The interaction between the training teams of EWS and the LFPI training has expanded each team’s technical knowledge to encompass crop agronomy, as well as soil and water conservation. The LFPI model also involved engaging with and developing the capacity of the LGU agricultural technicians.

These increased skills have flowed into other ACIAR projects for example LFPI project team introduced ICM vegetable production as viable livelihood option to farmers in the AMAEP (ACIAR Mindanao Agricultural Extension Project) involving a total of 6 Farmers Organizations in Ipil, Zamboanga Sibugay; Koronadal, South Cotabato and Ampatuan, Maguindanao. They ran training on improved vegetable production through ICM in the ACIAR Value Chain Project in Cagayan de Oro involving two Farmers Organizations. Similarly Ms Vale Justo, a crop protection specialist trainer from UPLB, ran FFS for two vegetable farming groups involved in the ACIAR Value Chain Project in Davao.

Of the 2072 farmers trained in ICM FFS, 968 were provided with basic inputs such as seed, seedling trays, plastic bed mulch, and fertilizer which gave them the immediate ability to put into practice the FFS training. The regular training and follow-up visits gave the support needed for the farmers to successfully grow their vegetables.

LFPI assisted five farmer organisations to set up a community revolving fund, whereby the farmers provided with inputs pay back into the fund. How each fund operates is specific to the group but has assisted in providing funds for inputs for subsequent plantings or assisting new farmers with inputs to grow vegetables.

Less tangible capacity impacts are from the many research assistants working on the project that have gone onto further study, or been employed as part of the EWS training team or by Department of Agriculture.

Two project collaborators (UPLB and NMACLRC) were trained at DAF, Mareeba for better understanding of aeroponic systems and growing agronomy and technologies.

Twenty researchers and technical staff (QDAF, UPLB, NMACLRC and BSU) improved their knowledge and skills in soilless production systems which included constructing protective structures and aeroponic units; managing the nutrient solutions, disease and insect-pest management; seed storage and evaluating the yield potential of aeroponically produced seed. The expertise developed in soilless culture especially in nutrition and disease management could be utilized for other soilless systems (hydroponics and aquaponics) and could improve production of other greenhouse crops.

Two small (UPLB and BSU) and one commercial scale aeroponic system (NMACLRC) are functioning. The skill set at the three research facilities and PCAARRD's commitment for the improvement of potato seed quality and plan for 2nd phase of the Philippine aeroponic project will expand the research and commercialization of this technology at both farmer and commercial private sector levels.

7.3 Community impacts

7.3.1 Economic impacts

The ICM project directly improved the economics of the 968 small holder farmers who were provided basic inputs for vegetable production and were given training and support through at least one cropping cycle. Similarly the project directly funded salaries of approximately 15 project staff and gave funds to support project travel. Research staff on the project gained promotion points by being directly involved with the project as well as through improved teaching ratings which are linked to the better learning environment provided by the funded field research blocks and additional teaching resources.

In coconut growing areas of Eastern Leyte devastated by typhoon Haiyan (Yolanda), vegetable production in the previous coconut farm communities has provided an opportunity for early returns in income and food supplies and fostered increased consumption of vegetables in areas that were being replanted with coconuts. Many of the farmers had not previously grown vegetables and they have benefited in both income and nutrition. This is also true in Bohol and Samar although most farmers were rice farmers and vegetables offered higher profitability. Anecdotal evidence is that many of the farmers have self-funded an expansion of vegetable production from the areas planted to vegetables with the initial project assistance.

An early evaluation survey of farmers who participated in the baseline survey as either project FFS participants or part of the non-FFS control group found a 50% increase in annual farm income in the project FFS participants. Evaluating changes across time, the income of the FFS group increased from ₱ 21,911.97 to ₱ 32,936.65. Over the same period the non-FFS trained group reported a 30% increase in annual farm income. This is a positive indication of the changes associated with the farmers' improved knowledge, understanding and skills in managing vegetable production which translates into increased vegetable income or increased yield and quality of vegetables produced.

The LFPI team facilitated the emergence of legally constituted, functional and organised productive farmer groups working in close collaboration with the local government unit (LGUs) vegetable production teams in Bohol. Although the project did not require a return on the initially provided inputs, five farmer groups collected re-payments as revolving capital for their next cropping season. The management of the fund strengthened the farmer organisations and provided a mechanism for small farmers to access credit for vegetable inputs. This has been seen as a positive change by the local Municipal Agriculture Office (MAO) and has resulted in further roll out of this methodology into other communities independent of this project. With recognized legal status, these groups can now apply for grants and are taking a more active role in their own community development. Six of the farmers' groups in Bohol are networking together and looking to become a local consolidator of vegetables for vegetable marketing.

Many of the farmers were keen to develop better business skills. Both EWS and LFPI incorporated more business skills training into their FFS. A number of the Bohol LGU agricultural technicials engaged with LFPI underwent Farmer Business School (FBS) trainer training and funds were leaveraged to conduct a FBS at Mayana Jagna with farmer participants.

PCAARRD are funding VSU to showcase and expand protective cropping for vegetable production in Eastern and Central Visayas based on the economic benefits to the farmers and local communities. The MAO in northwest Samar are similarly funding an expansion of protective cropping based on the success of the Samar ICM demonstration site.

Some of the specific practices associated with increased farmer profitability include:

- Farmers growing both sweet pepper and eggplant were the most profitable from the farmer survey, although they are a high risk combination given both are solanaceous crops with some similar diseases.
- Yields are consistently higher under protective cropping for tomatoes, sweet pepper and kangkong.
- Incidence of bacterial wilt is consistently lower under protected cropping
- Drip irrigation improved yields as well as saving labor, time, and water compared with the typical manual irrigation used by small scale farmers.
- Bed mulch reduced weeds, and a range of local organic mulches were effective alternatives to plastic mulch, thereby reducing disposal and purchase costs.

The transfer of aeroponic technology to white potato seed growers and the private sector has the potential to increase the rate and quality of seed potatoes, of desired high-value potato varieties and hence increase profitability of potato producers.

7.3.2 Social impacts

The formation of functional farmer groups as part of the FFS has not only improved farming skills but has developed community organisational and business management skills. One example is in Tunga, Leyte, at a site that EWS was engaged with Vegetable ICM training and resulted in the Women's' Association also engaging a government agency (Philippines Coconut Authority (PCA)) for cacao production and a piggery project assistance. In La Suerte, Bohol the local farmer group received funds for a water tank to support local vegetable irrigation.

Weekly activities in the FFS further developed the farmers' enthusiasm to learn, speak and express themselves within their small group; many of which have gone on to participate more actively in community decision making. This has been particularly marked for the women who participated in the FFS.

Those farmers recovering from the impact of Typhoon Haiyan found psychological healing through participation in the FFS and resultant productive vegetable production livelihood. Ms. Guillerma Sabijon, like many other farmers, had never been to school but after participating in the project FFS she proudly hangs her certificate on the wall of her home.

A total of seven Agricultural Technicians in Bohol, appointed in consultation with the local government, were directly involved in the project implementation as Landcare extension facilitators and who are now part of the pool of local trainers with enhanced skills on improved vegetable production in the province. Under a system of local governance, extension workers at these levels play a key role in charting agricultural development in their areas.

The commercialization of the aeroponic system to increase supply of clean seed of desired varieties should increase the number of potato growers. This could be an opportunity for a livelihood program to invest in a small aeroponic system to provide local small holder farmers access to cheap clean seed to grow for either gourmet or processing potato markets.

Visits of Australian team members to the Philippines and vice versa fostered a cultural exchange and understanding that goes beyond the technical exchange and impacts positively on their respective families as well.

7.3.3 Environmental impacts

An underlying principle of integrated crop management is to use natural and agrichemical resources efficiently to maximize crop productivity and profitability, but also to minimize negative environmental impacts. These principles were included in the farmer training with modules on crop production and protection with emphasis on growing healthy plants with optimum water and nutrient, recognising and monitoring for pest and beneficial insects, and crop sanitation; as well as modules on soil and water conservation including contour farming and mulching beds.

The targeted agronomy and crop protection research had a major focus on evaluating local materials, for example the use of banana leaf seedling cells were an effective alternative to plastic seedling trays, rice straw mulch was in some instances as effective as plastic mulch, or cabbage as a soil amendment for reducing bacterial wilt. Most of the pesticides evaluated have been selected as likely to have less negative environmental impact.

Among the Landcare partners in Bohol, the La Suerte and San Isidro farmers were the early adopters of contour farming.

Aeroponic production of clean or bacterial wilt-free potato seed reduces the need for further forest clearing to produce viable crops.

7.4 Communication and dissemination activities

The Vegetable ICM project used a range of communication and dissemination activities to both understand the crop protection, agronomic and other issues faced by small holder vegetable farmers as well as to train them, the project staff and extension staff in 'best-bet' good agricultural and crop protection practices that form the basis for an integrated crop management strategy (see short summary below or a fuller listing Appendices 1–5).

The Vegetable ICM project communicated with small holder farmers via season long farmer field schools, through the demonstration sites and co-operative demonstration farmers, through farmer field days, workshops and university anniversary days. The project will continue to communicate project outcomes with farmers via the best practice guides for each of the focus crops for field or protected cropping production, and via the integrated pest management guides and individual invertebrate pest or disease factsheets. The best practice and IPM guides have all been translated from English into Tagalog, Cebano and Waray languages. These extension materials will be available via the Department of Agriculture's Agricultural Training Institute extension staff, via the collaborative universities' websites and the ACIAR website. We had intended to also make available via a phone based app but this will need to be achieved in the follow-on project.

The farmer run demonstration sites have been a hub of farmer to farmer training and as a venue for field visits as part of project workshops and for farmer field days at the Samar site. The research sites at VSU, BISU and MOSCAT/USTP have been used extensively for student practicums, for student research projects and theses, and for farmer field days, often associated with the university anniversary celebrations.

Joint Australian and Philippine ICM workshops were conducted in association with small holder farm visits in Bohol in August 2013, in Leyte, Samar, Bohol and Claveria in July-August 2014 and in April 2015, which also included a site in Davao. At the two ICM week long workshops or 'Master Classes' key farmers and some extension staff were included along with the research staff.

The VSU entomologist, Professor Gerona ran nineteen vegetable pest identification and management workshops around Leyte in 2016–17, and Dr Gonzaga ran four two day crop protection workshops at VSU in 2017.

All the research staff attended professional or agricultural national or international conferences to present their research findings, and some have published in refereed journals (see Appendices 1 and 4).

Summary of the formalised project communication activities

- 2072 farmers trained in ICM FFS (968 with inputs)
- 3087 farmers, students and farm extension reached via FFD and technology expo, workshops, or presentations (an additional 5200 via VSU Anniversary days)
- 3150 VSU crop protection students visited the VSU field site
- 20 research staff trained in aeroponic production at UPLB, NMACLRC and BSU; 100 visitors to the aeroponic facility at DAF, Australia
- 23 papers, 27 posters with 8 and 20 papers respectively at international conferences
- 21 papers published in refereed journals, another 19 for an ATR special edition
- 30 BSc theses, 6 MSc theses and 3 PhD theses
- Best Practice Guides for field grown and protected cropped tomato, sweet pepper, ampalaya, pechay, and lettuce; field grown eggplant, kangkong and cabbage; as well as for seedling production and protected cropping. [Cebano, Waray and Tagalog]
- IPM Guides for tomato, eggplant, sweet pepper, ampalaya, pechay and kangkong also translated into Cebano, Waray and Tagalog
- Disease factsheets (60) [Cebano and Waray] invertebrate pest factsheets (15)
- 1 DAF factsheet and 1 video on aeroponics

- 1 NSW DPI factsheet on melon sanitation and 1 food safety best practice guide

8 Conclusions and recommendations

8.1 Conclusions

The three different models for farmer field school training used in the project each had strengths and weaknesses relative to the other models and related to the skill breadth of the trainers/facilitators. Initial feedback was positive and the early evaluation survey of the central Visayan training was that it did improve profitability of small holder farmers by 50% two years after training.

Farmer led demonstrations can be effective for showcasing new practices and for those practices to be difused to wider audiences. Having the farmer field schools and demonstrations commence at the beginning of the project did mean that materials were based on best-bet ICM practices and did vary depending on the prior knowledge and skill of the trainers or collaborative demonstrator farmers, and evolved of the course of the project.

Vegetable disease management

Bacterial wilt is the major disease that affects tomato, eggplant, pepper as well as bittergourd in Southern and Central Philippines. Phytoplasma that causes little leaf and target spot caused by *Corynespora cassiicola* were new records for southern Philippines in tomato and bittergourd, other emerging diseases of tomato were bacterial canker and septoria leaf spot.

The low cost protective structure consistently reduced bacterial wilt incidence in almost all the plant pathology trials conducted. Bacterial leaf spot and leaf mould were also reduced in a few trials which further highlights the importance of protected cultivation in the Eastern Visayas region where annual rainfall is very high (>2000mm per annum).

Effective management options for bacterial wilt in tomato included: cabbage residue as a soil amendment, foliar sprays of chitosan and chitosan plus acetylsalicylic acid (Aspirin) as well as Lomboy wood vinegar, drenching of rice hull and madre de cacao wood vinegars, and grafting tomato or sweet pepper onto resistant root stock, and were more or only effective when combined with protected cropping.

Commercial products Serenade (*Bacillus subtilis* strain QST713) and Liquid PhosPro (phosphate plus calcium; 0-16-0-4) had lowered bacterial wilt incidence but did not increase the yield of sweet pepper.

Bacillus thuringiensis var aizawai, *Lactobacillus plantarum*, Bio N and most of the wood vingegars tested were not effective in reducing the disease. Similarly, the varying soil pH did not have an effect on disease incidence and yield of tomato.

Wood vinegars from bamboo, banaba, ipil-ipil, lomboy, madre de cacao, malunggay, mango, rice hull and panyawan at 0.2% can protect tomato plants against *S. rolfsii* infection. Wood vinegars were phyto-toxic at higher concentrations.

Vegetable invertebrate pest management

There is poor understanding of insecticide modes of action, efficacy, relative toxicity or persistence in the environment. Even crop protection experts tend to group all pesticides into one homogenously ‘bad’ group and all biologicals or botanicals in one homogenously ‘good’ group.

The efficacy testing of a range of products for acaricidal or insecticidal properties helped highlight the variations in efficacy. None of the synthetic nor any biological or botanical insecticides or acaricides consistently controlled the target insects; reducing pest damage rarely resulted in increased yield, protected cropping usually improved efficacy, synthetic insecticides generally were the most effective, and when biological or botanical insecticides had an impact they were less effective but better than water control.

The fermented plant juice of madre cacao showed no effect on a range of sucking, mining and chewing insects on cabbage. The other botanical concoctions or biological pesticides showed some efficacy on some insects in some cropping situations. But even *Bacillus thruingensis*, a biological insecticide widely registered for use on lepidoptera, was washed off in the field and ineffective in 1 out for 4 field experiments on cutworm.

Not all botanical concoctions are safe for famers to apply or consumers to eat. The 7 herb plus concoction that was tested in three experiments includes tobacco as an ingredient. There are human health concerns with neem. Wood vinegars can be differentially phytotoxic and should be also screened for mammalian toxicity.

Agronomic technology

The findings of the agronomy component suggest that appropriate cultivars for each area, use of protective structures, efficient water delivery systems for irrigation, effective method of raising seedlings in different cultivation practices, suitable mulching materials and proper soil amendments are important considerations to improve production of vegetables. Cultivars such as “Green Span” and “Green Towers” of leaf-type lettuce, all heat tolerant cultivars of head-type lettuce, “Emperor” of sweet pepper when grafted to chili, “Season Red” of tomato when grafted to eggplant and planted in open field, and likewise grafted “Diamante Max” under protective structure in Leyte, and “AVTO 1173” fresh market tomato line in Claveria produced the heaviest yield and similarly the highest income.

The use of protective structure regardless of type increased yield of tomato, sweet pepper, eggplant, ampalaya, lettuce, pechay, and kangkong. UV stabilized plastic roofing of the structure effectively protected the plants from rain hence minimized plant disease, provided continuous growth and development of plants, retained soil nutrients and improved yield. Net roofing structure with G.I. pipe frame withstood strong wind, slightly minimized rain droplets and effectively avoided soil splash towards the crop which enhanced yield of pechay and lettuce.

The irrigation method using drip bottle under house-type structure with plastic roofing showed consistent advantage for tomato, sweet pepper and ampalaya by providing small but continuous supply of water throughout the day which identified the drip hose system’s lack of effectiveness in its irrigation scheduling and the disadvantages of sprinkler method.

Testing different methods of raising seedlings revealed that using seedling trays (seeds sown in seed box then pricked to individual plug of seedling tray and transplanted at right size) was superior with respect to crop’s performance compared to other methods such as direct seeding and seed box.

Mulching materials such as black plastic on tomato, silver plastic on cabbage, rice hull and straw on ampalaya, *hagonoy* on sweet pepper increased the yield over bare soil as weeds were effectively controlled. Application of organic amendments such as carbonized rice hull, vermicast, chicken dung, wokozim, biogreen, sea crop, wood venigar, wedelia, hagonoy, cabbage waste, wild sunflower and vermi leachate effectively increased yield and reduced bacterial wilt infections. The addition of these organic amendments provide nutrients to plants, enhanced nutrient retention, and some contained isothiocyanates that are harmful to soil borne pathogens. The research within the agronomic component showed that the combination of a number of agronomic practices on the focus crops can increase yield and improve sustainability.

Aeroponics

The low cost aeroponic system increases seed multiplication rates in mid and high-land areas of the Philippines, therefore site selection for commercial production units is important to lower the input cost.

Cold-stored minitubers showed uniform sprouting in sequentially harvested tubers in comparison to diffused light storage, therefore cold store facility should be developed to maintain seed quality and seed supply.

The small size minitubers produce similar tonnage and warehouse size tubers as that of conventional size seed tubers, therefore aeroponic seed could be directly sold to the farmers negating the need of further multiplication and indicates the system has a role in seed potato production relevant to both developing and developed countries.

The seed of late blight and bacterial wilt tolerant varieties could be made available to potato growers using aeroponic techniques, to reduce crop losses in integrated disease management plan. Aeroponic technology could also be used to produce “gourmet potatoes” using marginal lands/urban settings.

8.2 Recommendations

1. That this project underpins further investment by ACIAR and the Philippine government into Good Agricultural Practice (GAP) protocols in the Philippines.
    a. That it includes regular invertebrate pest and disease surveys of crops and the lodging of identified specimens into a central curated respository to be able to support region and country disease or pest-free status, and to inform farmer extension services.
    b. That crop protection product efficacy experimental standards are developed and crop protection recommendations are based on efficacy testing.
    c. That registered crop protection product information is readily available on the Fertilizer and Pesticide Authority web site and link to from the Department of Agriculture, that pesticide ‘modes of action’ and efficacy testing data be readily available to assist in making decisions about which pesticides are allowable and what are the more appropriate for the situation.
    d. That botanical and biological crop protection or plant stimulation products are subject to due diligence on human and environmental safety before recommended by state agencies.

e. Similarly that agronomic best practices such as protected cropping, drip irrigation, and mulches etc. be evaluated on their potential for enhancing the food safety of produce grown in those systems compared to conventionally grown systems, i.e. determine whether the best practice recommended systems reduce the risk of microbial and pesticide contamination.

2. Knowledge generated from this project offers opportunities for the Philippines to further develop climate resilient technologies based on evidence-based studies. The structural designs and cropping systems developed as appropriate for climate vulnerable provinces of eastern Visayas and northern Mindanao represent a significant body of knowledge and experiences that this project has contributed in the country's quest for climate smart technologies and offers opportunities to revisit the current organic agriculture program and offer science based ICM technologies.
3. That University teaching staff are encouraged and have support to conduct research and given more time to integrate findings into papers.
4. That ACIAR project investment encourages a balance of teaching and research workloads for project collaborators.
5. That pesticides are included in university teaching of crop protection and includes mode of action, target organism, non-target impacts, mammalian toxicity, persistence and movement through the environment, as well as application risks and methods for safe application.
6. That cultural practices such as soil preparation, planting on beds, disease-free well grown seedlings, optimal nutrition and moisture management are fundamental components of [vegetable] 'crop protection'.
7. That grower demonstrations of ICM include some side-by-side experiments (with and without protected cropping, bed mulch etc or different rates of fertilizer) with data collection to demonstrate treatment differences and encourage critical evaluation.
8. That follow-up surveys are constructed to evaluate the different style of FFS, and conducted with farmers participating in the project run FFS to provide feedback to LFPI and EWS training teams and subsequent ACIAR projects.

Plant pathology

9. Further survey work on extent of phytoplasma and viral diseases on vegetables be undertaken, and determine whether there are varietal differences in susceptibility.
10. Bacterial wilt management using combination treatments
    a. That a series of crop rotation and green manuring experiments are conducted over a number of years at VSU with regular testing of soil for bacterial wilt infectivity in pot and tomato seedling bioassays for data to underpin rotation recommendations.
    b. That treatments to improve soil drainage are evaluated for impact on bacterial wilt disease severity.
    c. Recommendations be subject to economic analysis
11. That Kamlong grafted tomatoes are tested for fusarium and phytophthora resistance or tolerance.
12. In Australia both sudden vine decline and gummy stem blight are emerging as serious diseases needing more study.

13. Need to maintain sound biosecurity to prevent exotic wilt pathogens from entering & establishing in Australia, this includes races of *Fom* not yet in Australia.

Entomology

14. That the University entomologists link more closely with the Department of Agriculture Regional Crop Protection units to develop quality control monitoring of insectary produced organisms and in developing an experimental basis for management programs and recommendations.
15. That positive controls for efficacy testing include locally preferred or used insecticides as well as the most IPM-friendly registered insecticide (registered on target organism, low mammalian toxicity, minimal impact on key beneficial organisms, isn't known to bio-accumulate, nor a threat to crustacea or important fishery biota).

Agronomy

16. Conduct additional research into typhoon-resilient structures, including quick-release fasteners for easy removal and reapplication of net or plastic roofing.
17. Further research on the use of drip hose irrigation system for rates and timing of application.
18. Further research on long term effect of organic mulches as it degrades and is incorporated in the soil.
19. That high and low tunnel structure demonstrations are supported in areas of high rainfall. That training in good basic agronomic practices (ground preparation, seedling production, nutrition, planting, trellising or pruning as required, irrigation management) and crop protection practices must accompany the demonstrations.

Aeroponics

20. That further investment is made into a pilot small-scale aeroponic scheme with seed potato growers, and supported by aeroponically competent technical researchers, economist and extension workers to evaluate its commercialization potential.
21. That best-practice cultural practices for growing potatoes are demonstrated, together with an integrated bacterial wilt management strategy and the clean aeroponically grown seed potato, in demonstration plots or 'model' farms in cooler mid and upland areas, where conditions are optimal for growing potatoes. Support needs to be provided for the co-operative farmers to implement non-bacterial wilt host rotations and to link to high value markets to support a higher level of management. Technical support from a plant pathologist, a good field agronomist, post-harvest and market expert as well as an economist would maximise the likelihood of success. A successful on-farm demonstration is a powerful extension tool for other farmers to change practices.

9 References

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9.2 List of publications produced by project

See Appendix 1 for refereed journal papers

See Appendix 2 for extension materials

See Appendix 3 for student theses

See Appendix 4 for poster and conference presentations

10 Appendices

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10.1 Appendix 1: Summary of journal papers

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10.5 Appendix 5: Summary Farmer Field Schools

Appendix 5 Summary FFS.pdf

10.6 Appendix 6: Summary of ICM trials

Appendix 6 Summary ICM Trials.pdf

10.7 Appendix 7: Summary of team training

Appendix 7 Summary of team training.pdf

10.8 Appendix 8: Summary of disease inventory

Appendix 8 Disease inventory.pdf

10.9 Appendix 9: Summary of invertebrate pest inventory

Appendix 9 Pest Inventory .pdf

10.10 Appendix 10 Aeroponic economic analysis

Appendix 10 Aeroponic economic a