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Improved domestic profitability and export competitiveness of selected fruit value chains in the southern Philippines

Component 4 – Improved and sustainable value chains for mango production in the Philippines and Australia

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Contents

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2 Executive summary

In both the Philippines and Australia, sustainable development of the mango industry is hampered by pest and disease losses, variable productivity, supply-chain deficiencies and market access challenges. The Component aims were to develop, evaluate and implement sustainable practices for the production and marketing of quality mangoes with less reliance on pesticide use, leading to improved incomes.

In the Philippines, the results have led to improved crop management methods, which were demonstrated to control the key targeted pests (thrips, cecid flies, mango pulp and seed weevils, anthracnose and stem end rot). As a result, losses and input costs were reduced, which translated into improved farmer profits. For the control of the mango postharvest diseases, anthracnose and stem end rot, a package of in-field fungicide spray treatments and postharvest treatments was developed and disseminated to growers. Nutrition studies were assessed in relation to disease incidence. The fruits developed anthracnose at ripening, regardless of chemical flower inducer or N-fertilizer levels. Extended pesticide withholding periods are required to ensure compliance with residue limits in export destinations such as Japan. For other export countries and for the local market, it is recommended to strictly follow preharvest good agricultural practice (GAP) guidelines. A key area of success in this component was the extension programs. A system of using “farmer clusters” and selecting and training key growers within each cluster was developed and provided a superior system of extension, reaching more farmers. In Australia, new integrated pest management (IPM) solutions for key production and market access pests were developed, including an effective pheromone trap for fruit spotting bugs and a chemical control method for mango seed weevil.

This component has improved the scientific and management capacity of scientists, extension workers, farmers and other stakeholders that will have benefits now and into the future. The most significant impact is the economic benefit that the farmers will gain in increased income due to higher yields and higher quality (pest and disease-free) fruits; correspondingly, the reduced yield losses, improved fruit quality and reduced production costs have increased farmer profits. In an economic analysis from Palawan, the IPM package produced an income of PhP 1,730 (AUD 42.00) per tree, in contrast the conventional farmers practice produced PhP 21 (AUD 0.50) per tree. In Southern Mindanao, it was estimated that IPM practices developed from this project could reduce losses and rejects by 20%, improve yields by 33% and reduce the cost of production by 16% (through reduced chemical control costs), which would produce an estimated 156% increase in farmer income. With improved systems of pesticide residue control, Philippine mangoes will be more competitive to export destinations. There will also be environmental, social and health impacts from a reduction in pesticide use and less chemical residues in the consumed fruit.

Future project work should concentrate on developing: IPM compatible inputs, pesticide resistant management plans, and area wide management strategies that engage not only the farmers, but also the contractors. Further research into organic inputs could provide some cost-effective solutions to nutrition, pest and disease problems, but more research with conventional synthetic chemicals and residue management is required. Farmers need to reduce their crop pest pressure (in particular thrips, cecid fly and fruit fly), disease incidence (to increase shelf life) and reduce the risk of pesticide residues. Research in nutrition and canopy management could provide improved methods of reducing pests and diseases, as well as producing export quality mangoes. The farmer cluster model should be extended, so as to reach more farmers and perhaps more importantly to include contractors. However, further resources are required to support research and extension staff.

3 Background

This Component was a part of a large multidisciplinary Project HORT/2007/067 'Improved domestic profitability and export competitiveness of selected fruit value chains in the southern Philippines'.

In the Philippines, mangoes (primarily cv. Carabao) are an important crop for both plantation and smallholder farmers. While a large portion of the industry is in Luzon, Mindanao in the southern Philippines is an important off-season supplier.

In both the Philippines and Australia, sustainable development of the mango industry is hampered by pest and disease losses, variable productivity, supply-chain deficiencies and market access challenges. This Component incorporated the development and evaluation of a number of strategies for improving mango industry sustainability in the Philippines and Australia. These have included: improved field and postharvest management of key pests and diseases, improved agronomic practices to stabilise crop yields and the evaluation of postharvest treatments to minimise residue levels and improve access to export markets. This Component used a focused case study approach of working with selected collaborators from the target areas of production and supply chain operations in the southern Philippines.

High pressures of insect pests and diseases have caused losses and damage levels ranging from 10 to 40 percent. The use of different postharvest treatments to reduce these losses has contributed to limiting market access, due to enforcement of Maximum Residue Limits (MRL), and thus restricting entry to overseas export markets. It has been estimated that 60–80% of mango production costs in the Philippines were due to the high levels of pesticides used (Bayogan et al., 2006). Despite this, the loss of fruit quality continues to be a major problem and the excessive pesticide usage has resulted in high chemical residues in the fruit. To address these concerns ACIAR initiated a project in 2003 on integrated pest and disease management with the main aim of reducing pesticide usage ('Integrated pest and disease management and supply chain improvement for mangoes in the Philippines and Australia', HORT/2003/071). The project identified that actual harvestable yield of mango is only 50–75% of the potential yield and of this; 50–68% of the harvested fruit is lost due to pests and diseases.

The build-up of disease inoculums and pest population levels in the field has necessitated this dependence on high pesticide use. To address these issues, an integrated approach was required to identify promising agronomic practices including better management of nutrients and water for improving fruit quality and increasing yield. To increase shelf life of harvested fruits, improved strategies were required for the control of: blossom and postharvest anthracnose, mango scab and stem end rots. Insect pest problems such as cecid fly, thrips, and the fruit spotting bug required research to ensure that IPM strategies were in place to provide sustainable methods of dealing with these pests. IPM strategies to deal with other established pests such as the pulp and seed weevils (initiated in the preceding project) were continued so that the findings could be adopted by producers and contractors to manage these pests. It was thought that a systems approach that could integrate field control strategies with improved postharvest disinfestations would reduce costs and the risk of unacceptable residue levels or disinfestation failures.

Key Issues

The overarching aim of this Component was to develop, evaluate and implement sustainable practices for the production and marketing of quality mangoes with less reliance on continuous pesticide use, leading to enhanced incomes for the growers and other stakeholders involved in the industry. Mindanao and Palawan were the target regions. The adoption of the Component outputs for sustainable management of pests and diseases and improved agronomic practices was fostered through close partnership with provincial extension officers, spray contractors and key supply chain members.

Partner country and Australian research and development issues and priorities

In 2010, the Philippines produced 843,508 tonnes of mangoes from 197,816 hectares (4.7 T/ha) with 23,470 tonnes exported (FAOSTAT, 2007-11). The country shares 2% of the world mango production and export trade. The industry is based on one cultivar ('Carabao'), with approximately 90% of mangoes produced in the country consumed as fresh fruits. The main export markets include Hong Kong, Japan and Singapore. Currently, mango production lags behind population growth in the Philippines and it is likely that domestic and export demand for mangoes will continue to grow. However, despite increases in area from new mango plantings, yields are declining.

Peak mango production in the Philippines is from February to May (counter seasonal to Australia). Smallholders as well as large plantations contribute to production and there is an active network of provincial agriculturists fostering improvement of crop management. Almost 73% of mango farms are under 3 ha and 27% are between 3 to 10 ha. Smallholder production (from farms under 3 ha) account for almost 48% of the total production (BAS 2013)

Field management of pests such as fruit flies and diseases such as stem end rots in the Philippines can be variable. Thus, there is a need to improve integrated pest management, develop effective controls for emerging new pests and extend market access compliance through judicious use of chemicals. Overall, pest damage, quarantine and supply chain problems can result in losses ranging from 10 to 30% per year, with smallholder producers being particularly disadvantaged (DOST-PCAARRD Industry Strategic S&T Plan for Mango, 2012). Disease losses can also be high, adversely affecting grower returns.

Pest and disease management has a significant impact on fruit quality, on market access and production efficiency. These constraints are best addressed through an IPM approach because of the benefits of reduced and targeted pesticide use. For market access pests, a combination of IPM and eradication, with a view to establishing area freedom for specific production regions, is considered the most appropriate. The Philippines has a mature mango industry, which seeks to sustainably improve profitability, by expanding market opportunities including exports. It was proposed that this be achieved by more effective use of integrated pest management and judicious use of chemicals, reducing pest and disease losses, improving compliance with quarantine/market access requirements and through improving technical performance and supply chain management.

This Component addressed R&D priorities identified within the mango industry strategic plans of the Philippines and Australia, and had the support of industry and R&D agencies in both countries. This Component also complements the other disease management projects such as PHT/1997/094, the DOST-PCARRD S&T Anchor Program for Mango in the Philippines and current and planned projects in Australia. Recognising the expected benefits of this Component, the Australian Mango industry Association (AMIA) and Horticulture Australia (HAL) continued to provide complementary funding to support other activities identified to be important and specific to Australian industry needs.

This Component brought together teams from Australia and the Philippines to work on specific research areas to increase mango production and improve fruit quality. The activities of this Component were implemented in continuous consultation with the Australian mango industry. The specific research areas were:

Insect Pest Issues

A previous project, HORT/2003/071 identified critical insect pests limiting productivity and marketing of quality mangoes in the Philippines and the biology and ecology of these pests were studied. This Component has developed and evaluated integrated pest management options that will be used to sustainably manage some of the target pests. This work has included activities associated with insecticide efficacy and the assessment of appropriate chemical controls.

Disease Issues

Disease management research in the preceding project (HORT/2003/071) focused mainly on the evaluation of a number of activators capable of enhancing the plants' natural defence mechanisms. Considering the relatively high pesticide levels in use, these findings were used to develop IPM practices with significantly reduced pesticides used for control of mango scab and stem end rot diseases. This work has also included activities associated with fungicide efficiency and the assessment of appropriate chemical controls.

Agronomic Issues

Lack of knowledge and skills on integrated crop, soil, nutrient and water management practices is a major constraint to increasing cost-effective production of mangoes. Thus, identification of such promising practices in conjunction with integrated pest and disease management practices has greatly benefited the mango industry and the farmers of both countries.

Agronomic issues addressed through this Component have focused on management practices for improving plant nutrition. Adequate and balanced crop nutrition is becoming increasingly important not only because of its positive effects on productivity and quality of mango but also due its close relationship with field disease development. Specific studies investigated nitrogen and potassium nutrition in relation to the stimulation of flushes and flowering as well as their influence on the management of anthracnose and stem end rots.

Pesticide residues issues

There have been several instances, where Philippine mangoes have been rejected by importing counties for exceeding the MRL of pesticides. In order to expand the export market, procedures need to be established to monitor residue levels in out-going fruits to ensure compliance with the target market requirements.

To ensure consumer confidence in food safety, a sound strategy was needed to test the levels of residues and identify appropriate agricultural management practices. In this Component pesticide residue levels of mango under current and proposed agricultural practices were measured and appropriate residue management strategies were recommended.

Development of integrated crop management strategies

The work on insect pests, diseases, crop agronomy and pesticide residues was brought together through the development, dissemination and implementation of integrated crop management strategies. These integrated crop management strategies have taken account of current best practices and the work being carried out in other projects such the Pakistan Agricultural Sector Linkages Programs (ASLP) (HORT/2005/153, 2005-2010 and HORT/2010/006, 2010-2014).

4 Objectives

The overall aim of this Component was to enhance the sustainability of the mango industry in the Philippines and Australia through a systems approach that will improve pest and disease management and the consistency of the supply of quality mangoes for targeted markets. The specific objectives were:

Objective1: To develop and evaluate sustainable practices for the integrated management of mango pests and disseminate the information to industry stakeholders.

- Study the ecology and management of cecid fly and thrips
- Evaluate fruit fly lures for baiting systems
- Evaluate habitat disruption to and conduct other studies on mango pulp weevil
- Evaluate basal bark applications of systemic pesticides for targeted pest management
- Develop semiochemistry formulations for attractancy testing against fruit spotting bugs and mango weevils
- Development of workshops and extension materials on IPM, pest and beneficial insect monitoring, insecticide application technology and chemical withholding periods and residues.

Objective 2: To develop and evaluate sustainable practices for the integrated management of field and post harvest diseases.

- Study management of stem end rots
- Epidemiology and management of mango scab
- Review and disseminate anthracnose disease findings
- Study mango disease epidemiology
- Study genetic resistance to mango diseases
- Develop integrated disease management strategies.

Objective 3: To develop and evaluate integrated crop management strategies for productive, profitable and sustainable production of high quality mangoes.

- Review of existing crop management research information to identify current knowledge gaps
- Determine the influence of mineral nutrition on yield, fruit quality and disease/pest defence in mango
- Develop standardised research protocols for assessing agronomic trials that are linked to plant defences
- Investigate the use of rapid leaf nitrogen measurements and methods for determining nitrogen status.

Objective 4: To evaluate food safety issues that limit better access and competitiveness in mango exports

- Review the supply chain and identify potential food safety issues in mangoes arising from pesticide use
- Document potential food safety issues from the review with steps on how these will be addressed to meet market needs and regulations
- Identify researchable issues and potential mitigation strategies to address the potential food safety issues
- Establish protocols to start addressing the issues identified
- Food safety researchable issues to be identified and addressed by relevant institutions.

Objective 5: Extension sub-component

Nb. this objective was added at project implementation by Dr Akem to address the need for effective technology transfer.

- Develop/ reproduce mango production brochure “Integrated Crop Management Operations Guidelines for Mango”
- Conduct Mango Technology Training/Forum
- Conduct Field Monitoring/Inspection and Evaluation

5 Methodology

Objective 1: To develop and evaluate sustainable practices for the integrated management of mango pests and disseminate the information to industry stakeholders.

Strategies were developed to integrate different control methods for the sustainable management of selected field pests, especially the emerging cecid fly, thrips, pulp and seed weevils.

In the Philippines

1.1 Ecology and management of cecid fly and thrips

This work was conducted in Southern Mindanao by Dr Celia Medina (UPLB), Dr Ana Notarte (Provincial Agriculture Office, Davao de Norte) and Ms Julia Sagolili (Provincial Agriculture Office, Davao de Sur). The following methodologies were attempted:

- Identifying the key biotic and abiotic factors regulating the population of thrips.
- Determining the taxonomic identity and ecological relationship of the cecid fly population in the shoots of mango and the cecid fly population in the fruits of mango.
- Evaluating the effect of the farmers' pest control practices on the population of predatory arthropods and parasitoids attacking cecid flies and thrips.
- Studying the potential of natural enemies as biological control agents against cecid fly and thrips.
- Designing and evaluating efficient and user-friendly monitoring systems for cecid flies and thrips.
- Conducted training and workshops to disseminate information and to develop integrated pest management strategies through participatory approaches
- Developed and produced appropriate extension materials.

The study on the ecology and management of cecid fly and thrips was conducted in Samal Island, Davao del Norte and Padada, Davao del Sur. At each site, random samples of panicles (of flowers or fruits) were collected at 7 day intervals, from 10 - 55 days after flower induction (DAFI). The panicles were collected from sprayed and unsprayed trees. All insects present in the samples were recorded.

Further basic studies were undertaken to understand and characterize the damage of thrips in mango. The taxonomy, biology and ecology of the two thrips species were also studied.

With a negligible population of natural enemies in the study sites, the impact of spraying on natural enemies could not be determined. This activity was subsequently dropped and an emphasis was given on the generation of basic bio-ecological information on thrips in mango.

1.2 Evaluate fruit fly lures for baiting systems

This activity was deemed no longer necessary because fruit fly lures are already being routinely used in mango orchards in the Philippines. Therefore, this activity was dropped from the program.

1.3 Evaluate habitat disruption and conduct other studies on mango pulp weevil (MPW) populations

This work was conducted in Palawan, where MPW occurs, by Dr Louella Lorenzana. The following methodologies were used:

- Continued to explore the potential to eliminate the MPW from Palawan.
- Carried out further studies on the biology and ecology of MPW.
- Followed through with the destruction of wild and domestic tree populations and restricted cropping over a 3–4 year period.
- Carried out economic assessments to help policy and eradication decision-making.
- Developed and evaluated best management options for the MPW with considerations of residue issues as a link to the residues study activities.

Field collection and laboratory culturing of MPW was done in Brooke's Point, Palawan. Preliminary laboratory tests were made to determine the appropriate dose of the frass (insect excrement) volatile, acetic acid, which could be attractive to MPW using glue traps. Preliminary tests on the trap design were also made.

There were two demonstration trials conducted in Barangay Pangobilian, Brooke's Point, Palawan. The two trials were conducted to compare an IPM treatment for MPW with the current "Farmer's Practices". The trials were evaluated through a cost benefit analysis of IPM. In the IPM treatment trees, 25% was open centre pruned, as was determined from the earlier ACIAR-IPM project (HORT/2003/071). The IPM treatment also consisted of field sanitation, pest monitoring, and chemical control. The farmer's practice relied on chemical control only (the application of insecticides).

<u>In Australia</u>

1.4. Evaluate basal bark applications of systemic pesticides for targeted pest management

This work was conducted in North Queensland by Dr Ian Newton (DAFF) and Mr Stefano De Faveri (DAFF). The following methods were undertaken:

Efficacy trials were conducted to evaluate if there is significant potential to use the basal bark application technology for bark penetrating chemicals. Field trials were conducted to evaluate the effectiveness of systemic insecticides mixed with basal bark penetrating chemicals at different dose rates and compared to a control and industry standard pesticides. Fruit quality assessments were performed to evaluate the treatments.

Basal bark applications did not control seed weevils; therefore other application methods of thiamethoxam were tested. Soil drench methods which included applying the chemical in small ground holes and direct soil injection were successfully trialled. These trials looked at different: chemical rates, application methods, soil types, geographic locations (within North and Far North Queensland) and the effects on other mango pests (mango scale, mealybugs and planthoppers).

1.5. Develop semiochemistry formulations for attractancy testing against fruit spotting bugs and mango weevils

In Australia

This work was conducted in Mareeba (Queensland) by Dr Harry Fay (DAFF) and in Brisbane by Dr Andrew Hayes (DAFF). The fruit spotting bug work was undertaken in collaboration with Dr Ashot Khrimian of the United States Department of Agriculture (Beltsville, Maryland, USA).

Using previous work on semiochemistry of fruit spotting bugs and mango seed weevils, further trials were conducted in both the lab and field to identify chemical standards responsible for mating and attraction of these insects. The response of insects was tested in single and combinations of the pheromone components through use of various methods in the organic chemistry labs, including Gas Chromatography Analysis and olfactometer choice tests. Following the laboratory studies, field trials were conducted to test the synthesised pheromones on wild insect populations. Further detailed methodology can be found in Khrimian *et.al.* (2012).

In the Philippines

Laboratory tests were conducted in order to develop semiochemistry formulations for attractancy testing against MPW. The appropriate dose and the type of trap design for attractancy to MPW was determined. The attractiveness of different doses of acetic acid in different trap designs was determined in a cage (1m x 0.5m x 0.5m) bioassay for 48 hr.

1.6. Development of workshops and extension materials on IPM, pest and beneficial insect monitoring, insecticide application technology and chemical withholding periods and residues

In the Philippines

A linkage was established with the Local Government Unit (LGU) of Brooke's Point, Palawan for the conduct of the field day for the IPM trial in Barangay Pangobilian, Brooke's Point.

Another linkage was established with a line agency of the Department of Agriculture, the Bureau of Agriculture and Fisheries Product Standards (BAFPS) for the conduct of the IPM workshops on pest and beneficial insect monitoring, insecticide application technology, residues and chemical withholding periods.

1.7 Conduct participatory action research (PAR) trials on mango IPM in Brooke's Point, Palawan

The IPM demonstration trial in section 5.2 was successfully implemented so that the next phase was to conduct PAR trials in 4 sites at Brooke's Point, with the involvement of 4 farmer partners. In the conduct of the PAR trial, IPM for mango production was followed using 10 mango trees per site. Marketable yield was determined and the net income per tree was calculated.

Objective 2: To develop and evaluate sustainable practices for the integrated management of field and post harvest diseases.

In the Philippines

The following activities were conducted in Southern Mindanao by Dr Oscar Opina, Dr Elda Esguerra, Dr Teresita Dalisay, Dr Virgie Ugay, Ms Merlina Juruena, Ms Julia Sagolili, and Ms Gina Fueconcillo.

2.1Study management of stem end rots

In the disease management study, systemic fungicides to be evaluated against SER (Stem End Rot) were identified. A mango farm located in Davao del Sur was visited and selected as the experimental site. Cultural practices, insect pest management and pest and weather monitoring were carried-out during the whole production period.

Following the preliminary evaluation of fungicides, the fungicide spray program was optimized and assessed for control efficiency against SER in Davao del Sur (high disease pressure) and Laguna (moderate disease pressure). Randomly selected fruits were brought to UPLB for further postharvest treatment and to USeP for ambient storage assessment. Two withdrawal batches were done in mango fruits treated with HWT. The first batch was withdrawn from cold storage after two weeks and maintained in ambient temperature for 3 to 7 days.

The study on the major sources and quantification of field inoculum of SER and diurnal pattern of SER inoculum as well as effects of temperature and relative humidity on the seasonal abundance of SER inoculum was assigned to thesis students, but the latter experiment was discontinued due to breakdown of the volumetric spore trap.

In 2009 fruit samples were collected at the end of the season and assessed for effects of the pre-harvest treatments on SER incidence at a laboratory at the University of Southern Philippines. Another batch of harvested fruit was evaluated at the Post Harvest Horticulture Training and Research Center (PHTRC-UPLB) to determine the additional effect of hot water treatment (HWT) and cold storage on SER.

Several other experiments were carried out over different seasons on mango fruits produced in the Luzon region, to evaluate the effect of different postharvest treatments against SERs. Mangoes sourced from Canlubang, Laguna during late off-season production (June) were used to detect the effectiveness of Extended Hot Water Treatment (EHWT), HWT, Fungicide Dip (FD) and Modified Atmosphere Packaging MAP. Early off-season (February) fruits from Food Terminal Incorporated (FTI) in Taguig, Manila were used in another experimental set-up involving assessment of SER incidence when fruit was subjected to a low dose UV-C irradiation and an integration of HWT, Carbendazim Dip (CD) and MAP. Evaluation of biological control strategies to manage SER was assigned to undergraduate thesis students. Three rates of Serenade™ with the bacteria *Bacillus subtilis* as the active ingredient were assessed for its effectiveness against postharvest diseases of mango. Isolate FI 3 (*Penicillium* sp.) and isolate SI 8 (a non-sporulating fungus) were also utilized.

In 2010 randomly selected fruits were brought to UPLB for further postharvest treatment and to USeP for ambient storage assessment. Two withdrawal batches were done in mango fruits treated with HWT. The first batch was withdrawn from cold storage after two weeks and maintained in ambient temperature for 3 to 7 days.

For the SER epidemiology studies, the spores of the pathogen were recovered from mummified blossoms, necrotic lesions of mango leaves, blighted panicles, dead and healthy looking stem terminals and dieback twigs.

Through the collaborative activity of project sub-components (insect and disease management, nutrition and chemical residue), the Integrated Crop Management (ICM) program for mango was developed and implemented in Davao del Sur with a mango grower, Mr. Jose Casonete. Benchmark information on yield and quality profile, farm practices and production profile were documented prior to implementation of activities. Best-bet practices with emphasis on pruning, pest identification, pesticide management and pest monitoring were identified, discussed and demonstrated.

2.2 Epidemiology and management of mango scab

Studies were conducted on the epidemiology of the disease mango scab.

For scab biology and management research, diseased specimens were collected during the trials. Management of scab was integrated with the experiments on SER, but scab evaluation was obscured by thrips infestation as scab symptoms could not be discriminated from thrips damage.

For the epidemiology of mango scab, scab diseased specimens were collected during the mango seasons. Potential slow-growing fungi were isolated from scab-like lesions. Fungi isolations were attempted and pathogenicity tests were undertaken on the suspected scab isolates.

2.3 Review and dissemination of Anthracnose disease findings

Research findings on anthracnose were reviewed and incorporated in the brochure titled “Integrated Crop Management Operations Guidelines for Mango”. Included in the brochure were the scientific results, which served as basis for anthracnose disease management. Drafts of this operations guideline were distributed to mango growers and other stakeholders.

<u>*In Australia*</u>

The following activities were conducted in North Queensland by Dr Chrys Akem (DAFF).

Detailed methodologies could not be obtained due to Dr Akem resigning from the position.

2.4 Study mango disease epidemiology

The following activities were performed:

- Reviewed the disease cycle of stem end rot to determine the role of ascopores as a source of disease inoculum.
- Used spore traps strategically located under and above tree canopies to determine periods of peak infections and relate these to environmental and phenological parameters
- Developed and evaluated conventional and molecular techniques that can be used for the early detection of infections by stem end rot pathogens in the field, and predict threshold levels on harvested fruits to assist decision making.

2.5 Study genetic resistance to mango diseases

- Characterised mango varieties (using the gene pool collection at the DPI&F research stations) to classify varieties according to disease resistance.

- Used the anthracnose and/or stem end rot disease resistant varieties to establish root stocks that could be used in future disease management research.

2.6 Develop integrated Disease management strategies

- Evaluated the impact of different agronomic practices such crop nutrition, especially nitrogen, growth regulators and inducers such as PBZ and irrigation practices on the development and expression of stem end rots on mango fruits.
- Developed and evaluated ICM practices that could be recommended to growers to adopt and reduce the incidence of anthracnose and stem end rots in their orchards based on the findings from plant defence activators and linked nutritional studies.

Objective 3: To develop and evaluate integrated crop management strategies for productive, profitable and sustainable production of high quality mangoes.

This objective investigated the effect of external inputs e.g. nutrients on physiological processes and attempted to link them with improved management strategies to produce quality fruits.

Activities:

In the Philippines

The following Activities were conducted in Southern Mindanao by Dr Domingo Angeles, Mr Bong Salazar, Ms Lourdes Cesar and Ms Julia Sagolili.

3. 1 Review of existing crop management research information to identify current knowledge gaps

Completed as part of MSc. Thesis, Khaing (2010).

3.2 Determine the influence of mineral nutrition on yield, fruit quality and disease/pest defence in mango

The experiment was conducted in a 'Carabao' mango farm located in Taysan, Batangas from November 2009 to March 2010. Each tree was weeded manually. A planting map was drawn to identify the treated plant. The plants were induced to flower using $CaNO_3$. Nitrogen was sourced from urea and used at different levels. The fertilizer was applied in shallow holes at about 50-75% of the canopy radius. Four levels of nitrogen were applied to mango trees as follows: Treatment 0 - 0 g N tree $^{-1}$, 0 g Urea tree $^{-1}$; Treatment 1 - 100 N g tree $^{-1}$, 220 Urea g tree $^{-1}$; Treatment 2 - 200 N g tree $^{-1}$, 440 Urea g tree $^{-1}$; and Treatment 3 - 300 N g tree $^{-1}$, 660 Urea g tree $^{-1}$.

The fertilizer levels were consigned with two types of foliar fertilizers, one containing K and the other containing Ca. A control treatment without foliar fertilizer was maintained. The K was applied with 2.4% KNO3 and Ca using applied was 3% CaNO3.

At the beginning of the experiment, ready to flower trees were selected and sprayed with 2.5% calcium nitrate (brand name Yara Liva). The inducer contains spreader sticker to reduce washing off by rain. At 10-12 days after flower induction (DAFI), 48 plants with uniform flowering were selected and applied with different levels of N in two split doses. All plants except control in nitrogen treatments were treated with 100 g of N in six shallow holes at the root zones around each plant as basal and covered with soil. At 30-35 DAFI, the rest of the N (100g for N_2 and 200 g for N_3, respectively) was applied. At 50-55 DAFI, the plants were sprayed separately with 2.4 % KNO_3 and 3%

Ca $(NO_3)_2$. The concentration of KNO_3 and Ca $(NO_3)_2$ is based on nitrogen 0.33%N. The foliar fertilizer was sprayed on the top and around the canopy to direct to the terminal shoots and leaves. The solution was stirred occasionally while spraying in order to get the uniform concentration. To prepare 2.4% KNO_3 and 3% $CaNO_3$ solutions, 2.4 kg and 3 kg of inducers, respectively were weighed and added into 2-4 L of water in separate containers of known volume. The solution was stirred until the inducer is completely dissolved; more water is added to reach 100 L. The experimental trees were sprayed with pesticides and insecticides following the recommended spraying program.

In 2010-11, two further project activities were undertaken: first was the effect of N, Ca and K on fruit quality and disease defence of mango; and second was a survey to establish the relationship between soil and tissue nutrition concentration on fruit quality and incidence and severity of anthracnose in mango.

A 2-ha farm planted to 12 year old 'Carabao' mango was identified in San Antonio Babak, Samal, Davao del Norte to be used for the nutrition study and to be conducted as part of an MS student thesis. The first activity was initially implemented in Davao del Norte, but due to low success on flower induction, the project site was moved to a different one in Davao del Sur where fruit and flower protection was being handled by the group co-operator.

Ten farmer co-operators were identified in Davao del Sur and 14 farmer co-operators in Davao del Norte for the survey on the relationship between soil and tissue nutrition concentration on fruit quality and incidence and severity of anthracnose. Each season, ten soil samples and ten leaf samples were collected from Davao del Sur and submitted to the laboratory of the Bureau of Soil and Water Management for analysis.

At project site # 1 in Brgy. Mabuhay, Bansalan, Davao del Sur, forty-two grafted ‘Carabao’ mango trees with more or less uniform canopy size, age, and vigour were used as experimental plants. Trees were induced to flower on October 21, 2010 using 2.5% potassium nitrate (KNO_3) and calcium nitrate ($Ca(NO_3)_2$). Mango trees responded positively to flower induction treatments. Fertilizer treatments proceeded with four levels of nitrogen in the form of urea and a complete fertilizer. They were applied during flowering, fruit set and fruit development. Flowers and fruits were maintained using a pest and disease management protocol. Leaf samples 4th to 5th from the apex of fruiting shoot were sampled for nutrient analysis. Fruits were collected from each tree and were transported to PHTRC-UPLB for the postharvest evaluation. Parameters analyzed were: number of days to peel color index (PCI) 6, percent weight loss at PCI 6, anthracnose incidence and severity, stem-end rot incidence, fruit firmness at PCI 6, total soluble sugar at PCI 6, titratable acidity at PCI 6. After the harvest in February 2011, the same set of mango trees were induced to flower again.

A replica site was also chosen from Brgy. Kaputian, Samal Island, Davao del Norte, where the trees were also sprayed with calcium nitrate. However, unfortunately due to recurrent rainfall after induction, a very poor flowering response (<10%) was observed; leaf flushes emerged instead of floral initials. The experiment was discontinued.

Another project Site in Brgy. Anonang Samal Island, Davao del Norte was selected by the project leader as the experimental site for the other half of the experiment. It consisted of approximately 3ha planted to 16-year old ‘Carabao’ mango trees. At the time of the visit, the trees were already at 12 DAFI with prominent and emerging floral initials. Since KNO_3 was used as an inducer on these trees, it was decided to use 20 trees from this farm and to spray another 20 trees with $Ca(NO_3)_2$ in Brgy. Kaputian in July 2011. The experiment was laid out, trees were tagged, and N fertilizers were applied following the research protocol. However, towards the scheduled harvest in

May 2011 in Brgy. Anonang, a high incidence of fruit drop was reported, and by harvest, there was an insufficient number of fruit to complete the trial.

The last two trials were started in January 2012. Trial one was in the same farm at Brgy. Mabuhay, Bansalan, Davao del Sur, and trial two, in Brgy. Villarica, Samal Island. Harvesting was completed in April 2012 for the farm in Bansalan, and in May 2012 for the farm in Samal City. However, yield data was not determined in the Samal Island trial due to pilferage of fruit a day before harvest, although sufficient samples were collected for postharvest evaluation at UPLB.

In Australia

3.4 Investigate the use of rapid leaf nitrogen measurements and methods for assessing the nitrogen status

This activity was not complete due to staff resignation.

Objective 4: To evaluate food safety issues that limit better access and competitiveness in mango exports

This objective aimed to maintain and expand market access by introducing procedures which monitor maximum residue limits (MRL).

The services of Mr Kevin Bodnaruk were used to undertake this objective and activities.

The study reviewed the supply chain and identified potential MRL compliance issues in mangoes arising from aspects of pesticide use. The possible areas of improvement and risk reduction strategies for export trade were then formulated for participants in the mango supply chain.

The initial step involved data mining and desktop screening of mango MRLs targeted on export destinations, to create a listing by pesticide. This was compiled and updated to aid in developing strategies that can minimise the risk of residue violations and ensure compliance in key export markets.

The pesticides investigated were prioritized on the basis of their significance to the Philippine mango industry. The following pesticides were identified as important:

- Cypermethrin was chosen to represent pesticides with high volume usage, i.e., with > 100 approved formulations in the market as well as potentially being applied close to harvest, i.e., a preharvest interval (PHI) of 7 days. In addition, violative residues of cypermethrin have previously been detected on Philippine mango exports to Japan.
- Tebuconazole was also selected due to its increased potential for use, and its analytical methodology was well known.
- Lambda-cyhalothrin was also chosen as it is one of the few pesticides registered for thrips, a major pest of mango in Mindanao, and for late season use against fruit fly, with applications close to harvest.

As a first step towards the objective, a compilation of MRLs from countries where Philippine mangoes are exported was prepared.

Supervised residue trials were established in Samal Island, Davao del Norte; Bansalan, Davao del Sur; General Santos City, South Cotabato (Mindanao); Cebu (Visayas); Cavite and Batangas (Luzon). The pesticide applications were based on the critical GAP, i.e., use of the highest label rate, the maximum number of applications and the shortest recommended interval. The spray application volume was pre-measured based on canopy height and diameter.

An outline of the supervised residue trials, which was superimposed with the insect and disease management sub-components, was coordinated with Davao del Sur and Davao del Norte collaborators. Field experiments on cypermethrin were conducted in Davao del Norte and Davao del Sur project sites. USeP had taken on the coordination of field experiments on the tebuconazole study superimposed with the disease management project. In the ICM experimental site, sampling was done on all trees/replicates at harvest, analyzing the last pesticide applied following the ICM (in this case, tebuconazole). At least 2kg or 12 mango pieces were brought to the laboratory for analysis.

Sampling was done after the last spray application following the FAO (Food and Agriculture Organization) protocols (FAO Manual 2009). The analyses of the residues were done at the NCPC-UPLB, BPI-NPAL and JefCor, a private laboratory. All laboratories were accredited by the FPA.

The supervised pesticide residue trials were monitored by Mr Lorenzo Fabro and partners were Dr Ana Notarte (Samal), Ms Yolanda Camillo (Digos), Dr Virgie Ugay (Bansalan), Mr Mark Neri and Mr Edwin Mayo Javier (General Santos), Mr Bert Castillo (Cebu), Mr Louise Pahuyo, Mr Bert Babaan (Cavite) and Ms Fe dela Cueva (Batangas).

Objective 5: Extension sub-component

The following activities were conducted in Davao del Norte and Davao del Sur by local government units (LGUs) of Davao del Norte and Davao del Sur headed by the Provincial Agriculturist with their agricultural technicians, and experts from associated universities:

- Twenty seven (27) training sessions and regular technical demonstrations of IPM interventions on the following topics:
  - Refresher Course on LGU Extensionist on Mango Technology
  - Mango Processing
  - Workshops on Mango Technology Fora

Davao del Norte LGU Activities:

- Meetings were held between SIMAGA and industry partners such as Diamond Star, Nakashin, Southern Philippines Fresh Corp., local funding institutions, and agrochemicals suppliers.
- Distributed production brochure titled, "Integrated Crop Management Operations Guidelines for Mango" to mango farmers.
- Conducted periodic monitoring and supervision of 50 mango farms.
- Identified 10 mango growers as members of the cluster for mango technologies. Initial implementation of mango production technologies in the clusters was underway.
- Conducted training on:
  - Cultural Management Practices of Mango
  - Pruning

  - Mango Nutrition and Fertilization
  - Pest and Disease Management
  - Thrips Identification, Its Management & Control
  - Post-harvest Technology
  - Mango Organic Farming
  - Vermiculture/Trichoderma utilization

Davao del Sur LGU Activities:

- Provided technical assistance on pruning, identification and control of pests and diseases to mango growers
- Held meetings on quarantine activities with mango growers
- Conducted training on:
  - Package of technology for mango
  - Mango quarantine for Davao del Sur
  - Soil sampling and nutrient management on bearing and non-bearing mango trees
  - Good Agricultural Practice for mangos
- External training of two researchers from collaborating institutions (USeP and LGU) in Australia on mango disease diagnosis and identification, through an International Mango Disease Workshop held in Darwin from May 1-5 2011. Following the workshop, they were also involved in project review and planning workshops of the Pakistan ASLP project where they received further training on project review and planning process.

6 Achievements against activities and outputs/milestones

Objective 1. To develop and evaluate sustainable practices for the integrated management of mango pests and disseminate the information to industry stakeholders.

no.	activity	outputs/ milestones	completion date	comments
1.1	Study the ecology and management of cecid fly and thrips (PC).	Taxonomic identity of cecid fly & thrips attacking mango	2012	*Scirtothrips dorsalis* and *Thrips hawaiiensis* infests flowers. *S. dorsalis* infests fruits. *Procontarinia* spp. infests new shoots.
		Knowledge of the role of biotic & abiotic factors regulating the population of cecid fly & thrips	2012	Population dynamics established. Natural enemy population was nil. Insecticide application intensified insect pest problem.
1.2	Evaluate fruit fly lures for baiting systems (PC)	Quantitative data on lure efficacy and attractancy for fruit flies in the Philippines	NA	Activity was deemed no longer necessary because fruit fly lures are already being routinely used in mango orchards in the Philippines.
1.3	Evaluate habitat disruption and other studies on mango pulp weevil (MPW) populations (PC)	Cost/benefit analysis Beneficial insect data in sprayed and unsprayed mango orchards	2011	Comparative data on disease development and MPW populations were collected from IPM and farmer field trials from which a cost benefit analysis was calculated based on the inputs applied and yields obtained. The IPM trees had a net income of PhP 1730 per tree compared to the farmers practice trees, which had only PhP 21 per tree. Data was collected on beneficial insects in both IPM and FP trees. They were predominantly Apidae and Muscidae.
1.4	Evaluate basal bark applications of systemic pesticides for targeted pest management (A)	Efficacy data to evaluate effectiveness of new application methods	2011	Efficacy and residue data obtained Modified soil drench applications were successful at reducing seed weevil and other insect pests. Basal bark applications did not work. This method does not seem possible. Other soil drench methods (injection and small ground holes) were successful.

1.5	Develop semiochemistry formulations for attractancy testing against fruit spotting bugs and mango weevils (PC&A)	Identification of pheromones responsible for fruit spotting bugs and mango weevils	2011	The use of 1 panicle equivalent of acetic acid placed in a vial inside a plastic bottle trap resulted in 57% attraction of MPM weevils present (PC). About 17 exploratory trials were conducted to determine the correct concentration of acetic acid for the baits to be used in the field and correct positioning of the trap within the mango tree. The results were not conclusive. More trials need to be conducted in order to get the correct method of MPW trap deployment (PC). Pheromones of fruit spotting bug identified and field tests complete. Possible mango seed weevil semiochemicals identified, these may be aggregation pheromones, as aggregation was significant (A).
1.6	Develop extension materials, conduct IPM workshops on pest and beneficial insect monitoring, insecticide application technology, residues and chemical withholding periods (PC&A)	Photos and seasonality datasets completed. Regional workshops completed	2012	This was linked with another MPW national project in Palawan and with the Bureau of Agriculture and Fisheries Product Standards It enabled the conduct of trainings on GAP for mango, during which we were able to present and discuss IPM for mango, insect monitoring, insecticide application, residues and pre-harvest intervals. Conducted a 3-day workshop in Aug 17-19, 2010 held in Batangas City and attended by 35 mango stakeholders and technicians of Regions 4A and 4B. Ten trainings were conducted in each of the 8 municipalities in southern Palawan and 2 in Puerto Princesa City, attended by a total of 370 stakeholders. Participatory action research (PAR) trials on mango IPM (including 25% canopy removal) were conducted in Brooke's Pt, Palawan. Conducted a Field Day on June 16, 2010 at Espeleta's farm to show the fruits that developed from the IPM trees. Field day attended by 45 mango stakeholders. Contributed information and the section on Pest Monitoring for the Mango Team production brochure "Integrated Crop Management Operations Guidelines for Mango".
1.7	Conduct participatory action research (PAR) trials on mango IPM in Brooke's Point, Palawan	Cost benefit analysis in mango IPM	Year 4	Conducted the PAR trials in 4 trial sites using 10 trees per site involving 4 farmer partners. A net income of PhP 2,543 per tree was achieved.

PC = partner country, A = Australia

Objective 2. To develop and evaluate sustainable practices for the integrated management of field and post harvest diseases.

no.	activity	outputs/ milestones	completion date	comments
2.1	Study management of stem end rot (SER) (PC)	Effective fungicides and new field management strategies for SER identified and evaluated.	2012	All systemic fungicides tested under field conditions provided significant protection against severe blossom blight infection and translated to higher yields. Carbendazim and Difenoconazole reduced SER incidence at fruit ripening under ambient conditions. An optimized fungicide spray program as part of the ICM interventions was developed and field-tested under high and moderate disease pressures. Through the collaboration with insect, nutrition and pesticide residue components, the IPM interventions significantly improved the yield and quality of mango fruits. The net income of the farmer also increased. The program was very effective in reducing the severe incidence of SER under moderate disease pressure but less effective under high disease pressure. Postharvest treatments such as hot water treatment (HWT), extended hot water treatment (EHWT), rapid heat treatment (RHT), UV-C radiation, fungicide dip, modified atmosphere packaging and cold storage were evaluated and refined for the control of SER. Preharvest fungicide spray in combination with one or two of the above postharvest treatments further reduced the incidence of SER within the acceptable level. A standard field management program for SERs based on the results of the field testings is necessary because of the fluctuating disease pressures and varying effects based on seasonal levels.

2.2	Epidemiology and management of mango scab (PC)	The causal agent of mango scab Identified, field management strategies evaluated.	2011	Scab diseased specimens were collected during mango fruiting season. Seven potential slow-growing fungi from scab-like lesions were isolated and characterised. Management of scab was integrated with the experiment on SERs. But scab evaluation was obscured by thrips infestation. Management strategies for scab were not developed because of delays in isolating the pathogen and the masking of effects by thrips symptoms
2.3	Review and dissemination anthracnose disease findings (PC).	Cost/benefit analysis Review completed and findings disseminate to growers.	2010	Conducted an ICM clustered study "Integrated Crop Management Operations Guidelines for Mango" was developed based on the research findings and practical experiences of local mango growers and researchers. Guidelines were produced and distributed to growers and other stakeholders.
2.4	Mango disease epidemiology focused on stem end rot (PC)	Field detection techniques in place for SER.	2010	In the Philippines; spores of SER pathogens were recovered from mummified blossoms, necrotic lesions of mango leaves, blighted panicles, dead and healthy looking stem terminals and die backed twigs. Among the identified inoculum sources, die-back twigs were found to be the major source of inoculum. The diurnal pattern of SER inoculum release was established. Results showed that the spores can be trapped from 11am-3pm with highest amount between 1-2pm. An early break-down of the spore trap used for the study made it difficult to collect data over a couple of seasons and activity was terminated after just one season. In Australia, investigations showed that SER pathogens were already present within the tissue of young mango flushes, suggesting need for an early pre-flower SER control.

2.5	Genetic resistance to mango diseases (A)	A report listing the resistance of different varieties in the gene pool.	2011	More than three quarters of the gene pool has been screened for reactions to mango postharvest diseases. A list of 20 top resistant entries has been compiled and crosses have commenced in collaboration with the breeder, using 3 of the top 20 to generate disease resistant hybrids. Biotechnologist was involved to investigate marker-assisted selections. The screening has not been completed because the late varieties in the pool had very few fruits last season for any meaningful replicated screening activity.
2.6	Integrated Disease Management (PC&A)	Demo plots on sustainable mango production in Samal Island established using the clustering approach	2012	*In the Philippines;* Ten cluster members within the Samal Island Mango Growers Association (SIMAGA) were identified and organized by the project team. Baseline information/data collections, group discussions and demonstration of production operations were undertaken and cluster members provided with related documents on GAP. Preliminary information on quality and yield profile was collected and cost and return of production was also established. *In Australia;* A timing of fungicide application trial confirmed that early spray applications using systemics are more effective than late applications on postharvest disease management.

PC = partner country, A = Australia

Objective 3. To develop and evaluate integrated crop management strategies for productive, profitable and sustainable production of high quality mangoes.

no.	activity	outputs/ milestones	completion date	comments
3.1	Review of existing crop management research information to identify current knowledge gaps. (PC).	Cost/benefit analysis. Existing crop Management information reviewed and gaps identified.	2009	Review completed as part of an MSc thesis, Khaing (2010). Cost benefit analysis not undertaken because of lack of enough quantitative data from the review undertaken.
3.2	Determine the influence of mineral nutrition on yield, fruit quality and disease/pest defence in mango (PC&A)	Relationship of plant nutrition to fruit yield established	2012	Experimental results showed that use of calcium nitrate as inducer tends to improve yield during low fruiting seasons, while increasing nitrogen levels after induction improved yield during higher fruiting years. However, the current rates and timing of fertilizer application in the study were not effective in significantly reducing the postharvest incidence of mango anthracnose.
3.3	Develop standardised research protocols for assessing agronomic trials that are linked to plant defences. (A)	Protocols developed by Philippine and Australian researchers Workshop given to plant defence researchers on the implementation of standard protocols.	2010	Seminar was delivered in the Philippines on the establishment and implementation of standard protocols on plant defences. Planned follow-up workshop using project data to demonstrate protocols did not take place because of resignation of linked scientist from the Pakistan ASLP project.
3.4	Investigate the use of rapid leaf nitrogen measurements and methods for rapid evaluation of fruit nitrogen status (PC&A)	Leaf nitrogen test protocols introduced and demonstrated in the Philippines. Identify suitable technology for rapid fruit nitrogen evaluation.		Protocols were introduced during an early visit by Australian collaborator. Suitable technology for rapid fruit nitrogen evaluation was identified early in the project but the work has not been completed because linked project staff member resigned and left the Department. Use of the test was not demonstrated because of the resignation. Activity not completed because trials to fine-tune the were disrupted by the farmer collaborator withdrawing support and scientist resignation.

PC = partner country, A = Australia

Objective 4. To evaluate food safety issues that limit better access and competitiveness in mango exports

no.	activity	outputs/ milestones	completion date	comments
4.1	Review the supply chain and identify potential food safety issues in mangoes arising from pesticide use in the field and postharvest. (PC)	Desk-top screening based upon the presence or absence of international evaluations and or MRLs. Evaluate compounds previously assessed by the Codex System	2009	List of Philippine registered pesticides in mango, GAP and MRLs (Codex, EU, US, Japan, ASEAN etc.) to export destinations was prepared. Information from Codex on the status of MRLs of pesticides registered for mango in the Philippines was updated Partnered with Fertilizer and Pesticide Authority and the Crop Protection Association of the Philippines, Bayer Crop Science and Dole Philippines to implement various field evaluations and training programs.
4.2	Document the identified food safety issues from the review with indicators on sources of problems (PC)	Links between field and postharvest pest and disease management strategies to the issues	2010	Food safety issues identified with violations of MRL due to misuse (use for other mango pests not recommended in the label and too short pre harvest interval) to include the use of cocktail pesticides. Pesticides identified and field studies were instigated at designated sites (Digos, Bansalan, Samal, Talikod, General Santos Cavite, Cebu and Batangas). Issues on food safety linked with pre and post harvest pest and disease management and non-GAP uses. Identified sources of problems: Non GAP uses and traceability. Need for farmer training and exporter education/ traceability and monitoring/farmers notebook No detectable residues were present on mango samples from the ICM component of the project. There is limited trade risk for lambda cyhalothrin if GAP was followed. No residue of tebuconazole was detected.

4.3	Researchable issues identified and potential mitigation strategies developed (PC)	Establish pesticide field trials in targeted production areas (Visayas and Mindanao) following GLP. Fruit collected and sampled in laboratories. Residue testing conducted in line with OECD & FAO guidelines.	2010	Training on supervised residue trials with co-operators and farmer extension training on MRLs and pesticide residues done in Davao del Sur, Dole plantation in General Santos, Bayer plantation in Cavite and Malvar Batangas. Identified pesticides important to the mango industry to focus on - cypermethrin, lambda cyhalothrin,, tebuconazole, thiamethoxam, difenoconazole. Field trials of selected pesticides in Davao del Sur and del Norte, Dole, Gen Santos, Visayas (Mandaue City Cebu) and Luzon (Maragondon, Cavite, Malvar Batangas) applied based on label recommendations. Pesticide residue database as a basis for informed decision on training and export strategy was prepared. Withholding period is recommended to double the pre harvest interval in the label for Japan as export destination.
4.4	Establish protocols to start addressing the issues identified (PC)	Workshops with different stakeholders to determine strategies to address residue issues.	2010	Protocol for the field portion of supervised residue trials was used in all trials. Protocol for determining export destinations based on the pesticide management of farms supplying mangoes for export Training of 41 farmers and spraying contractors in Samal Island on residues and related issues was done on October 14, 2011. Farmer extension materials (2 brochures in Tagalog and two brochures in Visayan dialect) were produced. One poster on accomplishments was presented in the final review and another poster on residues for farmers. Farmer training in all aspects of mango production was done in Bansalan (March 2, 2012) and in Samal (October 14, 2011) with the mango team.
4.5	Food safety issues being addressed (PC)	Research initiated on lessening the effects of the issues	2011	A dietary risk assessment was completed for cypermethrin, tebuconazole and lambda cyhalothrin residues. Training workshops on residues and MRL issues with mango stakeholders were conducted.

PC = partner country, A = Australia

Objective 5. Extension sub-component

no.	activity	outputs/ milestones	completion date	comments
5.1	Develop/ reproduce mango production guide	Distributed mango guide	2012	500 copies of the mango production brochure “Integrated Crop Management Operations Guidelines for Mango” was distributed to the mango growers.
5.2	Conduct Mango Technology Training/Forum	Increased awareness among mango growers on existing and developing technologies.	2012	Topics discussed during training included: Cultural Management Practices of Mango Pruning Mango Nutrition and Fertilization Pest and Disease Management Thrips Identification, Its Management & Control Post-harvest Technology Mango Organic Farming Vermiculture/Trichoderma Package of technology for mango Mango quarantine for Davao del Sur Soil sampling and nutrient management on bearing and non-bearing mango trees Good Agricultural Practice for mangos
5.3	Conduct Field Monitoring/Inspection and Evaluation	Early detection on the occurrence of pests/diseases	2012	Periodic monitoring and supervision of mango farms in Davao del Norte and Davao del Sur was undertaken.

PC = partner country, A = Australia

7 Key results and discussion

Objective 1: To develop and evaluate sustainable practices for the integrated management of mango pests and disseminate the information to industry stakeholders.

Strategies were developed to integrate different control strategies for the sustainable management of selected field pests, especially the emerging cecid fly, thrips, pulp and seed weevils.

In the Philippines

1.1 Ecology and management of cecid fly and thrips

Mango panicles collected from the project sites (Samal Island, Davao del Norte and Padada, Davao del Sur) were observed to be infested with mango leafhoppers and thrips but no cecid fly or sign of its damage was observed on the samples. Two species of thrips were identified from the samples: *Scirtothrips dorsalis* Hood and *Thrips hawaiiensis*. Both species are polyphagous with a wide host range of cultivated and wild plant species. Lifecycle studies of the previously identified mango pest, *S. dorsalis* Hood, were complete and documented. Moreover, the life-table of *S. dorsalis* on mango shoots and chilli pepper was documented to derive demographic parameters that would help in projecting future population build up.

Spraying with insecticides reduced the population of thrips in Davao del Sur. However, sprayed trees in Davao del Norte had a higher population of thrips than the unsprayed trees. The impact of spraying on natural enemies could not be determined because the population of predators was nil. This was most probably due to the widespread application of broad-spectrum insecticides in the area. These results indicate that the thrips have developed insecticide resistance and a lack of natural enemies may further exacerbate the situation.

In Davao del Sur, the population of thrips increased gradually up to full bloom and declined abruptly thereafter. Spraying with insecticides effectively reduced thrips populations such that thrips in sprayed trees were 50% less than in unsprayed ones.

In Davao del Norte, thrips population was generally low. It exhibited an increase in a similar pattern as that observed in Davao del Sur. Its peak population was observed around the full bloom and declined afterwards. Spraying had a variable effect on the population. Insecticides sprayed before full bloom controlled the population as compared to insecticides sprayed later at the flowering stage. “Chico chico”, a scarring phenomenon of fruits attributed to thrips, could not be confirmed with the observed population dynamics of the thrips. The decline in the thrips population towards fruit setting did not support a causal relationship between the thrips and chico chico. With the negligible population of natural enemies in the study sites, the impact of spraying on natural enemies could not be determined. This activity was dropped and emphasis given to the generation of basic bio-ecological information on thrips in mango.

During the fourth year of project implementation, the management of previously identified thrips in mango production systems was put into place in Samal Island, Davao del Norte and; Bansalan, Davao del Sur project sites. These included proper timing of pesticide application and addition of spreaders. The cecid fly (*Procontarinia* spp.) was found to infest new shoots of mango.

1.3 Evaluate habitat disruption and conduct other studies on mango pulp weevil

Laboratory tests showed that the use of one panicle equivalent of acetic acid placed in a vial inside a plastic bottle could attract and trap 57% of female adult MPW.

In the IPM treatment trees of both trial sites, leafhopper populations were successfully controlled. However, in the farmers' practice (FP) trial, trees in one of the trial sites had a very high population of leafhoppers. At the other FP site, mango flushes were produced instead of flower panicles, probably caused by the frequent rains that occurred in February. Beneficial insects of the family Apidae and Muscidae were noted on the IPM and FP trees. A link with other national research projects on MPW in Palawan was established and two workshops were jointly conducted and attended by different mango stakeholders in southern Palawan.

In the follow-up trial, the pests in the IPM treatment site (trees at Site #1) were successfully controlled. MPW was zero, fruit fly was reduced to 1.6%, anthracnose 3% and stem-end rot 2.9%. In the FP trees, the delay in chemical induction by the farmer co-operator, and the frequent rains in February produced flushes on mango trees instead of flowers. Another farm from the adjacent site of about the same age as the test trees was used for comparison. MPW population was 3.8%, fruit fly at 6.2%, anthracnose at 14.5% and stem-end rot at 4.2%.

In Site # 2, the pests in the IPM trees were also successfully controlled. MPW infestation was zero, fruit fly 0.8%, anthracnose 2.3% and stem-end rot 1.7%. In the farmer's trees, following FP, only 20 fruits were harvested of which infestation of fruit fly was 10%, anthracnose 10% and stem-end rot 10%. No MPW was found but the sample size was too small. The IPM trees yielded an average of 175 kg per tree and a net income of PhP 1,729.50 per tree, in contrast the FP trees yield was only 4 kg, or an income of only PhP 20.80 per tree. The marginal benefit cost ratio in IPM was 2.0. This ratio indicates better economic performance in IPM trees than in the FP trees.

<u>In Australia</u>

1.4 Evaluate basal bark applications of systemic pesticides for targeted pest management

In the Australian work, investigations focused mainly on the management of the mango seed weevil MSW using the insecticide thiamethoxam.

Basal bark applications of systemic pesticides failed to control mango scale and MSW. It was decided to change the methods of drench application for the following season.

In 2009 we changed drenching methods and demonstrated that thiamethoxam (Actara™) could effectively reduce MSW in sandy soils. It was found that seed weevil could be controlled by applying thiamethoxam into small holes dug into the ground (approximately 200mm depth) if applied in the irrigation zone next to the trunk. However, it was also thought that the chemical may only work on one side of the tree if only the one hole is made.

During the 2010 season, we expanded this research to include more efficient application methods and tested the chemical in different soil types.

In large scale grower trials, three methods of soil drench application were tested: a standard "hole" method (applied in small holes made with a spade next to the sprinkler head), the "pipe" method (an auger hole with 55mm diameter PVC water pipe left in the ground) and the soil "injection" method (a steel pipe/spike was connected to a garden type pressure spray pack, which injected the product directly into the root zone).

All three application methods significantly reduced MSW and mango scale when compared to controls. In most cases, however, there was no significant difference between the different application methods. The "soil injection" method shows particular promise, as it is easy and fast to apply, which should reduce labour costs. Thiamethoxam appeared to work better in the grower trial at Dimbulah, when compared to other locations. This was attributed to a difference in soil type.

In a trial that compared thiamethoxam rates (performed near Ayr in the Burdekin Valley), it was shown that the rates of 1.5g, 3g and 6g per tree of active ingredient (6, 12, and 24 grams of formulated Actara™), reduced MSW, scale and planthoppers (compared to negative controls). The 1.5g a.i. per tree rate controlled the pests equally as well as the 3 and 6g a.i. rates. However, in previous trials (2009) the 3 and 6g a.i. rates eliminated MSW. In a residue analysis, the chemical residues were only detected in the highest application rate (6g a.i.) and residues were not detected in the lower application rates (at 100 or 140 days after application).

The 2011-2012 trials were completed using multiple point direct soil injection (using more than one injection site per tree) at different rates of thiamethoxam and locations. It was found that injection at two points around the trunk was just as effective at controlling seed weevil than applying it in two “dug” holes. However, increasing to three injection points did not significantly increase efficacy. Increasing the rates of thiamethoxam (from 1.5g a.i. to 6g a.i. per tree) did increase efficacy. Under certain conditions, the thiamethoxam drench methods were also found to control mango scale, mealybugs and planthoppers. Further research was undertaken in a separate HAL funded project (Newton 2011).

1.5 Develop semiochemistry formulations for attractancy testing against fruit spotting bugs and mango weevils

In Australia

The pheromone components for the fruit spotting bug *Ablyletpelta lutescens* were identified. This pheromone was found to be an aggregation pheromone that attracts adult male, female as well as the nymphs. Further detailed results can be found in Khrimian *et.al.* (2012). Work has continued on the spotting bug traps in another HAL funded project (HAL project No. MT10049). Using olfactometer tests and behavioural methods, it was thought that mango seed weevils could possibly produce some aggregation pheromones. Some possible seed weevil pheromone compounds were also found, however, they were not thought to be highly attractive.

In the Philippines

In the Phase 1 ACIAR-IPM project it was found that among bioassays using standard chemicals of mated male frass components, acetic acid is the most attractive (73.3%). This finding is very important because in the development of bait traps the key component needs to be identified. Having established it as acetic acid the testing for bait traps could proceed.

In cage bioassay trials, it was found that the use of 1 panicle equivalent (pa eq) of acetic acid placed in a vial inside a plastic bottle trap could attract 57% attraction to mango pulp weevil female adults.

About 17 exploratory trials were conducted to determine the correct concentration of acetic acid for the baits to be used in the field and correct positioning of the trap within the mango tree. The results were not conclusive. More trials need to be conducted in order to get the correct method of MPW trap deployment.

In the Philippines

1.6 Development of workshops and extension materials on IPM, pest and beneficial insect monitoring, insecticide application technology and chemical withholding periods and residues

Workshops and extension details are outlined in sections 6(1.6), 8.2, 8.4, and 10.2.

1.7 Conduct of participatory action research (PAR) trials on mango IPM

PAR trials were conducted on 4 sites using 10 trees per site with 4 farmer partners, namely: Mr Edilberto Abinque, Mr Jose Gavino, Ms Leonora Zabalo and Mr Joselito Espeleta. In these trials there was no need to compare FP with the improved IPM for mango because in the previous experiment it was already shown to be effective and profitable. Here, the new technology (such as the improved IPM) was introduced to the mango farmers to enable local people to understand and take responsibility of their backyard mango trees. The PAR trial enabled the mango farmers to learn to adapt to changes in the mango production techniques and as such would lead to empowerment for the farmers.

In the PAR trial an average yield of 140kg of mango fruits per tree was harvested. A return above variable cost or net income of PhP 2,543 per tree was achieved. The technology is considered to be profitable, as it does not have an average variable cost that is more than the price of the output.

Objective 2: To develop and evaluate sustainable practices for the integrated management of field and post harvest diseases.

2.1 Study management of stem end rots

In the Philippines

Studies were conducted to improve management strategies against postharvest and field diseases of ‘Carabao’ mangoes; specifically stem end rot (SER) and scab in order to enhance the production and marketing of quality fruits. Pre- and postharvest experiments were consecutively conducted to assess their control efficacy against SER.

In the preliminary evaluation of systemic fungicides in Davao del Sur, systemic fungicides applied as preharvest spray treatments suppressed severe blossom blight and SER infection and was translated to higher fruit yields. The results showed that among the field treatments, carbendazim effectively reduced SER incidence when fruits were stored in ambient room temperature (28°C) and assessed 11 days after harvest (DAH). Azoxystrobin + Difenoconazole and Difenoconazole alone, significantly minimized SER by 40% at 17 DAH in cold storage. Further exposure to hot water treatment (HWT, 55°C for 10 min) and cold storage (13°C) decreased the disease incidence and prolonged marketable life of fruits for more than six days.

Consequently, the fungicide spray was optimized and implemented in production areas under high (Bansalan, Davao del Sur) and moderate (Calamba, Laguna) disease pressures. The fungicide spray regime included Azoxystrobin-Mancozeb-Carbendazim-Difenoconazole. Based on the quality and yield profile of the harvested mangoes, 82% were marketable while 18% were unmarketable due to cracks and severe damage of cecid fly and scab.

The improved fungicide spray program and HWT lowered SER incidence on mango fruits sourced from production areas under high (Davao del Sur) and moderate (Laguna) disease pressures. Treatments worked best under moderate disease pressure but less effective under high disease pressure with prolonged wet period which favoured disease development. Timely application of protectant and systemic fungicides, which commenced at full bloom stage, protected the blossoms and fruits under moderate disease pressure resulting in low SER incidence (22 to 57%). However, early onset and high SER incidence (100%) was observed on fruits sourced from Davao del Sur. Since the spray program minimally reduced disease pressure at harvest, further subjecting the fruits to conventional HWT and low temperature storage (13°C) markedly reduced SER incidence to 74 to 98% (Davao del Sur) and 1 to 15% (Laguna). Extending storage at 13°C from 14 to 21 days after treatment (DAT) increased SER occurrence. In addition, saleable life of mango fruits was significantly prolonged for 1.8 to 7 days (Davao del Sur) and more than 7 days (Laguna).

Postharvest management treatments and biological control strategies were also refined and carried out over different seasons of mango production in Luzon. HWT, extended hot water treatment (EHWT; 46ºC pulp temperature for 15 min), rapid heat treatment (RHT; 59°C for 30–60 sec), fungicide dip, UV-C radiation, modified atmosphere packaging (MAP) and cold storage suppressed SER at varying disease levels and extended saleable life of fruits.

Under high disease pressure, HWT appeared to be more effective than EHWT. RHT did not reduce SER incidence compared with the control. HWT significantly reduced SER incidence and extended saleable life of mango fruit as compared with EHWT and RHT.

Integration of HWT, FD and MAP significantly controlled the postharvest diseases. Dipping in Carbendazim and Tebuconazole controlled SER and extended saleable life of the mango fruits by 3 and 4 days, respectively. Carbendazim, Tebuconazole and Azoxystrobin controlled anthracnose which prolonged the saleable life by 3, 5, and 6 days, respectively.

In the low dose UV-C irradiation experiment, the most effective exposure time was 10 minutes to significantly delay SER progression and prolong the saleable life for 5-7 days. However, UV-C caused fruit blemishes and bronzing. Induced resistance was also exhibited in artificially inoculated mango fruits previously subjected to UV-C irradiation. Irradiation can be an active elicitor of constitutive antifungal systems in mango fruits resulting in sustained lower disease progression compared with non-UV-C treated fruits.

MAP aggravated SER development. Non-MAP fruits were not saleable after achieving table ripe peel colour. However, when fruits were heat treated and dipped in Azoxystrobin, the saleable life was extended for more than 9 days, while fruits treated with HWT + Tebuconazole had an extended saleable life of more than seven days.

Preliminary evaluation of biological control strategies against SER was undertaken. Three rates of Serenade™ with the bacteria *Bacillus subtilis* as the active ingredient were assessed for its effectiveness against postharvest diseases of mango. Isolate FI 3 (*Penicillium* sp.) and isolate SI 8 (a non-sporulating fungus) were also utilized. Results obtained from the experiment were not significant. Isolate SI 8 - treated fruits had the lowest SER incidence, however the effectiveness was not significantly different from the rest of the treatments. The marketable life of mango fruits dipped in all treatments was not extended.

After refinement of the postharvest treatments, the improved spray program as preharvest management practice was integrated with postharvest treatments such as HWT and fungicide dips (azoxystrobin, 150–175 ppm; carbendazim, 312.5 ppm; and tebuconazole, 125–156 ppm) significantly reduced disease and extended marketable life for almost eight (8) days. Timely application of protectant (mancozeb) and systemic fungicides (azoxystrobin, carbendazim, and difenoconazole) during the most critical stages of mango flower and fruit development ensured higher harvestable fruit yield and minimally lowered SER incidence.

On SER epidemiology studies, the spores of the pathogen were recovered from mummified blossoms, necrotic lesions of mango leaves, blighted panicles, dead and healthy looking stem terminals and “die-back” twigs. Among the identified inoculum sources, die-back twigs were found to be the major source of inoculum. The diurnal pattern of SER inoculum release was established. Results showed that the spores could be trapped from 11am-3pm with highest amount between 1-2pm.

Through the collaborative activity of project sub-components (insect and disease management, nutrition and chemical residue), the Integrated Crop Management (ICM) program for mango was developed and implemented in Davao del Sur. A mango grower (Mr Jose Casonete) was identified. Benchmark information on yield and quality profile, farm practices and production profile were documented prior to implementation of activities. Best-bet practices with emphasis on pruning, pest identification, pesticide management and pest monitoring were identified, discussed and demonstrated.

After ICM implementation, fruit yield, quality and economic sustainability were improved. Total yield increased from 500kg to 21mt before and after ICM implementation, respectively. Net income also improved from PhP -15,000 to PhP 312,000. Recommended ICM practices could enhance the sustainability of mango production. This joint activity with other project sub-components generated an IEC material entitled "ICM Operations Guidelines for Mango".

2.2 Epidemiology and management of mango scab

<u>In the Philippines</u>

On the epidemiology of mango scab, diseased specimens were collected during the mango season. Seven potential slow-growing fungi were successfully isolated from scab-like lesions. Conidia and morphological characteristics are typical of *Sphaceloma* sp. Isolation was continuously done while pathogenecity tests were undertaken on suspected scab isolates.

Management of scab was integrated with the experiment on stem end rot. Scab evaluation was obscured by thrips infestation, as scab symptoms could not be discriminated from thrips damage. Twenty eight percent (28%) scab severity was recorded in mango fruits harvested during the optimization experiment in Bansalan, Davao del Sur.

2.3 Review and dissemination anthracnose disease findings

<u>In the Philippines</u>

Incorporated into Activity 2.6 "Integrated Crop Management (ICM) through a clustering approach", below.

2.4 Study mango disease epidemiology

<u>In Australia</u>

Investigations showed that stem end rot pathogens were already present within the tissue of young mango flushes, suggesting need for an early pre-flower SER control.

2.5 Study genetic resistance to mango diseases

<u>In Australia</u>

The gene pool screening for disease resistance was completed. Results from three seasons were collated and reconfirmation of resistance on the highly resistant entries using both natural infection and artificial inoculations was completed on selected cultivars of interest.

A crossing program to incorporate resistance into new breeding lines was initiated with three (Batawi, Boribo and Sungi Siput) of the highly resistant lines. The initial target was to incorporate resistance for anthracnose into the new hybrids. After completing the correlation of fruit with seedling resistance under controlled conditions some of the entries were used to initiate a rootstock trial. Several varieties have been identified with good resistance to anthracnose and SER.

2.6 Develop integrated Disease management strategies

In Australia

Another activity has been the evaluation of softer field options for the management of postharvest diseases. In collaboration with a Biological control company agent (Zadco), three biological control products (Fulzyme, Superzyme and TRI D25) were evaluated singly in the field for their efficacy on postharvest diseases of mangoes. All three products showed some promising results on controlling mango anthracnose but none was effective on stem end rots. The company was interested in following up this activity as a fee-for-service contract trial so that the products can be evaluated in full spray programs for possible registration for anthracnose field control.

Another activity was the evaluation of timing of field fungicide applications on the management of post harvest diseases of mango. This activity was necessitated by questions from industry stakeholders who wanted to know the best time for a single spray application instead of the recommended 3 under less optimal disease conditions. As a follow up from 2009 season trail, it was demonstrated during the 2010 season that when conditions for optimal disease occurrence are prevalent, it is best to go with the 3 spray applications recommended, that start from flowering. When conditions are not optimal, a single spray application at fruit set was more effective than a single late spray at near fruit harvest.

In the Philippines

Integrated Crop Management (ICM) through a clustering approach

In 2008-2009, cluster members in Samal Island were identified and organized. Tools for benchmarking and assessment were developed.

In 2010-2011, a clustering approach was established in Samal Island, Davao del Norte, after a meeting with the LGU executives. Ten cluster members belonging to the Samal Island Mango Growers Association (SIMAGA) were identified and organized by the LGUs. Baseline information on each cluster member, their farm practices and farm production profile were noted. Focused group discussions on best practices had already been done. Mango farm production operations were also demonstrated with emphasis on pruning, pest identification, pesticide management and pest monitoring. Extension materials such as a list of available pesticides for mango, FRAC/IRAC Mode of Action Classification, Spray Program/options and “Integrated Crop Management Operations Guidelines for Mango” brochure were also introduced and distributed to the cluster members. Research collaborators actively monitored implementation of the activities.

Yield and quality profile of mango production in one of the co-operator’s farms were assessed prior to the implementation of the mango ICM program. The cluster member was able to harvest 10.48 tons of mango fruits from which 97% was marketable while only 3% was unmarketable. Sixty two percent (62%) of the marketable fruits passed for processing grade. The remaining percentage of the fruits passed for the Hong Kong and Japan markets. In the case of unmarketable mango fruits, 45% was due to pest damage mainly attributed to cecid fly and fruit fly while 55% was due to cracks, latex burn, windscar and others. Furthermore, randomly selected mango fruits were selected and stored in ambient temperature to assess postharvest diseases. Mango fruits had 17%

SER and 46% anthracnose incidence, with a 5% severity. On the basis of SER incidence, the marketable life of the fruits was extended by 2 days. No detectable pesticide residue was found in the mango samples. In addition, cost and return was also analyzed. Unfortunately, the cluster member incurred high expenses wherein break even was not met. Implementation of the ICM program for mango by the cluster member is currently on-going.

Findings from this research were utilized to develop an integrated disease management (IDM) strategy that was included in the Integrated Crop Management (ICM) program. Cluster members of SIMAGA were organized and demonstration plots were established at different districts in Samal Island. After the ICM implementation, fruit yield and quality and economic sustainability were significantly improved. The ICM Cluster approach was a collaborative activity with other project sub-components (insect management, nutrition and chemical residue). A brochure was produced, titled *"ICM Operations Guidelines for Mango"* which was distributed to cluster members and research participants.

Objective 3: To develop and evaluate integrated crop management strategies for productive, profitable and sustainable production of high quality mangoes.

This objective investigated the effect of external inputs e.g. nutrients on physiological processes and attempted to link them with improved management strategies to produce quality fruits.

<u>In The Philippines</u>

The result showed that the number of fruitlets per panicles was not significantly affected by three N levels and foliar application of KNO_3 and $CaNO_3$. Application of 200 g each of N and KNO_3 per tree gave the highest fruitlets per panicle. It was also observed that application of KNO_3, in general responded with maximum fruitlets per panicle. Fruit yield per tree was not significant among all the treatments. However, the highest yield (550 kg tree^{-1}) was obtained in 200 g N tree^{-1}. Treatment with nitrogen fertilizer alone was effective as compared to its combination with foliar fertilizers. Application of trees with KNO_3 and $CaNO_3$ foliar fertilizers have resulted in flowering for the second time which has contributed to yield reduction but an estimated 20-50% additional fruit yield is expected from the second flowering.

Fruit characters were significantly affected by different nitrogen levels and interaction of N + KNO_3 and $CaNO_3$ foliar applications. The maximum fruit weight was obtained from the trees applied with 300 g N and 200g N tree^{-1}, while the minimum fruit weight was recorded from the trees applied with 100 g N tree^{-1} + $CaNO_3$. Maximum fruit weight and flesh weight were measured in 200g N treatment. The highest and the lowest seed weight were obtained in 300g N + KNO_3 and 200g N tree-1 + $CaNO_3$ respectively. Application of 200 g N tree^{-1} resulted in lower seed weight and higher fresh weight. 100g N resulted in thickest peel of 1.83mm and the thinnest peel of 1.15mm was obtained in $CaNO_3$ treatment.

According to the result of nutrient analysis, the concentration of leaf N among treatments ranged from 0.82-1.27 %. The maximum value (1.47 %) occurred in 300 g N tree^{-1}. The differences, however, was not that significant. Higher leaf K concentration (1.27%) was observed from trees applied with 200g N tree^{-1} and the lowest (0.71%) was obtained from trees applied with 100 g N tree^{-1} + KNO_3 foliar application. The K concentration of leaves was not influenced by the effect of Nitrogen levels and interaction effect of Nitrogen, KNO_3 and $CaNO_3$ foliar fertilizer. 100 g N tree^{-1} + $CaNO_3$ foliar application treatment resulted in the highest accumulation of Ca (2.51%) in the leaves. The lowest Ca (1.13%) concentration occurred in 100 g N tree^{-1} + KNO3. Nevertheless, the Ca concentration increased as the trees spray of $CaNO_3$ foliar treatments. Leaf analysis revealed no significant variations on the Mg concentration as affected by the application of Nitrogen levels, KNO_3 and $CaNO_3$ spray. 100 g N tree^{-1} + CaNO3 treatment and no Nitrogen + CaNO3 treatments resulted in maximum Mg concentration (2.17%) and (2.1 %) respectively. The lowest leaf Mg concentration (1.38%) was showed in trees treated with 100 g N tree $^{-1}$.

Peel N concentration ranged from 0.4 – 1.31%. Treating plants at the rate 100 g tree^{-1} + $CaNO_3$ foliar application resulted in highest peel N of 1.31 %. Peel N concentration was statistically not significant among the treatments. In this experiment, all 300 g N tree^{-1} treated trees produced lower concentration of peel nitrogen. This showed that peel N did not increase linearly by increasing Nitrogenous fertilizer. Peel K concentration was not influenced by the effect of Nitrogen levels and Nitrogen + KNO_3 and $CaNO_3$. Maximum concentration occurred in control (2.14%) and the minimum was (1.01 %) in $CaNO_3$. All KNO_3 foliar applied trees produced higher peel K concentration than CaNO3 foliar application trees. Calcium level in the peel ranged between 0.24 – 0.31 %. Peel analysis revealed no significant variations on the peel Mg and Ca concentration as affected by different treatments.

The highest pH of the fruits (5.3) was obtained from the trees fertilized with 200 g N tree $^{-1}$ + KNO_3. The lowest pH (4.47) was obtained in control. The pH of fruits harvested from N + KNO_3 and N+$CaNO_3$ combinations had lower pH than only those applied solely of nitrogen. The highest TSS was calculated to be showed by fruit trees applied with 300 g N tree^{-1}. The lowest TSS was calculated in 100 g N tree^{-1} + KNO_3. The highest TA (0.28) occurred from the fruits harvested from the trees which fertilized with 300 g N tree $^{-1}$ + KNO_3 . Likewise, the flesh firmness (3 kg. cm^{-2}) was recorded in 300 g N tree $^{-1}$ + CaNO3 treatment combination. The fruits which were obtained from the trees applied with only N had lower firmness than the treatments of N + KNO_3 and $CaNO_3$.

The change in fruit peel colour was observed to be fastest in the fruits harvested from the trees of treatment 200g N tree^{-1} than the once harvested from the rest of the treatment trees. The longest shelf life index of SLI-9 days was observed in the fruits treated with CaNO3 alone as foliar spray, and the shortest shelf life of SLI-5days was observed in 300 g N tree^{-1} treated plants. In this experiment, longer SLI is attributed to reduction in incidence of disease, or the severity of the diseases.

The maximum fruit rot incidence (60.67% and 60.17%) occurred in 200g N and 300 g N tree^{-1} respectively. The maximum fruit rot severity (8.89%) was observed in the treatment applied 200 g N tree^{-1} and the lowest (1.89%) was recorded in 300 g N tree $^{-1}$ + CaNO3 foliar application. No nitrogen treatments resulted lower fruit rot incidence and severity compared with fruits taken from trees applied with only nitrogen. This showed that N enhanced disease severity in mango.

The lowest rate of stem end rot incidence was 0.67% and the highest (2.33%) was observed in 300 g N tree^{-1} + CaNO3. The highest and lowest value of incidence and severity of stem-end rot occurred in the same treatment. In this study, stem end rot severity was higher than anthracnose severity because of extended dry spell characterized by increased temperature and absence of rain. Absence of the moist and warm condition congenial for the fruit stem end rot pathogen has greatly reduced the severity of the fruit rot disease during the experiment period.

The total N concentration of leaves at 45 days after fruit set had a positive relationship with the fruit rot severity and leaf K also had a positive correlation with the percentage of fruit rot severity (R^2 = 0.25). Higher K uptake probably caused a shortage of Ca. The Ca shortage resulted in improper formation of the plant cell walls, leading to increased disease infection. The magnesium content of leaves had a negative relationship with the percentage of fruit rot severity.

The result indicated that anthracnose severity was negatively correlated with leaf N: K, N:Ca concentration, peel K and Ca concentration. Yield and leaf nutrient were positively correlated. The total N, K and Ca concentration of leaves after 45 days of fruit set had a positive relationship with total soluble solid (TSS). But the relation was not significant.

200 g N treated trees gave highest yield, fruit weight, flesh weight and highest seed weight, and the fruits ripened faster than those harvested from the rest of the treatments. However, the fruit rot incidence and severity was also observed to be highest for the fruits obtained from the same treatment. From this experiment it could be recommended that for best quality disease free fruit is CaNO3, and it has enhanced shelf life. Under the 300g N tree-1 + $CaNO_3$ treatment, the fruit firmness is higher indicating that it can withstand long distance transportation to explore good market value. It also showed that this treatment has increased incidence of stem end rot but the severity is not of much concern. 300g N $tree^{-1}$ + KNO_3 treated trees resulted the lowest fruit rot incidence and severity and also fourth highest yield. Therefore it could be recommended to control fruit rot disease and higher yield for this experiment.

An activity was initially implemented in San Antonio Babak, Samal, Davao del Norte, but due to low flower induction, the project site was moved to a different one in Davao del Sur where fruit and flower protection was being handled by the group co-operator. Of the 80 trees induced to flower, 67% of those sprayed with calcium nitrate $Ca(NO_3)_2$ and 60% with potassium nitrate KNO_3 flowered. Flowering intensity ranged from 5-20%.

In 2010-11, the pre-harvest data gathered from project site No. 1 (Mabuhay, Bansalan, Davao del Sur) showed that flowering intensity (flowering response was 100% whereas average flowering intensity was 73%), fruit retention and number of wrapped fruits is higher in trees induced with calcium nitrate $Ca(NO_3)_2$, although the incidence of “sigay-sigay” (unfertilised fruitlets) and scab is a little bit higher as compared to KNO_3 induced trees. A total of 775 kg of 120 DAFI mango fruits were harvested from 40 trees in February 10, 2011. Although all mango trees responded positively to induction treatments, no fruits were harvested from two trees induced with KNO_3. This was accounted to high incidence of fruit drop and damages due to pest and diseases. Generally, $Ca(NO_3)_2$ induced trees resulted to higher average yield with 97 kg and lower percent of non-marketable fruits with 15.17%, as compared to KNO_3 with 52 kg and 23.97%, respectively. Among the N levels, average yield is highest in 0.69kg/tree N at 85 kg for KNO_3 induced; and in 0.92kg/tree N at 132 kg for $Ca(NO_3)_2$ induced.

From the postharvest evaluation, initial results showed no differences among the treatments. A follow-through analysis will be done to determine if there are significant differences in the treatments. Leaf and fruit tissue analyses for N, K, and Ca are also still on going. Postharvest disease incidence showed that anthracnose begun to infect on the 6^{th} to 7^{th} day with 100% incidence. On the other hand, there is a lower incidence of SER in all treatments.

On mango nutrition studies, the flower inducer, $Ca(NO_3)_2$ produced greater total yield and better marketable yields than KNO_3. Fruit yields increased with increasing N level, regardless of flower inducer used. Postharvest qualities of mango fruits were highly comparable regardless of the chemical flower inducer type and N-fertilizer levels.

All mango fruits developed anthracnose at ripening, regardless of chemical flower inducer or N-fertilizer levels. Onset of anthracnose was earlier in fruits coming from trees with no N-fertilizer but this was not significantly different from those fruits harvested from trees, which received N-fertilizers. No significant differences were noted among treatments in terms of the relationships between tissue nutrient concentration, fruit yields and quality.

More substantial findings were generated regarding the relationship between nutrition and fruit yield, quality, and disease defence, after having two more successful trials in 2012 at Bansalan and Samal City. Yield comparison in Bansalan was made since the same farm was used in 2011 and 2012. In 2011 Bansalan harvest, average yield was 99 kg $tree^{-1}$, with the minimum yield at 33 kg $tree^{-1}$, and the maximum yield at 158 kg $tree^{-1}$. Yield level during that season was comparable across the four levels of applied nitrogen. Statistically significant differences were only effected by flower inducer, with $Ca(NO_3)_2$ resulting in fruit yield twice as much that of KNO_3.

On the other hand, the 2012 Bansalan harvest was better than the 2011 trial. Average yield was 183 kg tree^{-1}, and the minimum and maximum yield were 109 kg tree^{-1} and 276 kg tree^{-1}, respectively. Unlike in the 2011 season, the type of flower inducer did not have a significant effect on fruit yield. What did appear to influence the yield was the amount of N fertilizer split-applied during bud emergence, fruit set, and active fruit development. The positive effect of N fertilizer on fruit yield was apparent since the control level exhibited the lowest yield (0 kg N tree^{-1}), while trees which received the lowest amount of N fertilizer (0.46 kg N tree^{-1}) had almost twice that of the control. This N treatment also seemed to be the optimum, as a substantial decrease in fruit yield was observed when the N dosage was further increased to 0.92 kg tree^{-1}.

The much higher yield, up to 300% in some treatment combinations, in 2012 relative to 2011 season, suggests that 2011 was the lean year and 2012 was the peak year of mango production in Brgy. Mabuhay, Bansalan. Although historical records of fruit yield in the farm has to be checked, and further yield evaluation has to be conducted to verify this claim. Nevertheless, if this biennial production cycle in mango is considered, our research results show that the use of $Ca(NO_3)_2$ as a flower inducer during the lean year would result in a higher fruit yield relative to KNO_3. Nitrogen application after induction does not result in significant yield increases during a lean year. On the other hand, during a peak production year, either $Ca(NO_3)_2$ or KNO_3 may be used as inducer, but trees have to be fertilized with N after induction (0.46-0.69 kg tree^{-1}) to get a yield increase.

Similar to the results in 2011 of Bansalan trial, treatments (flower inducer and N-fertilizer levels) had no significant effect on the postharvest qualities (firmness, pH, TSS, TA, and TSS/TA) of harvested samples from Bansalan and Samal in 2012. Moreover, all fruits also produced anthracnose regardless of treatment. Single factor effects were observed on the number of days to onset and peel colour at onset of anthracnose, with the response varying depending on farm location. Development of dark necrotic lesions during storage was significantly delayed by N fertilizer application after induction (Bansalan) or by the type of flower inducer (Samal). In Bansalan, the number of days to onset of anthracnose on fruits from 2012 harvest was relatively longer in fruits harvested from trees which received 0.46 kg N and 0.69 kg N fertilizer each after induction (6.50 days and 6.70 days of storage, respectively). On the other hand, onset of anthracnose was observed earliest at peel colour ratings of 4.45 and 4.46 in fruits from trees which received 0.46 kg and 0.69 kg N, respectively. Higher peel colour rating (4.73) to anthracnose onset was recorded at 0.92 kg N tree^{-1} treatment.

The case was different for fruits harvested from Samal City. Anthracnose incidence was not significantly different across N fertilizer treatments; instead the type of flower inducer appeared to influence anthracnose development in harvested fruits. Specifically, fruits from KNO_3-induced trees developed anthracnose earlier, i.e., 5.97 days of storage when peel color rating was 4.79. This was significantly different with that of fruits harvested from $Ca(NO_3)_2$-induced trees (6.29 days of storage when peel colour rating was 5.07).

Although statistical analyses revealed that the type of flower inducer or N fertilizer application after induction could significantly delay the onset of anthracnose symptoms, the magnitude of these differences may be of no practical importance. The observed differences among treatments may have bearing only on disease onset but not on disease development. Once visible anthracnose symptoms manifest on the fruit, disease development in fruits from all harvest trials (Bansalan and Samal), regardless of treatments, progressed rapidly in an almost linear manner.

The seemingly non-significant effect of treatments considered in the project may be attributed to frequent rainfall events in the area. Either sudden precipitation after flower induction resulted in poor flowering response and high pest infestation, or too much rainfall resulted in very high incidence of fruit drop. It is also presumed that, with high precipitation, mango trees had poor uptake of the applied N fertilizers. High relative humidity also favoured the growth and spread of pest and diseases. Thus, it was very difficult to elucidate the role of N and Ca nutrition in fruit quality and disease defence since the fruits have poor initial quality and too much of the disease inoculum.

In Australia

3.1 Investigate the use of rapid leaf nitrogen measurements and methods for assessing the nitrogen status

In 2008-2009 agronomic trials to standardize and link plant nutrition to plant defenses were established.

In 2009-2010, agronomic trials to standardize and link plant nutrition to plant defences ran into some problems with the collaborating grower and were re-focused on the quick determination of nitrogen status during the season as a link up with the Pakistan ASLP project that focused on this activity.

The study on the use of SPAD for rapid nitrogen diagnosis was dropped because of disconnected linkage at the Australian end due to changes in project personnel.

As noted in methodology, not all activities in Objective 3 were completed.

Objective 4: To evaluate food safety issues that limit better access and competitiveness in mango exports

This objective aimed to maintain and expand market access by introducing procedures which monitor minimum residue levels.

Data mining and desk top screening of Maximum Residue Limits (MRLs) in mango in targeted export destinations and pesticides currently being evaluated by Codex and ASEAN MRL have been put together for information purposes. The Fertilizer and Pesticide Authority (FPA) have just adopted a Philippine Mango MRL based on pesticide registration data, Codex, and the Japanese positive list.

Information on local label recommendations of registered pesticides for mango in relation to pesticide management schemes of farmers was evaluated in relation to MRL violations. All mango exports to Japan were analysed for chlorpyrifos, cypermethrin and lately, profenofos. Recently violations for tebuconazole and flusilazole were detected on mango exports to Japan. The data generated in these three sites may be used for a proposal of MRL based on Philippine GAP (good agricultural practice). Raining the possibility that the MRL violation occurred as a result of non-compliance with Philippine GAP, especially since the MRL for tebuconazole is not in the Japan positive list and therefore follows the default value of 0.01 µg/g.

Potential sources of compliance problems identified were:

- Farmers not following label instructions in terms of usage especially the preharvest interval (PHI).
- Mango farmers are heavy users of pesticides and pesticide mixtures.
- MRL violations can occur due to incorrect timing frequency and/or application of inappropriate pesticide for a targeted pest.
- Observance of recommended PHI can be poor, particularly if the market price is favourable.
- The exporters lack mechanisms for monitoring of the pesticide management schemes at the farm level.
- At times, pesticides detected are disallowed by the exporter, thus reducing the usefulness or utility of certain bioeffective compounds.

- A perceived solution is the generation of residue data for the major pesticides used.
- Also possible utilization of farmer or farmer groups education/training on residues and its relation to GAP and withholding period or PHI, the requirement of a farmer pesticide notebook for applied pesticides.

The following pesticides to be studied were identified based on importance to the Philippine mango industry, analytical capability and IPM compatibility:

- Cypermethrin - chosen to represent a pesticide with high volume usage with >100 formulations in the market. A good candidate for the first 'pilot' compound, since violations of the cypermethrin MRL has been found in Philippine mango exports to Japan.
- Tebuconazole - identified with a > potential of use, and may be developed as a post harvest treatment for export to the US market.
- Lambda cyhalothin - chosen since it is one of the few pesticides registered for thrips and fruit fly which attacks close to harvest.
- Thiamethoxam - as a systemic insecticide, to provide useful information to stakeholders such as Dole for their mango export.
- Profenofos - the only registered pesticide for thrips, which is the major pest problem of Davao del Sur and Davao del Norte.
- Mixture of thiamethoxam and lambda cyhalothrin – used intensively by project collaborators and mango producers.

All the chosen pesticides were also based on the idea that the ACIAR project may contribute to the database for a possible Codex MRL or a basis for a review of the current Codex MRL. The strategy identified for identifying pesticides to be studied included pesticides used in the Philippines that are not included in the Japanese positive list and therefore follow the default value of 0.01 µg/g. Studies on pre and postharvest use of tebuconazole was looked into in coordination of the disease management sub-component of the project. The MRL from the use of tebuconazole as post harvest dip in the USA is 0.15 µg/g.

An outline of the supervised residue trials, which was superimposed with the insect and disease management sub-components, was coordinated with Davao del Sur and Davao del Norte collaborators. Field experiments on cypermethrin were conducted in Davao del Norte and Davao del Sur project sites. USeP had taken on the coordination of field experiments on the tebuconazole study superimposed with the disease management project.

Supervised pesticide residue trial SPRT protocols were drafted, but collaborators had a hard time following the detailed information needed for SPRT trial. Pesticide residue information was also part of the "Integrated Crop Management Operations Guidelines for Mango" brochure drafted by the ACIAR mango team. Recommendations included increasing the withholding time on top of the label PHI for mango intended for export to Japan. This is especially true if the MRL is at the default value.

Analyses of Supervised Residue Trials

Cypermethrin

The cypermethrin residue study was done in five different sites and residues in four were all below < 0.001 mg/kg at the label Pre Harvest Interval (PHI) of 7 days after spraying. However, at the General Santos, South Cotabato site, the residues were 0.038 mg/kg, i.e., above the Japanese positive list MRL (0.03 mg/kg) but below the Codex or EUMRLs of 0.7 mg/kg.

Maximum cypermethrin residues with a label PHI of 7 days was 0.35 µg/g maximum at 0 days after spraying (DAS), 0.14 µg/g at 3 DAS and non-detectable 7 days onwards in the Bansalan site (Davao del Sur). Cypermethrin residues were likewise non-detectable at 7 days onwards for the Digos and Samal site.

Analysis of bagged fruit (practice of Mindanao and Visayas) and unbagged fruit (practice of Luzon) was done on fruit sampled near the time of the last spraying. Samples of both bagged and unbagged fruit harvested at 28 days after spraying (DAS) had residues of cypermethrin at < 0.001 mg/kg from the Bansalan, Davao del Sur site. As most of Mindanao exports are from bagged fruit, MRL violations despite this practice could be due either to contamination from the bag during harvest or via absorption of the pesticide through the bagging material, which is always in close contact with the fruit.

For all the trials, the use of local GAP would not result to MRL violation. Considering the worst case scenario, it is recommended that if the export market is Japan, a lengthened withholding period be required. The alternate strategy, if an extended PHI is not possible, is to target alternate export destinations such as the EU or those countries adopting the Codex MRLs, such as Singapore. Another strategy is to lobby Japan to impose the current Codex MRL of 0.7 mg/kg. For now, studies with this compound will be suspended because of the FPA-CPAP effort to generate new bioefficacy information and GAP on Cypermethrin as well as residue profile of these new label recommendations.

Tebuconazole

Tebuconazole is one of the fungicides studied in this project. The Bansalan, Davao del Sur experiment resulted in <0.005 µg/g at spraying when considering that the label PHI (pre harvest interval)/withholding period for tebuconazole is 22 days. Tebuconazole residues were not detected (< 0.001 mg/kg) in the Bansalan site (Davao del Sur) but found at the limit of detection (0.001 mg/kg) at spraying in the Talikud site (Davao del Norte). In fruit sampled 7 DAS, the residues declined to non-detectable levels in Talikud and to 0.019 mg/kg in General Santos. However, in fruit from the Luzon site in Cavite, residues were still relatively high at 14 DAS with a concentration of 0.037 mg/kg and non detectable at 21DAS, which would not comply with the Japanese MRL of 0.01 mg/kg. Therefore, it is suggested that an extended export harvest interval should be followed for mangoes grown in these regions.

Studies on tebuconazole were also done at Cebu, a mango producing province in the Visayas. A residue level of 0.15 mg/kg was found 25 DAS which is also higher than the value of Japan (0.01 mg/kg). However, this would be acceptable for exports to the USA, where that country's MRL is based on a post-harvest usage dip.

Again, following the GAP would not result to residues at harvest. However, considering the varying MRL {0.1 ppm (JMPR, 2008), FPA: 1 ppm, and Japan: 0.01 (default)}, it would still be wise to increase withholding period for Tebuconazole if it is for export to Japan. The data generated could also be submitted to JMPR for consideration.

Lambda cyhalothrin

Lambda cyhalothrin had maximum residues at 0 DAS 0.12 µg/g and 0.09 µg/g at 0 DAS and 3 DAS, respectively. Residues were < 0.001 µg/g at 7 DAS and thereafter.

Residue trials were based on the label recommendations for lambda-cyhalothrin which has a label PHI of 3 days and is recommended for thrips, a problem in Davao, as well as fruit fly which attacks close to harvest. Residues from three sites at 3 days after spraying were 0.075 mg/kg at Bansalan, Davao del Sur but no detectable residues found at General Santos, South Cotobato and Malvar, Batangas sites. Based on these results, risks of violative residues appear minimal and would not exceed the Codex/EU MRL of 0.2 mg/kg or the Japanese MRL of 0.5 mg/kg. There are minimal trade risks for using this pesticide when use is based on current label recommendations.

While a formulation mixed with Thiamethoxam was studied at General Santos, South Cotobato. Residues were not detected at 7 DAS or 3 DAS indicating that GAP implementation will result in low risk in the export market.

Dietary intake

Estimates of short-term dietary intake were assessed for cypermethrin, lambda cyhalothrin and tebuconazole based on the highest whole fruit residues found for each compound in the trials, an acute reference dose value (as estimated by the FAO/WHO Joint Meeting of Pesticide Meeting of Pesticide Residue Experts (JMPR)), and international mango large portion consumption values for children and the general population obtained from the WHO GEMS/Food database, see Table 1 below. The methodology followed is as outlined in Chapter 3 of JMPR (2004).

Given the calculations were based on whole fruit residues, rather than the edible portion, the potential level of exposure can be considered an overestimate, i.e., overly conservative. The results from the residue trials, therefore, indicate that when cypermethrin, lambda-cyhalothrin and tebuconazole are used in accordance with current label instructions it can be concluded that the short-term intake of residues are unlikely to present a public health concern.

Pesticide Residue Management Discussion

This study identified a number of factors with the potential to constrain the mango industry from successfully complying with importing country standards. Specifically these were:

- the availability of locally generated residue trial data;
- a lack of available data on the use of pesticides in relation to residues;
- the availability of analytical capacity and methods;
- a lack of monitoring of GAP.

Compounding the above for the Philippine mango industry is the lack of information on the residue profile of the pesticides being applied. It was apparent that the majority of growers have little awareness of residue related issues and little or no idea of what residue levels might be present on harvested fruit.

This lack of information was found to impact on differing elements along the mango supply chain, i.e., both during and after production. To address these knowledge and capacity gaps an effective residue management system is needed. The first step would be the generation of the required information, i.e., determination of appropriate export GAP for priority pesticides. Integral to this would be the initial pesticide prioritization process and the generation of residue profile data for the nominated pesticides.

Table 1. Maximum percentage of the ARfD found in the short-term dietary risk assessments

Compound Name	ARfD (mg/kg bw)	Highest residue	Percentage of ARfD)	
		(mg/kg)	Children, 1–6	General Population
Cypermethrin	0.04	0.038	3	1
Lambda-cyhalothrin	0.02	0.15	10	5
Tebuconazole	0.3	0.075	1	2

Pesticide Residues in Food–2003. Report of the JMPR 2004, FAO Plant Production and Protection Paper 176. Rome, Italy, 15–24 September 2003.

Residue monitoring is done within the Philippine mango industry but this has been limited to problematic pesticides only, i.e., due to previous MRL violations. A more proactive approach is needed and should be targeted on those pesticides identified as having greatest risk of violative residues. However, credible residue laboratories in the Philippines, with the capacity to meet the analytical sensitivity and capability of monitoring programs in importing countries, are limited. Resources for the sustainability of these analytical laboratories are also inadequate as this is fully supported by the Philippine Government. Revenues generated from export mango are not returned back directly to maintain and sustain the Residue Laboratories. It can therefore be difficult for exporters to ensure compliance pre-shipment with ever tightening MRL standards, particularly where the MRL can be set at a default value of 0.01 mg/kg, as with Japan.

The first observed major violation of the mango exports to Japan was for chlorpyrifos, due to a lack of understanding. It was determined that the problem arose, in part, through a lack of awareness of the reduction in the MRL from 0.5 mg/kg to 0.05 mg/kg, and primarily from an off-label, i.e., unapproved, use of chlorpyrifos to control ants prior to mango harvest. The exporters and regulators reacted by reducing the use of chlorpyrifos in mango production.

The next MRL violation was with cypermethrin, which had replaced chlorpyrifos in the pesticide management schemes of farmers. This violation also occurred as a result of off-label use. The majority of the MRL violations were from the southern Philippines, where pesticide usage can be intensive. The production of mango in Mindanao is year-round, as compared to single season cropping in Luzon. Since off-season mangoes can command a higher price, there is a tendency for more intensive use of pesticides to ensure blemish and damage-free fruit.

Consequently, it was recognized that the potential sources of residue problems were: farmers who are not following label instructions as per approved use patterns, especially with respect to harvest intervals and off-label use, i.e., using the chemical against other pests not listed on the label. Sometimes, spraying contractors use tank mixtures of more than 2 pesticides per application. A potential solution is to implement farmer or farmer group education/training on understanding residues and their relation to GAP and withholding periods or pre-harvest intervals.

A further recommendation is to train/convince mango farmers to keep pesticide notebooks to record the details of pesticides applied, i.e., the brand name and concentration, frequency and time (growth stage) of application. Auditing of these records would provide assurance that the GAP, i.e., label recommendations, were followed and that the pesticide applications were appropriate for the intended target pest. Also, it is recommended that the recorded information should be openly shared between the consolidator/exporter and the consumer, if necessary.

The next key stakeholder is the exporter, who with the help of the consolidator, aggregates fruit harvested from different mango farms or farmer clusters. Pesticide application and management should be monitored by the consolidator/exporter. They should be able to trace back fruit to the producer, if required. A system of traceability should be put in place and strengthened so as to identify sources of violations should MRL breaches occur. An export strategy could also be developed to identify alternative export destinations based on the PHI and MRL/tolerances in target markets.

Finally a viable export-oriented mango Industry needs the support of credible, fully-equipped pesticide residue laboratories with well trained personnel. These laboratories should have sustainable capacity to analyze new pesticide chemistries at very low concentrations.

Objective 5 - Extension

While agricultural research and information generation remain indispensable factors for a productive, sustainable and dynamic agriculture industry, extension and dissemination are equally important. Once this information reaches the farmers' level, it translates to higher productivity and eventually leads to economic growth and advancement.

The local government units (LGUs) of Davao del Norte and Davao del Sur headed by the Provincial Agriculturist with their agricultural technicians conducted regular technical demonstrations and project briefing, as part of the extension activities of the project. IPM interventions such as sanitation, pruning, fertilization, pest monitoring, needs-based pesticide control, bagging, and insect pheromone application were demonstrated to mango cooperators and farmers. Workshops on Mango Technology Fora were also conducted by the LGUs. These activities were regularly held by the LGUs and experts from associated Universities. Regular meetings, updates and workshops were also conducted.

Twenty seven (27) training sessions were conducted in Davao del Norte and Davao del Sur on the following topics:

- Cultural Management Practices of Mango
- Pruning
- Soil Sample collection and Fertilization
- Pest and Disease Management
- Thrips Identification, Its Management & Control
- Post-harvest Technology
- Mango Organic Farming
- Vermiculture/Trichoderma
- Good Agricultural Practices (GAP)
- Refresher Course on LGU Extensionist on Mango Technology
- Mango Processing

In Davao del Norte, 10 mango grower members of Samal Island Mango Growers Association (SIMAGA) were identified as members of the mango cluster. The cluster was linked to industry partners such as Diamond Star, Nakashin, Southern Philippines Fresh Corp., local funding institutions, and agrochemicals suppliers. Mango production brochure "Integrated Crop Management Operations Guidelines for Mango" was distributed to mango farmers. Periodic monitoring and supervision of 50 mango farms were conducted. In Davao del Sur, meetings on quarantine activities with mango growers were held.

The program increased the awareness to farmers on the management practices of mango farming, of which mango production clustering was also organized. Close coordination/open communication with exporters, financial institutions and other stakeholders were also maintained for improved collaborations.

Training and extension activities are listed in section 8.2 and 8.4

8 Impacts

8.1 Scientific impacts – now and in 5 years

Findings on the biology, ecology and management of identified mango insect pests (mango pulp weevil, thrips, and cecid fly) and epidemiology of mango diseases (anthracnose, stem-end rots, and scab) have provided a fundamental understanding that is essential for the development of future pest and disease management strategies. The work on thrips and cecid fly has provided new insight into their behaviour and integrated control. Stem end rot, scab and anthracnose have been studied and new strategies for control developed and added to the ICM package. Tolerance of some varieties to anthracnose and SER has also been identified.

Soil nutrition and its effect on the natural defence of mango fruits against disease will result in profitable and efficient production systems that increase fruit yields without risking high levels of postharvest disease development. New research has identified important influences of N on fruit yield and quality and alternative use of calcium nitrate to induce flowering, as well as new ways of detecting leaf N via leaf colour in mango. In the same way, studies on the chemical residue limits for mango will set an example for the development of standards for other fruit commodities. This has also contributed to the database of information on residues of pesticides on mango for consideration of a National and/or CODEX MRL. In Australia the results from the fruit spotting bug pheromone work and the mango seed weevil insecticide work have been used in subsequent continuing HAL funded research projects (HAL project No. MG10049 and MG10011, Newton 2011) and have contributed new methods of pest control.

The findings from the project research have been presented at national, regional and international conferences and workshops, showcasing the scientific capabilities of the affiliated staff and the contributions of the project research to knowledge in different disciplines.

8.2 Capacity impacts – now and in 5 years

Active exchange of information, ideas and insights between Filipino and Australian collaborators increased the capacity of all participants of the project. Project Leaders and staff working on the different activities, increased their knowledge in the areas of crop protection, crop nutrition, irrigation management, food safety and extension. Opportunities were also provided to undergraduate and postgraduate students to conduct experiments in conjunction with the project activities. Research outcomes were presented to local and international conferences to increase the beneficiaries of the project to a broader audience. Opportunities were also provided to undergraduate and postgraduate students to conduct experiments in conjunction with the project activities. Seven (7) students have conducted research projects during the course of the work two of which were MSc thesis.

Undergraduate students:

- Alvin Caesar Olanday-“Extending the Storage and Saleable Life of Mango (*Mangifera indica* L. cv. Carabao) Fruits through Integrated Postharvest Management of Stem End Rot Caused by *Lasiodiplodia theobromae* (Pat.) Griff. and Maubl.;
- Tom Dean Espano-“Enhancing the Effect of Low Dose UV-C Irradiation for the Control of Stem End Rot of Mango (*Mangifera indica* Linn cv. Carabao);
- Erik Jon De Asis-“Integrated Postharvest Management of *Lasiodiplodia theobromae* (Pat.) Griff. and Maubl. and *Colletotrichum gloeosporioides* Penz. in Mango (*Mangifera indica* L.) cv. Carabao;

- Glenrose Belen-"Management of Anthracnose and Stem End Rot Disease of Mango (*Mangifera indica* Linn cv. Carabao) using Extended Hot Water Treatment; and
- Gladys Dacanay-"Epidemiology of Mango Stem End Rot: Inoculum Sources of *Lasiodiplodia theobromae* (Pat.) Griff. And Maubl. on Mango (*Mangifera indica* L.) cv. Carabao.

Graduate students:

- Melissa Palacio-"Improved Preharvest Fungicide Spray Program and Integrated Postharvest Management Treatments to Reduce Stem End Rot of 'Carabao' Mango Fruits.
- Khaing, M.T. 2010. Leaf and fruit nitrogen, potassium, and calcium concentrations in relation to fruit yield, quality, and severity of anthracnose in mango (*Mangifera indica* L.).

Extension workers were able to hone their skills in technology transfer and other extension activities. Mango farmers now have the capacity to diagnose pests and diseases, nutrition requirements, and the knowledge to apply necessary interventions to improve the production of mango.

The capability of Local Government Units and collaborators to conduct supervised residue trials has been enhanced. An increased capability of local residue laboratories to undertake analysis of mangos for specific pesticides using GLP is foreseen, with participation in local inter-laboratory quality monitoring to gain confidence in the analysis of specific pesticides.

Cross-visits to Australia and vice versa to experience and witness the mango industry, provided good insights for researchers and farmers. There were 4 participants in a Component leaders study tour to Australia and 12 Filipino growers benefited from the industry study tour to Australia. In both tours, participants "walked the chain", from orchard to markets to shops, where they experienced all facets of the Australian mango value chain. A side trip to the APVMA in Canberra has contributed to the capacity building of the residues component leader, in terms of evaluation of pesticide residues, from the Australian regulators point of view. The study visit by the mango industry enabled growers and others to think about the possible improvement to the Philippine mango industry.

Two researchers from collaborating institutions (USeP and LGU) were trained in Australia on mango disease diagnosis and identification, through an International Mango Disease Workshop held in Darwin from May 1-5 2011. Following the workshop, they were also involved in project review and planning workshops of the Pakistan ASLP project where they received further training on project review and planning process.

Hands on training, within supervised pesticide residue trials, educated collaborators (as well as farmer clusters and spraying contractors) on GAP, withholding periods and other residue issues. Some hundreds of Filipino farmers have benefited from training, workshops, field demonstrations market exposure. This has included over 700 growers attending workshops on agronomy, IPM and pesticide residue management.

8.3 Community impacts – now and in 5 years

Farmer and spray contractors increased awareness in the food safety aspect of food production, and chemical residues (as affected by GAP and PHI) has enhanced the production of quality mangos. It is expected that the MRL findings and associated crop management recommendations will create more export opportunities within the next 5 years.

The clustering approach adopted to transfer integrated crop management principles and practices continues to bring together grower communities to tackle issues of mango production and marketing at a community level. This has created an atmosphere of togetherness with the communities to take on common challenges.

8.3.1 Economic impacts

The economic benefit that the growers have gained is the increased income due to higher yields and higher quality (pest and disease-free) fruits; correspondingly, the reduced yield losses, improved fruit quality and reduced production costs have increased profit margins. With residues below MRLs, Philippine mangoes will be competitive to various export destinations and alternative export market destinations could be identified based on the pesticide management practices (developed in this project) of the mango farmer.

The organized marketing system (through the contracts and arrangements undertaken through this project) with external buyers, both for domestic and export markets, are offering growers larger margins and increased profits for their fruits.

Adopting the IPM and ICM practices developed in this project could significantly lift the income of smallholder mango farmers. In an economic analysis from Palawan, it was demonstrated that by adopting the IPM package from this project, farmers would significantly increase their profit margins. The IPM recommended treatment produced an income of PhP 1,730 (AUD 42.00) per tree, in contrast the conventional “farmers practice” yield was only PhP 21 (AUD 0.50) per tree. The marginal benefit cost ratio in IPM was 2.0. This ratio indicates better economic performance in the IPM treatment compared to the conventionally managed trees. In another economic study (based on estimates), from Southern Mindanao, Preciados *et.al.* (2013) found that IPM practices developed from this project could: reduce losses and rejects by 20%, improve yields by 33%, reduce the cost of production by 16% (through reduced chemical control costs) and increase farmer income by an estimated 156%.The estimated net value of benefits from collaborative IPM research in the Philippines Region XI for mango was approximately PhP1.25 billion (AUS$25 million), with a benefit-cost ratio of 51:1.

8.3.2 Social impacts

Social impacts have been achieved in relation to community awareness of pesticide use, and a change in mind set and pesticide management strategies of the farmers and spraying contractors (in terms of the usage of pesticides in relation to chemical residues). This will result in mango residues in the local and international market that are below the accepted MRLs.

A change in attitude of farmers, contractors, local government units and landowners about how to increase productivity through the use of integrated crop management practices for mango production is anticipated.

The grouping of growers into clusters is having a social effect within the community as other social issues (besides mango production and marketing) are discussed during the clustered social gatherings, i.e. it is bringing the community together.

8.3.3 Environmental impacts

The project outputs will improve the productivity and income of smallholder mango farmers through the rehabilitation of mango smallholder farms that are seriously threatened by pests and diseases and misuse of pesticides via a crop management system approach. This approach enhances the economic sustainability, diversity of crop resources and environmental protection through appropriate pesticide management. Therefore, this project has a direct bearing on the sustainability of mango production and maintenance of the integrity of the environment. There will be a reduction of pesticide misuse as a result of the awareness and management of chemical residues, thus resulting in lesser and wiser/judicious use of pesticides. This scenario will result in less pesticide applications and therefore indirectly less residues in the environment and less impact on non-target organisms. The reduction in excessive pesticide use is having beneficial environmental impacts through increased awareness and regulated use.

8.4 Communication and dissemination activities

An organizational meeting was conducted in January 2009, to discuss the activities to be conducted on the IPM, disease and nutrition subcomponents of the mango project in cooperation with the Provincial Agriculture Office, UPLB, USeP, and mango growers of Samal Island Mango Growers Association (SIMAGA).

The local government units (LGUs) of Davao del Norte and Davao del Sur headed by the Provincial Agriculturist with their agricultural technicians conducted 27 technical demonstrations, as part of the extension activities of the program. IPM interventions such as sanitation, pruning, fertilization, pest monitoring for need-based chemical control, bagging, and insect pheromone application were demonstrated to mango cooperators and farmers. Extension activities on residue management were conducted with farmer groups/clusters through formal and informal training activities. Extension brochures in two dialects (Tagalog and Visaya) were produced for Samal and Bansalan farmers.

Links with other research projects on MPW in Palawan were undertaken. Two workshops were conducted on October 27, 2009 attended by 157 mango stakeholders and the second, on December 1-2, 2009 attended by 50 technicians in Puerto Princesa City Palawan, for mango insect monitoring and insecticide application. Posters and fliers on MPW control that were produced from the ACIAR-IPM Phase 1 project were distributed to LGU technicians and mango farmers in southern Palawan.

An IPM workshop was conducted on pest and beneficial insect monitoring, insecticide application technology, residues and pre-harvest intervals. A linkage was established with another line agency of the Department of Agriculture, the Bureau of Agriculture and Fisheries Product Standards (BAFPS) for the conduct of the workshop. The 3-day workshop was held on Aug 17-19, 2010 in Batangas City and attended by 35 mango stakeholders and technicians of Regions 4A and 4B.

Another linkage was established with the Local Government Unit (LGU) of Brooke's Pt., Palawan in the conduct of a field day for the IPM trials in Brgy. Pangobilian, Brooke's Pt. The field day was conducted on the June 16, 2010 at one of the project sites to demonstrate the fruits that developed from the IPM trees and to discuss the IPM protocol. This field day were attended by 45 mango stakeholders. A hand out of the IPM protocol and the cost and return analysis in the IPM trees were distributed during the field day.

In the chemical residue study, stakeholders in the SPRT trials were involved in the information dissemination through seminars/training with farmers as well as dissemination of information in scientific conferences and mango congress. A discussion with officials of the Fertilizer and Pesticide Authority (FPA), Croplife (Bayer, Syngenta, Dole) and the Crop Protection Association of the Philippines was made. Extension activities were done with farmer clusters through formal and informal training. Extension brochures in two dialects (Tagalog and Visaya) were produced for Samal Island and Bansalan farmers.

9 Conclusions and recommendations

9.1 Conclusions

Much of the IPM research work in this project concentrated on the biology and management of thrips. Two species of thrips were identified, both species being polyphagous with a wide host range of cultivated and wild plant species. Within the mango production areas where the studies were undertaken, natural enemies such as predacious insects were absent, which was attributed to the overuse of broad-spectrum insecticides. Lifecycle studies of the thrips were studied and management strategies implemented. These included monitoring techniques and the use of appropriate timing of pesticide application and addition of spreaders to spray applications. In Palawan, an IPM package was developed that not only controlled the mango pulp weevil (MPW), but also reduced other pests and diseases, resulting in substantial increases to potential farmer profit margins. This strategy should be incorporated in the on-going province-wide program to eradicate MPW in southern Palawan. Likewise, another economic analysis has estimated that if the recommended integrated pest and disease management could be adopted by mango growers in the Southern Philippines, they could potentially increase their income by 156%. In Australia, researchers developed methods to control the closely related Mango Seed Weevil using soil drench techniques with a systemic insecticide (thiamethoxam). These methods and results were shared with the Philippine researchers and could provide them with further control options.

For the control of the mango postharvest diseases, anthracnose and stem end rot (SER), a package of pre-harvest in-field fungicide spray treatments and postharvest treatments was developed and disseminated to grower clusters. Systemic fungicides were found to suppress blossom blight and SER infection. Hot water treatment, fungicide dips, modified atmosphere packaging and cold storage decreased the disease incidence and prolonged marketable life of fruits. Nutrition studies concentrated on the value of specific nutrients in relation to disease incidence. All mango fruits developed anthracnose at ripening, regardless of chemical flower inducer or N-fertilizer levels. No significant differences were noted among treatments in terms of the relationships between tissue nutrient concentration, fruit yield and quality.

For export and pesticide residue safety, extended withholding periods are required to ensure compliance with MRLs in export destinations such as Japan. For other export countries like Hong Kong, Korea and China and for the local market, it is recommended to strictly follow GAP guidelines. For problematic persistent pesticides, it is recommended that the last application occur at 90 days after flower induction (DAFI) to allow degradation of residues to non-detectable levels.

Although a considerable amount of research has been done into mango IPM, broad scale adoption of IPM has been minimal. The continuing overuse of broad-spectrum pesticides in the southern Philippines is more than likely counter-productive to controlling mango pests. It is highly likely that some of the pests (e.g. thrips and leafhoppers with short lifecycles) have developed resistance to some of the older broad spectrum insecticides. In which case, using such insecticides exacerbates the problem by killing off the natural enemies and preserving the pests. Such situations can also induce “insecticide flare” of pests, which may not have otherwise been a major issue. Furthermore, there is a general lack of alternative narrow spectrum or “IPM friendly”, insecticides that are registered or available to the Philippine mango industry, and the alternative insecticides that are available tend to be too expensive for the growers. The problem is exacerbated by spray contractors which can sometimes adopt a “one spray for all pests” approach. This practice could eradicate the natural enemies in the entire area, effectively making an IPM approach useless.

A key area of success in this component was the extension program. However, effective IPM uptake has been minimal (particularly amongst spray contractors) and extension could still be improved to reach more growers. There are generally not enough LGU extension staff available (and their resources are stretched) to effectively reach all mango growers. Organizing "farmer clusters" and selecting and training key growers within each cluster was trialled and could provide a better system of extension at reaching more small-holder farmers.

9.2 Recommendations

1. That research be conducted on understanding the biology of the thrips, *Scirtothrips dorsalis* and *Thrips hawaiiensis*, in relation to weather events (rain in particular). This may assist implementation of more targeted spray applications, and species identification in relation to crop phenology and levels of economic damage (i.e. which thrips is doing the damage?).
2. That further research be conducted on the biology and management of cecid flies.
3. Future pest management work should concentrate on developing: IPM compatible products, resistant management strategies, and Area Wide Management strategies that engage not only the farmers but also the contractors.
4. That research be conducted on ways to improve pest monitoring and determine economic thresholds. This could also help to reduce unnecessary calendar-based insecticide applications which would reduce the farmers input costs and preserve natural enemies.
5. That research be conducted on more economically viable farm input alternatives, including more cost effective disease treatments (preharvest and postharvest) and fertilisers. Further research into alternative organic inputs could provide some cost effective solutions to nutrition, pest and disease problems.
6. That further research in nutrition and canopy management could provide improved methods of reducing pests and diseases, as well as producing larger export quality mangos.
7. For pesticide residues and food safety, it is recommended that the extension of information dissemination and awareness should be strengthened especially on the understanding of residues, MRLs, GAP and PHI to those who are applying pesticides and how this can affect trade. This should be extended to other major players in the mango supply chain. A system of traceability to the producer or source is recommended. This should be coupled with a farmer's notebook as a requirement for farmer clusters supplying the export market. Monitoring by the consolidator/exporter of pesticide applications by the farmer will further reduce risk.
8. That more residue data be obtained to help understand degradation of residues in major production areas. A proactive approach should be targeted on those pesticides identified as having greatest risk of violative residues. This should be coupled with better laboratory facilities and trained personnel. To ensure that exports follow appropriate import standards, support is required for regulation, promotion and laboratory costs.
9. More resources are required to support extension staff, in particular for the reproduction and distribution of printed materials in local language.
10. That farmer clusters be extended. Clustering of farmers has provided a useful model for co-ordinating work (e.g. flower induction) and disseminating information, but this model needs to be extended so as to reach more farmers and perhaps more importantly to include contract growers.

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11 Appendixes

11.1 Appendix 1: Registered Insecticides

***Table A1.* The Fertilizer and Pesticide Authority (FPA) registered insecticides in mango and corresponding pre-harvest interval (PHI) and Maximum Residue Limits (MRLs).**

Insecticide	Label PHI (days)	Critical GAP active ingredient/ 100L	Philippine MRL	Codex MRL	Japan Positive list
acetamiprid	14	3.75	5	x	1
beta cyfluthrin	28	10.16	0.02	x	0.02
beta cypermethrin	1	7.5	0.05	x	0.05
BPMC	14	109.38	x	x	0.3
buprofezin	15	100	x	0.1	0.5
carbaryl	1	425	3	x	3
carbosulfan	14	80	0.05	x	0.3
cartap	10	62.5	3	x	3
chlothiadinin	10	2.5	1	x	1
cyfluthin	7	3.75	0.02	x	0.02
cypermethrin	7	9.38	0.03	0.7	0.03
cyromazine	14	35.16	0.2	0.5	0.5
deltamethrin	1	1.56	0.5	x	0.5
diazinon	14	150	0.1	x	0.1
dimethoate	14	75	1	1	1
dinetofuran	7	25	2	2012*	1
esfenvalerate	2	3.125	1	x	1
fenvalerate	2	15	1	x	1
etofenprox	7	12.5	5	x	5
fenthion	14	203	5	x	5
gamma cyhalothrin	3	4.69	0.1	0.2	0.5
imidacloprid	20	5 to 31.5	1	0.2	1
lambda cyhalothrin	3	2.34	0.5	0.2	0.5
phenthoate	14	156.25	0.1	x	0.1
profenophos	7	62.5	0.05	0.2	0.05
pymethrozine	50		1	x	0.1
thiamethoxam	65	3.9	1	2010*	0.2
spinosad	7		0.1	x	0.3

11.2 Appendix 2: Registered Fungicides

***Table A2.* FPA registered fungicides in mango and corresponding pre-harvest interval (PHI) and Maximum Residue Limits (MRLs)**

Insecticide	Label PHI (days)	Philippine MRL	Codex MRL	Japan Positive list
azoxystrobin	3-7	1	0.7	1
captan	0	5	x	5
carbendazim/ benomyl/thiophanate methyl	14	2	5	2
chlorothalonil	7-14	0.5	x	0.5
difenoconazole	21	1	0.07	1
dithiocarbamates	5-7	2	2	2
cyromazine	-	-	0.5	*
tebuconazole	22	1	0.1 (proposed)	*
propineb	3-7	2	x	*

** If there was no indicative value under the column on Japan Positive list, the default value of 0.01 mg/kg will apply.*