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Final report

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Contents

1 Project overview.

In both the Philippines and Australia, sustainable development of the mango industry is hampered by pest and disease losses, variable productivity, perishability of the fruit, supply-chain deficiencies and market access challenges.

In the Philippines, mangoes (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, while Guimaras in the Visayas has special quarantine status (export to Australia/ USA) as free of pulp weevil.

In Australia, production is across all of northern part of the country extending from Gympie in Queensland around to GIB Gin in southern Western Australia. The major domestic variety is Kensington Pride (KP) with KP and R2E2 the major export varieties.

In both countries field infestations by insects cause losses and damage levels ranging from 10 to 40 percent, or limit market access, particularly for small-scale farmers. Mango farmers use pesticides, baiting and biological/management strategies, but current measures place too much reliance on chemical controls leading to concerns about excessive pesticide use. The emergence of new pest problems (e.g. fruit spotting bug) also requires attention to ensure the IPM strategy provides reliable solutions otherwise it is unlikely to be adopted by producers or application contractors (the latter are the key target ‘user’ group in Mindanao). Systems approaches that integrate field control with postharvest disinfestation will reduce costs and the risk of disinfestation failures.

Deficiencies in the supply chain can affect fruit quality and market opportunities. Improvement in the knowledge that farmers, traders and marketers have of the areas for improvement, requirements, logistics and linkages in a particular supply chain will provide opportunities for business expansion and improved profits. Accurate analysis of supply chains will provide a ‘road map’ from which technical or business priorities can be identified and strategies implemented to bring about improvements. Such knowledge needs to be understood and shared to assist all sectors from retail and export customers, traders and farmers to improve the volume and reliability of produce supplies and industry performance.

These two critical issues were the initial major focus of the research activities proposed, however an additional smaller research activity was incorporated into the project some two years into the program. This activity was to finalise parts of HORT/1997/094.

This resulted in the project have five principle research activities:

1. Integrated Pest Management in the Philippines
2. Integrated Pest management in Australia
3. Mango Supply Chain Management in the Philippines
4. Mango Supply Chain Management in Australia
5. Field evaluation of plant host defence activators

This is how this project report is structured.

2 IPM – Philippines

Objective 1: Pest management research in mango in the Philippines

Objective 2: To improve control and detection of mango pulp weevil in the Philippines.





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2.2 Executive summary

Field studies were conducted to develop improved recommendations for integrated pest management and judicious pesticide use. Baseline data were taken as the basis for the recommendations. Pest identification and monitoring were the indices of knowing the insect population and its degree of damage for the different control methods employed.

Data collected from the baseline surveys showed that mango growers/cooperators were dependent solely on chemical control as their method of suppressing pests and diseases having an average of 13 chemical spraying cycles. Most of all the cooperators did not practice insect pest monitoring as their basis for employing control measures. Done only minor pruning or no pruning at all, sanitation and even fertilization scheme were not given too much attention and no soil analysis conducted.

Five insect pests were identified namely cecid fly, mango leafhoppers, blossom blight, mango seedborer and mango fruit fly that damage mango leaves, flowers and fruits. Cecid fly damage the new and even old leaves while mango leafhopper and blossom thrips on flowers. On fruits, mango seed borer contributed much of the damage with an average fruit damage of 19.53% followed by mango fruit fly 11.00% and cecid fly 3.47%.

Integrated pest management interventions such as regular sanitation, pruning, balanced fertilization, pests monitoring as basis for need-based chemical application, yellow/white sticky and light traps, early bagging, insect pheromone and use of lorsban impregnated plastic successfully reduced the percent fruit damage of 4.78% with 6 spraying cycles done at 8, 15, 21, 35, 42 and 55 days after flower induction and gave significant yield of 139.59 kilos per tree as compared to farmer's practice with 7.49% and yield of 50.77 kilos per tree. On the cost and return analysis IPM gave the highest return of investment (164.00%) with an increment of 99.50% over that of farmer's practice (chemical spray alone).

Observations on field populations of mango pulp weevil adults at quiescent stage were made. An IPM work plan was developed against 3 pest problems, such as leafhopper, mango pulp weevil (MPW) and fruit fly. This work plan was anchored on 4 IPM strategies, i.e., cultural control, pest monitoring, chemical control and physical control.

Crude extracts were collected from mango fruits, male and female weevils (virgin and mated) and male and female weevil frass (virgin and mated) to determine attractancy to virgin female weevils. The components of mated male weevil frass was determined by GC-MS and standard chemicals were used to determine attractancy to virgin female weevils.

Data on the survey conducted in northern and southern Palawan was made access to as well as data from mango x-ray examination for MPW infestation. Adult weevils stay up to the main branches of mango trees at quiescent stage. The IPM work plan consisting of cultural, physical and chemical control and pest monitoring was able to reduce MPW population to 2%. Physical control (bagging) enabled the reduction of spray application to 5 times throughout the fruit production period.

Mated male frass at 3 frass equivalents elicited the highest attraction (73.3%) to virgin female weevils. Twenty-four components were identified by GC-MS from mated male frass and acetic acid, one of the components is able to elicit the same percentage attraction. Survey in northern Palawan has shown that the area is still free from MPW.

2.3 Background

Mango (Mangifera indica) has significantly contributed to the country's export earnings third to banana and pineapple (Fernandez, DA-SMARRDEC). Several municipalities and component cities of Davao del Norte have a project on plant now pay later on mango through organized groups such as farmers' cooperatives and individual farmers. As shown on the survey, there are about 1,614.30 hectares planted to mango in the province in 1999 and estimated increase by 55% in 2001 in which 60% are at bearing stage, (HVCC profile 2001).

However, despite of the expansion area, production is still very low due to poor quality of produce caused by pests and diseases (Golez & Bignayan, 1992). Mango, like most fruit tree crops, is usually attacked by two or three key pests, several secondary pests and by a large number of occasional pest in localized areas where it is grown (Murray, 1991). Of 260 species of insect and mites that have been recorded as minor and major pests of mango, 87 are fruit feeders, 127 are foliage feeders, 36 feed on the inflorescence, 33 inhabit buds, and 25 feed on branches and the trunk (Peña & Mohyuddin, 1997). The three to four key pests, including fruit flies, pulp weevils, tree borers, and mango hoppers require annual control measures. Secondary pests generally occur at sub economic levels, but can become serious pests as a result of changes in cultural practices and mango cultivars of because of indiscriminate use of insecticides against a key pest (Mohyuddin & Mahmood, 1993).

Current mango pest management practices are affected not only by the domestic and export fruit market, but also by consumer attitudes toward health concerns and the cosmetic appearance of the fruit. In general, mango pest management is largely dependent on the use of pesticides (Shaw, 1961; Balock & Konzuma, 1964; Nachiappan & Baskaran, 1986; Golez, 1991; Peña, 1993). Control of mango fruit pests by chemicals alone has been complicated by development of pest resistance and resurgence and elevation of minor pests to major pests' status (Cunningham, 1989) Costs of pest control have mounted to 60-70% and in some cases increasing amounts of pesticides are required to keep the large number of pest's species under control, hence, this study.

In the Philippines the pulp weevil, Sternochetus frigidus has only been recorded from southern Palawan, and quarantine restrictions prevent movement of fruit or planting material. At present, only one locality, Guimaras Island, is approved as pulp weevil free for export consignments and there is ongoing interest in both improving control of the pulp weevils on Palawan and developing strategies to expand localities that are approved as pulp weevil free for export. Some progress has been made in understanding the biology and control of pulp weevil, including new information on floral volatile atrractants, oviposition stimulants and options for insect trapping. Current controls involve restrictions on movement of plant material (to limit spread) and field management of affected sites. Transport of planting materials and all its parts including fruits from known infested areas such as Palawan is prohibited. Better techniques for detecting the pulp weevil as well as identifying its distribution in Palawan for area freedom need to be identified to improve exporting opportunities for local growers. Complimentary studies on the pest's biology, distribution and control need to be conducted to promote better management of this pest in Palawan.

2.4 Objectives

General:

To develop improved recommendations for integrated pest management and judicious pesticide use.

To improve control and detection of seed and pulp weevils

Specific:

- To identify major insect pests in the area
- Asses pest population and develop integrated pest management interventions that judiciously minimize pesticide usage and improve quality of mango
- Develop information education campaign materials, conduct technology forum and demonstrations for technology dissemination
- To acquire additional ecological and behavioural data on the quiescent stage of pulp weevil in order to develop effective management strategies and to contribute to the development of revised quarantine protocols and area freedom monitoring
- To study mango volatiles and investigate pheromones of pulp weevil to provide opportunity to develop and test lures to trap this insect

2.5 Methodology

2.5.1 IPM Studies comparing IPM strategies versus farmers practice

Time and Place of the Study

The studies were conducted in Davao Del Norte and Davao Del Sur. Trials where carried out in Davao Del Sur at Mamacao, Kapalong cropping season 2005- 2006, Kauswagan, Panabo City

2006, Penaplata, Island Garden City of Samal – 2006 and Babak, Island Garden City of Samal 2007-2008. In Davao Del Sur at studies where conducted at Santa Cruz, Kiblawan and City of Digos at three trial sites (2005-2008).

Experimental Design

The experiment was laid out in randomized complete block design replicated three times. The following were the treatments:

Treatment 1 - Integrated Pest Management (intervention)

Treatment 2 - Farmers' practice (chemical control)

Treatment 3 - Control (no pest control)

Treatment 1 (IPM) the following management practices were done:

Pests Control interventions:

Light Trapping

Light trapping with the use of kerosene in Mamacao and electric operated bulb (Kauswagan and 2 sites in Island Garden City of Samal) were used in the study to reduce the insect population (nocturnal and light attracted pests) and to monitor insect population. One light trap was placed at the center of the sample mango trees and start five days after flower induction at three days interval till 60 days after flower induction (DAFI).

Yellow sticky trap

Yellow sticky made of G.I. sheet were cut into 2 x 2 feet and placed in 1 x 2 x 3 inches lumber. Six sticky traps were installed in between the experimental trees 1.5 meters above the ground, engine oil were brushed unto the trap every five days or when oil diminished (Figure 1).

Figure 1. Yellow and white sticky traps placed within the IPM sample trees.

Chemical control based on pest monitoring

Spraying of insecticides was done based on the pest populations (Figure 2).

Sites	Days after flower induction
1. Mamacao, Kapalong	8, 14, 21, 33, 40, 47, 54
2. Kauswagan, Panabo City	11, 17, 23, 33, 38, 50
3. Penaplata, IGACOS	8, 15, 21, 35, 42, 55
4. Babak, IGACOS	9, 15, 21, 33, 42, 50, 55

Figure 2. Pests monitoring activities done in each experimental sites 15 days interval at non-bearing and 7 days interval at fruiting stage of the crop.

Chemical strip application

One strip of Lorsban impregnated plastic was tied around the trunk of the tree to prevent ants. Tying were done 45, 65, 85 days after flower induction (Figure 3).

Figure 3. Lorsban impregnated plastic wrapped around the trunk/branches.

Methyl eugenol application

Methyl eugenol solution, a male fruit fly attractant was placed in an improvised container and hanged strategically around the IPM sample trees. Application was done 45, 60, 75 and 90 days after flower induction.

Figure 4. Methyl eugenol placed in cotton with improvised contain hung under the IPM sample trees.

Early Bagging

Bagging was done 50- 55 DAFI using ordinary newspaper (Figure 5).

Figure 5. Sample of fruits bagged with news paper.

Handpicking and proper disposal of fruit drops (crop hygiene)

Hand picking of fruits drops, burying/burning and proper disposal were done to avoid spread of pests. Done during 60, 70, 80, 90 and 100 days after flower induction (Figure 6).

Figure 6. Hand picking of mango fruit drops and proper disposal.

Treatment 2 – Farmer's Practice.

All cultural management practices were decided by the co-operator and were only recorded. Co-operators come up with the chemical calendar spraying and the following schedules were:

Sites	Schedule of spraying days after flower induction
1. Mamacao, Kapalong- 16 cycles	0, 8, 14, 19, 25, 32, 35, 42, 47, 54, 59, 64, 70, 80, 90, 100
2. Kauswagan, Panabo City - 14 cycles	0,11, 18, 25, 34, 39, 44, 54, 59, 66, 72, 79, 86, 93
3. Penaplata, IGACOS – 13 cycles	8, 14, 19, 25, 32, 36, 42, 47, 54, 59, 70, 80, 90
4. Babak, IGACOS – 11 cycles	10, 17, 23, 28, 33, 38, 42, 48, 55, 61, 91

Treatment 3.

For control tress, no chemical control employed, however, other cultural management practices such as sanitation, fertilization, and paclobutrazol application were applied.

Experimental Layout

Each study used 23 randomly selected mango trees with more or less the same tree size and canopy. The treatments were randomly assigned to the various trees tagged in the experimental area. Ten sample trees were used in IPM and ten for farmer's practice while control only three sample trees were used per site as the co-operator did not allow us to use more trees.

Experimental Procedure

Site Selection

For Davao del Norte, four trials sites were chosen namely Mamacao, Kapalong, Kauswagan, Panabo City both located in the mainland of Davao del Norte and the two other sites were Penaplata and Babak, Island Garden City of Samal which had 2 cropping seasons (2006 -2008). One hectare mango field were selected strategically located in the identified mango growing municipalities in the province having 10 to 16 years old mango trees (Figure 7).

Baseline Survey

Survey on the baseline data on farmer production management practices has been done in three sites involving orchard and backyard-type mango production (50-300 mango trees). Survey was focused on collection of information on the different management practices both in non-bearing and bearing trees. Data on yield and post harvest management done in each locality especially the co-operators' practices were taken.

Cultural Care and Management

- Field Sanitation. General weeding was done around the experimental area during the start of the trial. Succeeding brushing/slashing was done between mango trees using a grass cutter and bolo. Round weeding and sweeping were done on the canopy before flower induction and thereafter.
- Pruning. Removal of undesirable vegetative parts, crowded branches, insect-infested and diseased branches, leaves, flowers and other plant parts were done before the flower induction and right after harvest. Small branches were cut first followed by large branches, clean cut were made and all debris were removed to clean the surroundings
- Fertilization. Soil analysis was done before the start of the trial to determine the appropriate fertilizer recommendations. Small canal (30 cm deep and 100 cm away from the trunk were made after pruning
- Growth Regulation. Paclobutrazol (growth retardant) was applied as soil drench one month after flushing. Applied 30 cm away from the base of the tree at the rate of 4 ml solution per meter canopy diameter and mixed with 5 litres of water. Soil moisture at field capacity towards saturation prior to paclobutrazol application.

Sites

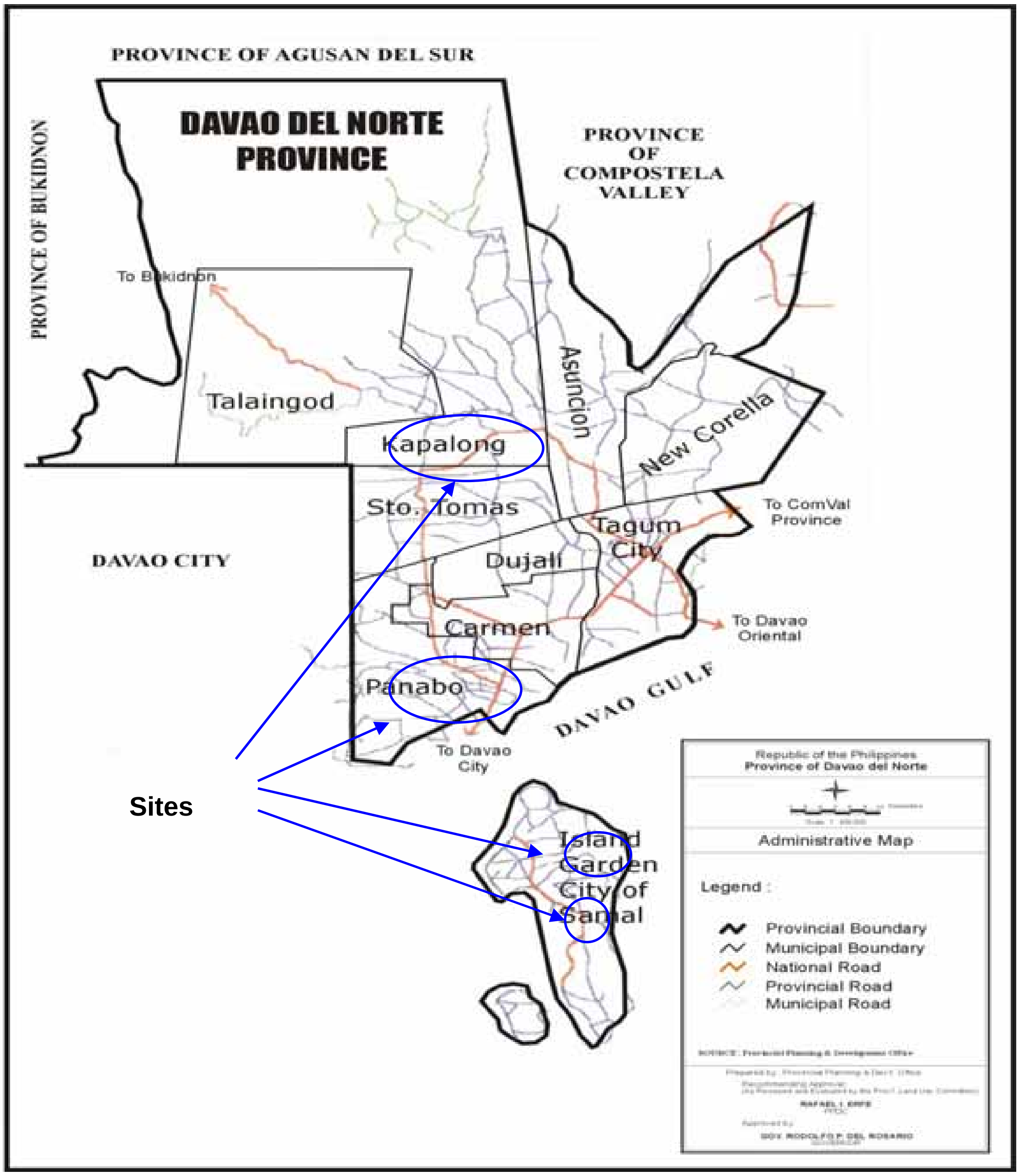

Figure 7. Map of Davao del Norte showing the four experimental sites Mamacao, Kapalong, Kauswagan, Panabo City and Penaplata and Babak, Island Garden City of Samal.

Flower Induction. Flower induction was done after three months from cultar application at the rate of 2.5% potassium nitrate (5 kg/200 litres water). Follow up induction was done 1 day after the first induction at the rate of 1.5% KNO3 (3 kg/200 litres water) (Figure 8).

Figure 8 Flower induction done 2 months after paclobutrazol application at 2.5% KNO3.

Disease Control. Major disease of mango such as anthracnose, scab and others was controlled by fungicides based on monitoring of disease incidence. Dosage as based on manufacturer's recommendation

Harvesting. Harvesting was done 110- 115 days after flower induction, done 9:00 till 11:00 in the morning (Figure 6).

Sorting/Grading and Packaging. Direct sorting and packaging were done right after harvest to minimize handling operations and damage. Non-marketable fruits were separated from marketable one.

Conduct of field Day. A week before the scheduled harvest of the study, field day was set to showcase the result of the study. Provincial/City/Municipal and barangay officials, technicians, farmers, contractors, non-government organizations and neighboring provinces were invited during the event for technology disseminations. Seminars / meetings / hands-on demonstration were also conducted to replicate the technology.

A. Baseline data: Co-operator's Management Practices. Mango management practices of the four co-operators were gathered and were the basis for IPM interventions made.

B. Major Insect Pest Identification. Mango insect occurred observed and monitored in the designated sample trees were examined and recorded and brought to Bureau of Plant Industry for proper identification and observation.

C. Insect Population/Damage

1. Cecid Fly

   1.1. Number of blisters/shot holes on leaves. These were taken four times at 7 days interval after development of new flushes. For old leaves, number of shot holes was recorded data was taken from 25 randomly selected leaves in each treatment.

   1.2. Number of blister on fruit. Twenty five randomly selected fruits were used for counting the number of blister on the fruit. Data collection was taken at 40, 50, 60, 70, 80 and 90 DAFI. Leaves and fruit blister were recorded according to the following rating scale:

   1 - 0 blister

   3 - 1-25 blister/leaf

   5 - 26-50 blister/leaf

   7 - 51-75 blister/leaf

   9 - 76 – greater blisters/leaf

2. Mango Leafhopper

2.1. Number of leafhopper. Number of leafhoppers (nymphs and adults) was counted from test plants of each treatment. Data collection was taken at 7, 14, 21, 28 and 35 DAFI. Collection was done from 9:00 am to 11:00 am.

2.2. Degree of Damage. Degree of leafhopper damage was gathered from twenty five randomly selected panicles per test trees at 14, 21, 28 and 35 DAFI. Following damage rating scale was used in collecting data:

1 - Minimal damage (5-24% of the panicle destroyed)

3 - Moderate (25-50% damage)

5 - Severe (51-70% damage)

7 - Very severe (71-100% damage)

3. Thrips/Tip borer

3.1. Number of Tip Borer. Data was collected from 25 randomly selected panicles per tree. Data gathering was taken at 7, 14 and 21 DAFI.

3.2. Number of thrips. Population of thrips was counted per sample panicles per tree of each treatment.

D. Yield Component

Fruit Yield. Number of fruits harvested per sample trees of each treatment was recorded at harvest. This was computed into Tons per hectare. Fruits damaged by insects was recorded and segregated for examination.

Fruit weight. Fruit weight was recorded from 25 randomly selected fruit from the pre-determined sample panicles in each treatment at harvest.

E. Weather Data

The daily rainfall, relative humidity and temperature were gathered through the facilities of PAG-ASA in Davao del Norte.

F. Cost and Return Analysis

The production cost and income per tree per hectare was computed on the prevailing cost f labour and prices of farm inputs. The Return of production Cost (RPC) was computed using the formula:

$$RPC = \frac{\text{Net income}}{\text{Total Production Cost}} \times 100$$

2.5.2 Mango pulp weevil studies

Behavioural study

Observations on field populations of mango pulp weevil adults were started when the ‘carabao’ mango trees (15- to 25-ft tall) were at the dormant stage. Observation was conducted continuously for a 24-hr period throughout the dormant stage following the method of De Jesus et al, 2003.

Investigate field control of pulp weevil including chemical application efficiency

An IPM work plan (Table 1) was developed based on pest problems reported by the farmers. These pests include: mango leafhopper, pulp weevils and fruit fly. This IPM work plan is anchored on 4 IPM strategies, such as, cultural control, pest monitoring, chemical control and physical control. Farmers’ crop protection practice was also recorded which consisted only of chemical control (Table 2). Data on insect pest population, disease incidence and yield were also gathered. The experiment was conducted in 10 single - tree replicates in a complete block design.

Attractants

Preparation of Crude Extracts

In the laboratory, 500 mated female weevils were enclosed in a 100 x 100 cm Teflon bag and volatile chemicals emitted were adsorbed in 1g Tenax AG packed in a glass column. Air in the Teflon bag was pulled by a vacuum pump at a flow rate of 3 L min-1 for 24 hr. The volatiles adsorbed in Tenax AG were extracted by Soxhlet in n-pentane and concentrated in a micro Kuderna-Danish set-up. Final volume was reduced to 2ml. All samples were stored in the freezer. Aliquot samples were dried in N2 gas to determine the weight of the volatiles. Crude extracts were also collected from 500 mated male weevils, 500 unmated female and male weevils, frass from 500 mated and unmated male and female weevils. In the field, twenty-year-old mango trees with mature flushers were induced to flower using KNO3 at 1.5% concentration. After 70 d, the fruits were ready for collection of volatiles. Volatiles and crude extracts were collected in the method described above.

Y-tube Bioassay

The attractiveness of the crude extracts from weevils and frass was assayed in a Y-tube olfactometer (De Jesus et al, 2004). The data obtained in the Y-tube bioassay were statistically analyzed by the use of the X2 test for a fixed-ratio hypothesis. The results were analyzed as two-choice data (Zar, 1974).

Collection of Headspace Volatiles by SPME

Frass from (500) mated male weevils were enclosed in a 25 x 38 cm Glad oven bag and volatiles emitted in 24 hr were adsorbed by SPME fibre injected into the oven bag. The SPME fibres were brought to the National Chemistry Instrumentation Centre (NCIC), Ateneo de Manila University for identification of the components.

Distribution of Pulp Weevil in Palawan

A survey for presence or absence of pulp weevil led by Dr. Hernani Golez is being conducted in the different mango growing areas of Luzon. Data on the survey in northern Palawan will be accessed. A meeting with the 8 Municipal Agriculturists and 1 City Agriculturist of southern Palawan was conducted and surveys were carried out to determine the distribution of MPW Palawan

X-ray Technology in Detecting Pulp Weevil

The City Agriculturists' Office (CAO) of Puerto Princesa is operating the Mango Pulp Weevil Detection Center in Irawan, Puerto Princesa City. Mango x-ray data was accessed. Special arrangements were made with the CAO so that data on the number of weevils per fruit was also recorded.

2.6 Achievements against activities and outputs/milestones

Objective 1: Integrated field management systems and judicious pesticide use

Aim: To develop improved recommendations for IPM and judicious pesticide use.

no.	activity	outputs/ milestones	completion date	comments
1	Expanded baseline data of farmer pest management knowledge and practices collected across additional regions	Comprehensive farmers' cultural management practices from 4 farmers were gathered and served as our basis for IPM improvement.	July 2005	Most growers using up to 16 pesticides applications and no crop hygiene or other IPM practiced.
	Pest biology data	Collected pest population/damage on the five major insect pests and preliminary basis for chemical control.	July 2008	
	Data and recommendations on alternative control measures and pest specific chemicals to reduce reliance on broad spectrum chemicals.	Acquired data on the efficacy of alternative control measures.	2005-2007	
	Revised IPM and spray recommendations that incorporate project findings and farmer/spray operator perspectives.	Developed/improved IPM strategies: using pest monitoring, sticky and light traps and fruit fly lures also insecticide strips and crop hygiene.	July 2008	
	Feedback, extension materials and reports on Techno-demos and field.	Develop information education campaign materials; conduct capability building, technology and demonstrations.	Aug 2008 ongoing	

Objective 2: To obtain further knowledge on the ecology, behaviour, pheromones and control options for mango seed and pulp weevils

Aim: To improve control and detection of seed and pulp weevils.

no.	activity	outputs/ milestones	completion date	comments
2	Revised data on the distribution of pulp weevil on Palawan	Sampled areas of Palawan for the presence of MPW	July 2008	Combined with USDA surveys of Dr Hernani Golez
	Additional ecological and behavioural data on pulp	Acquire additional behavioural and ecological data on pulp weevil	July 2008	
	Updated literature information on seed weevil biology and control	Information packages prepared and meetings with farmer groups and extension personnel completed	Aug 2008	
	Data and recommendations on use of potential attractants for insect traps and other control options – pulp weevil	Acquired data and recommendations on use of potential attractants for insect traps and other control options	July 2008	
	Preliminary assessment data on X ray technologies for detecting pulp weevil	Acquired data on X-ray technologies for detecting pulp weevil	July 2008	

2.7 Key results and discussion

2.7.1 IPM Studies comparing IPM strategies versus farmers practice

Baseline data on the cultural management practices conducted by seven mango co-operators in Davao del Norte and Davao del Sur was carried out in October 2005. The data showed that all growers were using the same management practices. For dormant stage of the crop co-operators leave the farm unattended no weed and pests control employed. Field sanitation (under brushing) done once a year after flower development. Co-operators practice minor pruning or no pruning at all that some branches interloped and made the area humid and no aeration. On the nutrition aspect of the plant, co-operators were not able to analysed the soil for appropriate fertilizer recommendations, in Mamacao, Kapalong used general recommendations while in Kauswagan, Panabo City and two sites in Island Garden City of Samal no definite amount being applied just based on the availability of supply and not particular with the requirement of the plant. Application were done once a year only and during flowering stage no foliar fertilizer applied. Determination of timing for flower induction was based on visual observation on the maturation of the leaves. Two co-operators used calcium nitrate at the rate of 3-4 kilos per 200 litres water as flower inducer while the other two used potassium nitrate at the rate of 4 kilos per 200 litres of water.

For insect control, co-operators did not monitor the occurrence of pests and disease they just sprayed based on the set schedules and dependent on chemical control both for insect pests and disease incidence. In Mamacao, Kapalong co-operator sprayed 12 cycles done during 8, 14,21, 33,37, 42, 49, 50, 60,70, 90 and 100 days after flower induction. Kauswagan, Panabo City and Penaplata IGACOS practiced 13 cycles calendar spraying and for Babak IGACOS site average of 14 cycles and that the co-operators sprayed again if heavy down pour of rain comes after each spraying. Co-operators practice bagging at 60-65 DAFI with smaller size of ordinary newspaper. On the yield Mamacao area got an average yield of about 12.22kg/tree, Kauswagan 79.00 kg/tree, Penaplata 116.00 kg/tree and Babak 7.69 kg per tree respectively. Sorting was not practiced and price was based in all-in category, dictated by the buyers (Table 1).

Insect Pests Occurrence

In Mamacao, Kapalong farm it was observed and recorded that new flushes (7 days old) of mango were infested with Cecid fly or Gall midge (Procontarinia sp.) the same is true in Kauswagan, Panabo, and the two sites in Island Garden City of Samal. On the flowering stage of the crop it was found out that Mango leafhopper (Idieoscopus clypealis Leth.) infested the inflorescence, however, mango leafhopper was not observed in Kauswagan farm during the study, rather tip borer (Chlumetia transversa). Blossom thrips (Scirtothrips dorsalis) was recorded in four sites that infested also the flowers. On fruits, it was observed that mango seed borer (Noorda albizonalis), fruit fly (Bactrocera philippinensis sp.n.) and cecid fly were the three insect pests that damage the fruits in four study farms (Table 2).

Insect Pest Population and Damage

Cecid Fly

Based on the data gathered cecid fly (Figure 12) was one of the major insect pests that damage leaves of mango and this would be accounted by monitoring the number of blisters per leaf taken during 7, 14, 21 and older leaves in all designated sample trees in four experimental sites in Davao del Norte and is given in Table 3. Average number of blisters per leaf in Mamacao site showed no significant difference on the control methods, the same result was obtained in Kauswagan farm both from 7 days old leaves to older leaves however, it can be noted that as the leaves get older more blisters were found, this could be because control measures were not given during the dormant stage of the crop to maintain the insect population at the lower level.

In Penaplata and Babak sites, data showed significant difference on the different control methods used. IPM interventions got the lowest number of blisters per leaf of 7.05 in Penaplata and 3.15 in Babak as compared to farmer's practice having 10.86 and 4.55 respectively. This can be explained that chemical alone can not really suppress the insect population but it should be coupled with regular sanitation and pruning to make the microclimate unfavourable to the insect population build up not surpass economic injury level. Further, IPM focuses on just reducing or modifying the impact of pests to tolerable levels (Hegley, et al. 1993).

Mango Leafhopper

Table 4 presents the average number of mango leafhoppers per panicle of mango trees as affected by different control measures in four experimental sites taken from 7, 14, 21 and 30 days after flower induction. Analysis of variance showed significant difference in Mamacao, Penaplata and Babak sites. IPM and Farmer's Practice showed no significant difference among treatment means. It was noted that during 30 days after flower induction both control measures (IPM and Farmer's Practice) mango leafhopper populations were below the economic threshold level. On the other hand, mango trees without control measures succumb to high increase in population in all sites especially in Mamacao, Babak that contributed to no yield aside from unfavourable weather conditions during the conduct of the study. However, in Kauswagan site no mango leafhopper was recorded during the conduct of the study.

The result of the study conforms to the study of Mohyuddin and Mahmood (69) that adults of mango leafhopper suck the cell sap from inflorescence and flower buds. The infected flowers shrivel, turn brown and ultimately fall off, thereby affecting the yield adversely. During severe attack, the pest may destroy the entire crop. The peak population occurs when fruits are pea size. At post bloom stage, a population of two adult insect per inflorescence is enough to cause yield reduction. During feeding, leafhoppers excrete honeydew, upon which sooty moulds develops, interferes with photosynthesis and adversely affecting plant growth and yield. Affected inflorescence turn brown, become dehydrated and fruit set does not occur.

Blossom thrips

Table 5 presents the average number of thrips (Figure 14) per panicle as affected by different control measures in four mango farms. Analysis of variance (Appendix Table 5) showed no significant difference between IPM and farmer's practice in four farms and successfully minimizes the population as compared to the treatment 3 – no control. This result can be explained that the IPM and Farmers Practice showed the same degree of control measures to the blossom thrips.

Mango Seed Borer

The percent fruit damage caused by mango seedborer (Figure 15) is given in Table 6. Analysis of variance showed no significant difference in three farms of Mamacao, Kauswagan and Penaplata among the treatment means of IPM and farmer's practice while in Babak farm it showed highly significant having 7.89% and 24.55%. The result can be explained that during the last experiment biological control (Trichogramma sp.) was used in the experiment that some eggs of mango seedborer were parasitized by the wasps.

Fruit Fly

The percent damage of mango fruits brought about by mango fruit fly was taken from all the fruits drops and fruits examined during harvest. Among the two control measures tested, IPM interventions in Babak mango farm significantly gave the lowest fruit damage of 1.17% compared to farmer's practice 25.20% (Table 7, 1%DMRT). The result implies that application of growth pheromone (methyl eugenol) effectively control the population of male fruit fly that lessen the reproduction of the female applied at 45, 60, 75 and 90 days after flower induction. Studies showed that methyl eugenol is considered the most powerful male lure for oriental fruit flies. It has used successfully for control and eradication of B. dorsalis in Oahu (103), Tota Island (104), Okinawa, Kume, Miyako and Yeayama Islands (50) and has also been used for monitoring B. umbrosus (F.) in the Philippines (112). Fruit flies both species were controlled by mass trapping of males with methyl eugenol; and infestation were brought to sub-economic levels in Pakistan (69).

Cecid Fly on Fruits

Table 8 shows the percent mango fruit damage attributed by cecid fly in four mango farms in Davao del Norte. Apparently, the two insect control methods successfully controlled the cecid fly population and subsequent damage to the fruit. The result implies that a farmer can really reduce the number of spraying with the same degree of control measures not only in cecid fly but in other major insect pests of mango.

Percent fruit damage caused by seedborer, fruit fly and cecid fly

Table 9 presents the summary on the percent fruit damage caused by seedborer; fruit and cecid fly as affected by the different insect control methods. Data showed that among the three major insect pests on mango fruits seed borer was the major insect pest in Davao del Norte that causes 19.53% damage followed by mango fruit fly 11.00% and cecid fly contributed 3.47% damage. While on the different control measures, it was found out that integrated pest management having only 4.78% damage was better than calendar chemical spraying having 7.49% respectively. The result clearly revealed that integrated approach of controlling insect pests can be of advantage over the chemical alone or calendar spraying. According to Cunningham (1989) current mango pest management practices are affected not only by the domestic and export fruit market, but also by consumer attitude toward health concerns and the cosmetic appearance of the fruit. In general, mango pest management is largely dependent on the use of pesticides. Control of mango fruit pests by chemicals alone has been complicated, by development of pest resistance and resurgence and elevation of minor pests to major pest status. Costs of pest control have mounted and in some cases increasing amounts of pesticides are required to keep the large number of pest species under control.

Mango as an export fruit has a relatively high value, and the highest prices are paid for undamaged, high quality fruit. On the other hand, mangoes grown for domestic consumption in many tropical countries have low values. For these reasons, the economic thresholds of those pests which attack the fruit will be low for export fruit and quite high for fruit destined for internal consumption. The foundation of integrated pest management as presented by Flint and van den Bosch (1981) is based on sampling, economic thresholds and natural mortality in agroecosystems. Integration of improved strategies suited in each locality (selective pesticides, biological control, host plant resistance and pheromones and trapping devices) is an important strategy in sustainable agriculture.

Yield (kg/tree)

Table 10 presents the mean yield (kg/tree) of mango trees as affected by the different control measures for insect pests in four mango farms harvested 115, 104, and 110 days after flower induction. The analysis of variance (ANOVA) revealed a significant difference among treatment means. Treatments under integrated pest management interventions obtained the highest yield in four mango farms with an grand mean of 139.59 kilos per tree followed by farmer’s practice 50.77 kilos per tree. The result implies that a farmer can even have more profit in IPM approach, less exposure to chemicals and most of all to consumer’s health.

Cost and Return Analysis

The cost and return and income of the ten mango sample trees as affected by different insect pests control measures in four mango farms are presented in Table 10. Results revealed that mango trees subjected to Integrated Pests Management interventions the highest return of investment of 196.00% in Kauswagan and 132.00% in Penaplata as compared to farmer’s practice having 81.00% and 48% respectively. On the other hand the two farms located in Mamacao, Kapalong and Babak, IGACOS gave a negative ROI due to unfavorable conditions during the conduct of the study that causes heavy defoliation of the flowers during full bloom and fruit drops at fruit setting and fruit development. Further in Mamacao, disease incidence of scab and blossom blight affected greatly the flowers and fruits though fungicides application where done.

Weather

The monthly rainfall in Mamacao, Kapalong was higher during the conduct of the study (April – September 2006) which contributed much on the occurrence of diseases that contributed much to low production while in Kauswagan, Panabo City it was noted that during the conduct of the study (May – August 2006) was just sufficient favours to the growth and development of the flowers and fruits of mango thus getting better yield. In Penaplata, IGACOS it was noted that rainfall pattern during the fruiting season of the study August – November 2006 was favourable to crop thus higher yield was obtained. However, In Babak, IGACOS from September to January 2008 it was noted and recorded that heavy down pour of rain occurred especially during full bloom – October 2007 that reduced the pollinators and increase the occurrence of pests and diseases and fruit drops because of strong winds accompanying the rain (Figure 17). According to Naik et.al., (1943,1965,1966) cool temperature during inflorescence development contribute to the reduction in the number of perfect flowers and the increase in perfect flowers in later emerging season of the flowering stage correlates with the higher average temperature. Anthesis and dehiscence are delayed by low temperatures or overcast day (Singh et al. 1986).

Table 1: Baseline data on the cultural management practices done by the four co-operators in Davao del Norte before the start of the integrated pest management trial October 2005 – January 2007

Cultural Management Practices	Mamacao, Kapalong 2005 - 2006	Kauswagan, PanaboCity 2006	Penaplata, Island Garden City of Samal 2006	Babak, Island Garden City of Samal 2007-2008
1. Sanitation	Under brushing (once a year)	Under brushing (once a year)	Under brushing (twice a year)	Under brushing (twice a year)
2. Pruning	No Pruning	Minor Pruning	Minor Pruning	Minor Pruning
3. Fertilization	1 kg 14-14-14 / tree (once a year) No foliar application during Flower/fruit development No soil analysis -	No definite amount (once a year) No soil analysis – general recommendation No foliar spray during flower & fruit development	No definite amount (once a year) No soil analysis – general recommendation No foliar spray during flower & fruit development	No definite amount (once a year) No soil analysis No foliar spray during flower& fruit development
4. Flower Induction	Calcium nitrate 6 kg / 200 litres, 7 DAFI – 2nd supply 3 kg / 200 H2O Visual observation on leaves	Potassium nitrate 4 kg / 200 litres H2O Visual observation on leaves	Potassium nitrate 4 kg / 200 litres H2O Visual observation on leaves	Calcium nitrate 4 kg / 200 litres H2O Visual observation on leaves
5. Insect pests control	- During dormant stage no pests control - During flowering/fruiting stage - 12 cycles spraying done @ 8, 14, 21, 33, 37, 42, 49, 50, 60, 70, 80, 90, 100 DAFI and follow-up spray if rains follows after each spraying - Bagging 60-65 DAFI	-During dormant stage no pest control -During flowering/fruiting stage – 13 cycles of insecticides spraying done @ during flower induction, 8, 15, 21, 28, 35, 42, 49, 56, 63, 70, 77, 84, 91 DAFI and follow-up spray if rain fall after each spraying -Bagging 60-65 DAFI	During dormant stage no pests control During flowering/fruiting stage – 13 cycles of insecticides spray done @ 7, 12, 18, 23, 32, 38, 45, 52, 59, 70, 80,90, 100 DAFI and follow-up spray if rain fall after each spraying - Bagging - 60-65 DAFI	During dormant no pests control During flowering/fruit stage – 14 cycles of insecticides spray done @ 0, 10, 17, 23, 28, 33, 38, 42, 48, 55, 61, 70, 80, 91 And follow-up spray if rain fall after each spraying - Bagging 60-65 DAFI
6. Harvesting	114 days	104 days	108 days	110 days
7. Sorting/ packaging	No sorting	No sorting	No sorting	No sorting
8. Marketing/ price	All-in lowest price (P11.00)	All – in lowest price (P 15.00)	All-in lowest price P16.00	All-in lowest price P16.00
9. Maintenance after harvest	Leave the plant, no maintenance such as pruning	Leave the plant, no maintenance such as pruning	Leave the plant, no maintenance such as pruning	Leave the plant, no maintenance such as pruning

Table 2. Major insect pests of mango identified in four mango farms in Davao del Norte from October to January 2008.

Sites	Pests		
	Leaves	Flowers	Fruits

1. Mamacao, Kapalong	Cecid fly	Mango leafhopper Blossom thrips	Cecid fly Mango seed borer Fruit fly
2. Kauswagan, Panabo City	Cecid fly	Blossom thrips	Cecid fly Mango seed borer Fruit fly
3. Penaplata, Island Garden City of Samal	Cecid fly	Mango leafhopper Blossom thrips	Cecid fly Mango seed borer Fruit fly
4. Babak, Island Garden City of Samal	Cecid fly	Mango leafhopper Blossom thrips	Cecid fly Mango seed borer Fruit fly

Table 3. Average number of blisters per leaf of mango caused by cecid fly as affected by different control measures in four mango farms in Davao del Norte from 2005 – 2007 observations.

Leaves Maturity (days)					
Treatments	**7**	**14**	**21**	**Old**	**MEAN**
Mamacao site					
IPM	3.8a	2.9a	2.8b	7.2a	4.17
FP	3.7a	3.0a	3.3ab	7.8a	4.45
Control	3.5a	3.5a	3.8a	7.9a	4.67
MEAN	**3.66**	**3.13**	**3.30**	**7.63**	
Kauswagan site					
IPM	3.3a	3.2a	3.0a	5.3a	3.70
FP	3.2a	3.0a	2.9a	5.9a	3.75
Control	3.5a	3.4a	3.2a	5.5a	3.90
MEAN	**1.67**	**3.20**	**3.03**	**5.57**	
Penaplata site					
IPM	2.20b	7.13a	3.20	15.70b	7.05
FP	3.96a	2.00b	1.80	35.70a	10.86
Control	2.16b	0.93c	1.20	2.46c	1.69
MEAN	**2.77**	**3.35**	**2.07**	**17.95**	
Babak site					
IPM	6.10a	1.40b	3.00b	2.10a	3.15
FP	6.40a	4.30a	4.20a	3.30b	4.55
Control	5.20b	4.20a	4.60a	3.90b	4.97
MEAN	5.90	3.30	3.93	3.10	

Means within a column having common letters are not significantly different at 5% level by DMRT.

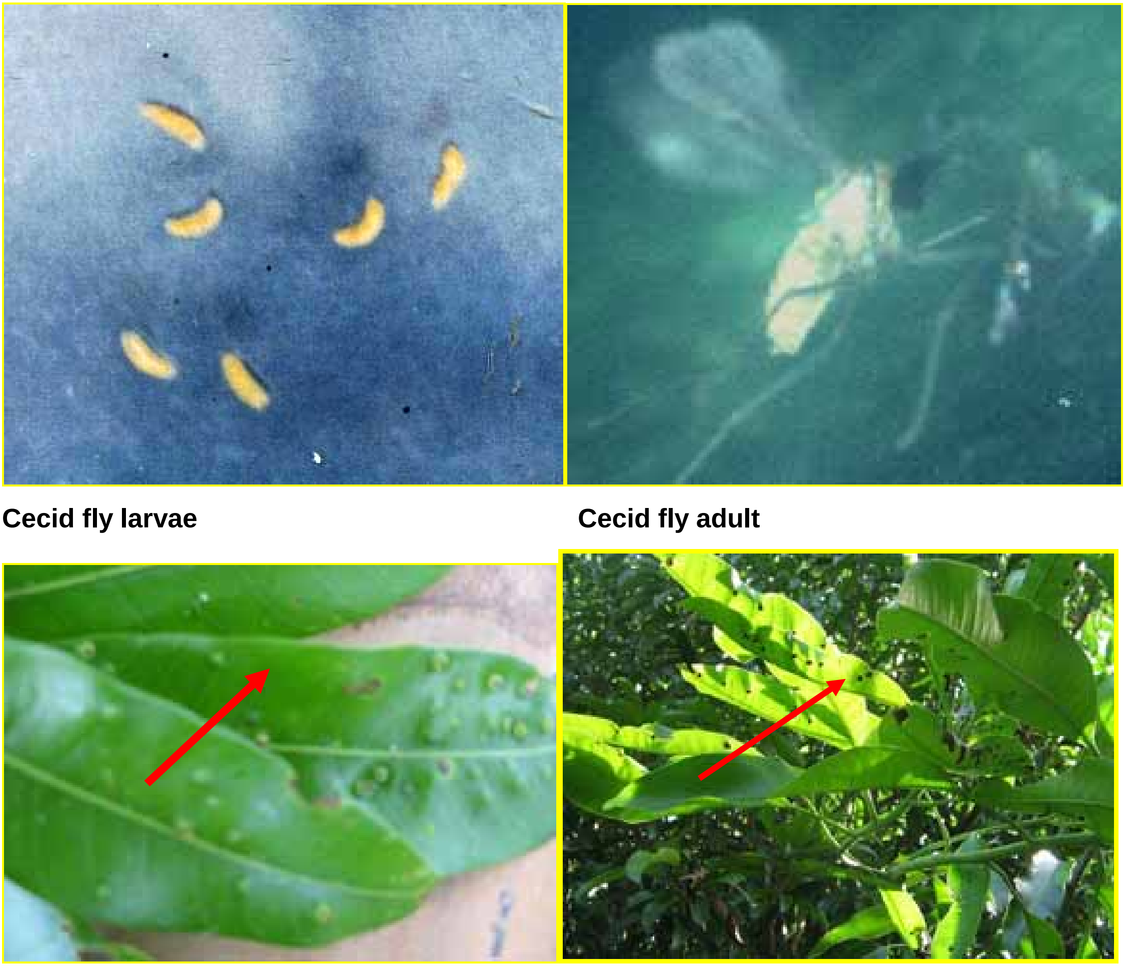

Figure 12. Cecid fly larvae, adult and damage on leaves and fruit.

Table 4. Average number of mango leafhoppers per panicle as affected by different control measures in four mango farms in Davao del Norte during 2005 – 2008 fruiting season.

Leaves Maturity (days)					
Treatments	**7**	**14**	**21**	**30**	**MEAN**
Mamacao site					
IPM	1.00a	2.00b	0.06b	0b	0.76
FP	1.20a	2.20b	1.00b	0b	1.10
Control	1.50a	3.00a	4.20a	5.30a	3.50
MEAN	**1.23**	**2.40**	**1.75**	**1.77**	
Penaplata site					
IPM	0	0	3.00b	2.00b	1.25
FP	0	3.33b	0.28c	1.65b	1.73
Control	0	11.45a	14.56a	15.20a	10.30
MEAN	0	4.93	2.07	6.28	
Babak site					
IPM	2.30b	1.40b	0.43b	0.28b	1.10
FP	2.50b	0.85b	0.38b	0.41b	1.04
Control	4.00a	3.40a	1.70a	5.94a	3.76
MEAN	5.90	3.30	3.93	3.10	

Means within a column having common letter are not significantly different at 5% level by DMRT.

Mango leafhopper nymphs **Mango leafhopper adults**

Figure 13. Mango leafhopper, nymphs and adults and its damage on the flowers.

Table 5. Average number of thrips per panicle as affected by different control measures in four mango farms in Davao del Norte during 2005-2008 fruiting season

Treatments	Sites				Means
	Mamacao	Kauswagan	Penaplata	Babak	
IPM	5.80b	0. 50b	0.70b	0.80b	1.84b
FP	8.10b	1.10b	1.50b	1.31b	3.00b
Control	25.80a	13.50a	15.10a	19.48a	18.47a
MEAN	13.23a	5.03b	5.77b	7.20b	

Means within a column having common letter are not significantly different at 5% level by DMRT.

Figure 14. Picture of blossom thrips and the withered flowers brought by the pest.

Table 6. Percent fruit damage caused by mango seedborer as affected by different control measures in four mango farms in Davao del Norte during 2005-2008 fruiting season.

Treatments	Sites				Mean
	Mamacao	Kauswagan	Penaplata	Babak	
IPM	16.11 a	1.87 b	7.18b	7.89 b	8.26 b
FP	16.04 a	1.47 b	3.33 b	24.55 a	11.35 b
Control	0.00	48.98 a	29.00 a	0.00	38.99a
MEAN	13.23 a	5.03 b	5.77 b	7.20 b	

Means within a column having common letter are not significantly different at 5% level by DMRT.

Figure 15. Mango seed borer, larva, adult and its damage on fruit.

Table 7. Percent fruit damage caused by mango fruit fly as affected by different control measures in four mango farms in Davao del Norte during 2005-2008 fruiting season.

Treatments	Sites				Mean
	Mamacao	Kauswagan	Penaplata	Babak	
IPM	13.98 a	0.85 b	5.33b	1.17 b	5.33 b
FP	10.71 b	0.74 b	3.22 b	25.20 a	9.97 b
Control	0.00	43.29 a	27.50 a	0.00	17.70a
MEAN	8.23 b	14.96 a	12.02 a	13.18 a	

Means within a column having common letter are not significantly different at 5% level by DMRT.

Figure 16. Mango fruit fly its larvae, adult and damage on fruit.

Table 8. Percent fruit damage caused by cecid fly as affected by different control measures in four mango farms in Davao del Norte during 2005-2008 fruiting season.

Treatments	Sites			Mean
	Mamacao	Penaplata	Babak	
IPM	0.16 a	1.66b	0.41 a	0.74 b
FP	0.10 a	3.12b	0.57 a	1.26b
Control	0.00	25.50 a	0.00 b	8.50a
MEAN	0.09 a	10.09 b	0.33 a	

Means within a column having common letter are not significantly different at 5% level by DMRT.

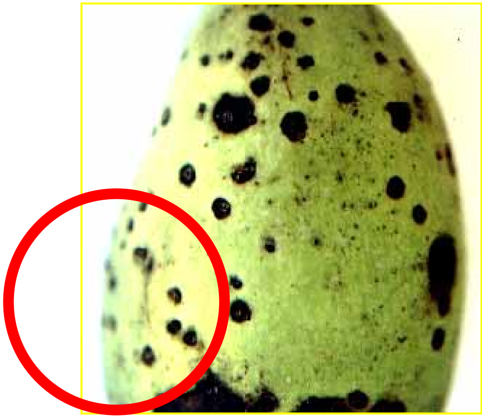

Figure 17. Typical picture of a mango fruit damaged by cecid fly with round black blisters

Table 9. Summary table on the percentage fruit damage caused by three insect pests (seedborer, fruit fly and cecid fly) on mango fruits in four mango farms during 2005-2008 fruiting season.

Insect pests	IPM	Farmer's Practice	Control	Total
Mango seed borer	8.26	11.35	38.99	58.60
Mango fruit fly	5.33	9.97	17.70	33.00
Cecid fly	0.74	1.16	8.50	10.40
Total	14.33	22.48	65.19	

Table 10. Average yield (kg) per tree 104-115 days after flower induction as affected by different control measures in four mango farms in Davao del Norte during 2005-2008 fruiting season.

Treatments	Mamacao	Kauswagan	Penaplata	Babak	MEAN
IPM	33.35 a	218.91a	276.40a	29.69 a	139.59 a
FP	12.35 b	201.95 a	191.20 b	11.90 b	50.77 b
Control	0.00 c	120.00 b	7.33c	0.00 c	31.83 c
MEAN	15.23 b	180.29 a	158.31 a	13.86 b	

Means within a column having common letter are not significantly different at 5% level by DMRT.

Table 11. Cost and return analysis as affected by different control measures in four mango farms with 10 sample trees per treatment in Davao del Norte during 2005-2008 fruiting season.

	IPM	FP	Control
A. Mamacao -2005-06			
Production cost	13,218	25,637	3,383
Yield (kg)	333.5	123.80	0
Gross income @ P24/kg	8,004	2,971.20	0
Net income	(5,214)	(22,665.8)	(3,383)
Return of investment	-	-	-
B. Kauswagan - 2006			
Production cost	17,773	26,769	6,705
Yield (kg)	2,189.10	2,019.5	360
Gross income @ P24/kg	52,538.40	48,468	8,640
Net income	34,765.40	21,699	1,935
Return of investment	1.96	0.81	0.28
C. Penaplata - 2006			
Production cost	28,597	31,082	3,760
Yield (kg)	2,764	1,912	22
Gross income @ P24/kg	66,336	45,888	538
Net income	37,739	14,806	(3,222)
Return of investment	1.32	0.48	-
D. Babak – 2007 -08			
Production cost	12,248	18,905	2,608
Yield (kg)	296.90	119.0	0
Gross income @ P24/kg	7,125.60	2,856	0
Net income	(5,122.40)	(16,049)	(2,608)
Return of investment	-	-	-

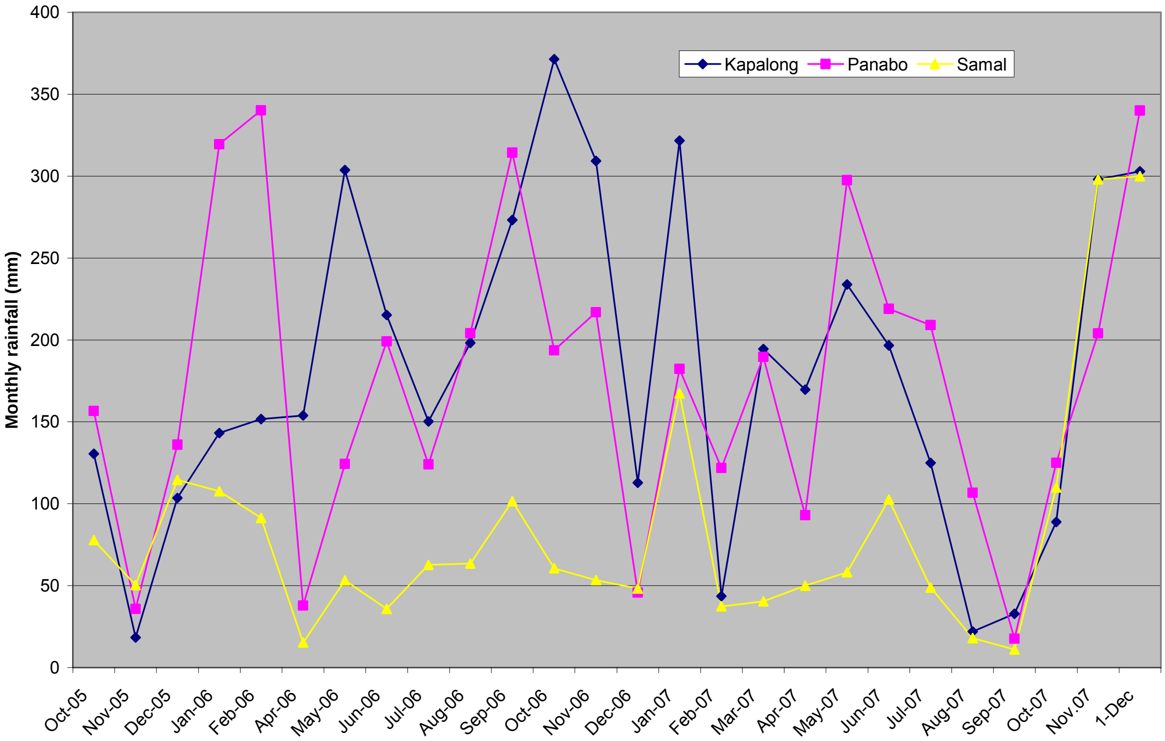

Figure 18. Graph showing the monthly rainfall (mm) in Kapalong, Panabo City and Island Garden City of Samal 2005-2007.

Davao Del Sur

Hartikka mango orchard (May to September 2006) showed that IPM experimental trees have the least number of thrips (14.45), mango leafhopper (1.35), cecid fly (7.27) and scale insect (0.24) but with highest number of biological agents (31.51). On the contrary, farmer's practice had the highest number of thrips (27.68), mango leafhopper (2.56), cecid fly (9.42) and scale insect (0.35) with the lowest number of biological agents (16.50). Control trees did not significantly vary in insect pest and biological agent counts on either IPM or FP. This result implied that least insecticide applied on IPM trees during the cropping period allows parasites and predators to multiply and help regulate insect pest population at a lower level. The variability of insect pests and biological agents on control trees could be attributed to spray drift during insecticide operation, especially during windy days. Population mean count of the most important insect pests of mango and its biological agents in Davao Del Sur are presented in Table 12.

The same trend on pests and biological agent population was observed at Navales backyard mango farm (June to October 2006). Mean thrips count was low on 1PM trees (3.11) comparable with control trees (2.5) but significantly lower to farmers practice (4.82). The same population trend was also observed on mango leafhopper (1.35) cecid fly (7.12), with the highest number of biological agents (57.25) recorded.

Comparing the pest population density between mango orchard and backyard mango farm, the former have higher pest population count except the number of biological agents recorded. This result may have attributed to bigger size and higher number of trees on orchard compared to backyard mango farm. In the succeeding years (2007-2008), the project site was transferred to Crisologo mango orchard farm to induce more small trees, control tree free of pest damage charge, and the availability of manpower during spray operation. The same procedure was followed except fertilization was based on soil analysis. Findings revealed similar population trend of insect pest and biological agents. Still, 1PM trees got the lowest number of insect pest population with highest population of biological agents compared to farmer's practice. Variable result obtained from control trees still attributed to spray drift during pesticide application. On the contrary, biological agents were high on 1PM experimental trees but significantly lower on farmers practice. To summarize insect pests and biological agents population trend for a period of three years, IPM experimental trees were consistently and significantly lower in insect pests and higher in biological agent populations compared to farmers practice. These findings implied that IPM trees receiving lower number of pesticide application allowed natural enemies to multiply to limit the population of insect pest at lower level. However, there were cases on the variability of pest population count on control trees that could have been the toxic effect of pesticide drift during spray operations especially on windy days. Moreover, the higher number of predator and parasite count on 1PM and control trees were due to the least number of pesticide sprayings and spared them from exposure to toxic substance. The action of biological agents in regulating insect pest population resulted to low insect pest population on IPM experimental trees in all sites. Farmers practice experimental trees applied as much as 8-12 times pesticide sprays per cropping season affected the population density of biological agents, hence, unable to regulate insect pest at lower level.

Table 12. Occurrence of common mango insect pests and its biological agents per site. Davao del Sur. May 2006 February 2008.

Site	Treatment	Insect pest & biological agents of mango				
		Thrips	Leafhopper	Cecid fly	Scale insect	Bio-agents or NEs
Hart May-Sept. '06	IPM	14.45b	1.35b	7.27 b	0.24 b	31.51 a
	FP	27.68a	2.56a	9.42 a	0.35 a	16.50 c
	C	15.49b	2.23 a	8.77 ab	0.36 a	19.75 b
Cris1 June- Oct.'07	IPM	15.11c	1.90 c	5.94 c	0.17 b	31.00 a
	FP	21.42 a	3.05 a	6.92 b	0.23 a	17.00 c
	C	19.47 b	2.30 b	7.0 a	0.23 a	24.00 b
Cris2 Oct.'07- Feb.'08	IPM	10.12 b	1.3 b	4.14 c	0.13 c	23.50 a
	FP	19.36 a	3.04 a	6.7 a	0.22 a	12.00 c
	C	18.20 a	2.97 a	6.33 b	0.19 b	19.50 b
Nav June to Oct.. '06.	IPM	3.11 b	1.35 b	7.12 b	0.43 a	57.25 a
	FP	4.82 a	2.53 a	8.59 a	0.39 b	33.00 c
	C	2.5 c	0.96 c	7.97 b	0.23 c	38.00 b

Based on the economic analysis (Table 13), IPM experimental trees in all sites have a return on investment (ROI) ranging from 19.45% to 35.89% while FP experimental trees have a negative ROI except Hartikka Mango Orchard with 15.15%. Production cost on FP was spent largely to chemicals. These negative ROI obtained from FP was primarily due to higher farm input used. Control trees rarely developed fruits until harvest due to pest attacked at early stage implying that mango production is dependent on pesticide application. Export quality of fruits on both IPM and FP did not vary despite higher number of spray application on the former indicating that need-based pesticide application could produced as much as quality export on FP. Further, both treatments used bagging because mango growers were required by buyers to do so. Likewise, control trees did not produced export quality fruit due to zero pesticide spray, indicating the dependency of mango production to pesticide control.

Table 13. Yield Data/Economic Analysis Differences Per Site. Davao del Sur. May 2002 to February 2008.

Site	Treatment	Yield parameters				
		Total yield (kg)	Prod'n Cost (P)	Gross Income (P)	Net Income (P)	ROI
Hart. June-Oct. '06	IPM (9 Trees)	1,499.94 kg 170KG	P25,386.75 P299.75	P34,498.62 P3,910.00	P9,111.87 P5,086.75	35.89% 20.74%
	FP(9Trees)	1,329.94 kg	P25,087.00	P30,588.62	P4,025.12	15.15%
	C (3)	50 kg	P1,623.75	P 1,150.00	(P473.75)	0
Cris1 June- Oct.'07	IPM (10)	404 kg 117.KG	P7,182.24 (P3,559.36)	P9.696.00 P2,808.00	P2,513.76	34.9%
	FP (10)	287kg	P10,741.60	P6,888.00	(P3,853.60)	0
	C (3)	15.30kg	P1,148.99	P110.16	(P1,038.3)	0
Cris2 Oct.'07- Feb.'08	IPM (10)	202kg 15.0KG	P5,415.91 (P4,241.56)	P6,464.00 P480.00	P1,048.09	19.45%
	FP (10)	187.0kg	P9,657.47	P5,984.00	(P3,673.47)	0
	C (3)	4.59kg	P781.76	P146.88	(P634.88)	0
Nav May-Sept. '06.	IPM (9Trees)	331.92 kg 78.92 KG	P7,580.32 P1,277.93	P8,629.92 P2,051.92	P1,614.24	23%
	FP(9Trees)	253.0 kg	P6,302.39	P6,578.0	(P2,509.43)	0
	C (3)	8.49 kg	P647.52	P220.74	(P709.26)	0

2.7.2 Mango pulp weevil studies

Volatiles attractive to the mango pulp weevil

Volatiles from male and female weevils, frass and green mango fruits were adsorbed in Tenax AG and extracted by Soxhlet in n-pentane. Olfactory attraction of weevils was investigated by behavioural bioassays for attractancy. When crude extracts of weevils, frass and green mango fruits were presented to starved weevils (male or female) in a Y-tube bioassay, the weevils showed definite responses. The fruit was most attractive (63.3%) at 5, 7 and 8 fruit equivalents. The highest attraction (73.3%) was found from virgin female weevils to mated male frass. About 24 volatile chemical components from mated male frass were identified by gas chromatography – mass spectrometry (GC-MS). Bioassays using standard chemicals are being conducted to identify the key component from mated male weevil frass that is attractive to the female weevil. The 73% attraction of virgin female weevils to mated male frass is higher than the previously reported attraction of mango pulp weevils to mango floral volatiles (70%). This finding provides the first evidence of female weevil attraction to compounds in mango pulp weevil males.

Result of GC-MS analysis shows 24 components from the frass volatiles of mated male weevils These components consist of hydrocarbons, carboxylic acids, aldehydes, ketones and alcohol. The major component is Hexane, 2,5-Dimethyl (22.90%). Acetic acid which is a component of the mango flower found attractive to the mango pulp weevil (De Jesus et al, 2004) is also present in frass and is the second highest component (17.77%). In the mango flower acetic acid was present only at a low amount (0.06% relative abundance).

Bioassays using standard chemicals of the mated male frass components show that acetic acid is most attractive (73.3%) This 73.3% attraction of virgin female weevils to acetic acid is the same as its attraction to mated male frass. This finding is important because acetic acid could be used as the key component for testing of bait traps for future experiments. Furthermore the use of single component is more practical in field applications compared to blends of components.

Behavioural study

Field studies showed that weevils stay on branches of mango trees and that removal of 25% diameter of the tree canopy is important to expose the weevils to sunlight to help reduce natural field infestations.

Field control of pulp weevil

Our IPM work plan has further reduced the number of spray applications to 5 compared to the farmer's 9 spray applications in the previous season. This IPM work plan is a modification of the work plan by Medina et al, 2005 that used 7 spray applications. Physical control (bagging of fruits) was incorporated into the IPM work plan and this has enabled the reduction spray applications to 5 times only.

Distribution of Pulp Weevil in Palawan

The number of mango trees targeted for Region IVB was 140,952. Of these a total of 145,287 fruits have been collected and dissected giving more than 100% accomplishment. Based on the data collected not a single specimen of the weevil (mango pulp weevil/ seed weevil) was found from the fruits examined and dissected.

Table 14. Integrated pest management (IPM) program for mango pulp weevil formulated for New Panay, Sitio Maasin, Brooke's Point, Palawan.

DAFI	Crop Phenology	IPM Strategy			
		Cultural Control	Physical Control	Pest Monitoring	Chemical Control
1		Open-centre pruning Sanitary pruning Field sanitation Brush weeding			Cypermethrin (Bushwack) applied at the trunk
7	Budbreak	Debris removal			
10				√	
11	Panicle elongation	Watering			Cypermethrin (Bushwack) applied at tree canopy
15		Debris removal		√	
18					Actara + 18-18-18 foliar fertilizer + Score
19				√	
21		Debris removal		√	
24	Full bloom	Watering			
25				√	
36	Fruit set	Debris removal			Pyrometrozine (Chess)
39				√	
43				√	
50				√	cypermethrin + Score + 18-18-18 foliar fertilizer
56	Fruit development	Brush weeding Debris removal Fallen fruits removal	Bagging		
72		Debris removal Fallen fruits removal			
100		Debris removal Fallen fruits removal			

Table 15. Farmer's crop protection practice in New Panay, Sitio Maasin, Brooke's Point, Palawan.

DAFI	Crop Phenology	Crop Protection Practice
7	Budbreak	cypermethrin
11	Panicle elongation	
14		cypermethrin
21		imidacloprid
24	Full bloom	
36	Fruit set	
56	Fruit development	cypermethrin
63		carbaryl
70		cypernethrin + copper oxychloride
77		cypermethrin
91		cypermethrin
98		cypermethrin

Table 16 Chemical composition of frass volatiles of mated male pulp weevils.

Component	Relative Abundance (%)
Hexane, 2,5-Dimethyl	22.90
Heptane, 2,4-Dimethyl	12.17
Octane, 4-Methyl	10.06
Octane, 2,3,7-Trimethyl	2.28
Dodecane, 4,6-Dimethyl	0.80
Eicosane, 7-Hexyl	3.63
Pentacosane	3.06
Undecane, 4,7-Dimethyl	4.06
Decane, 2,4-Dimethyl	3.64
1-Heptanol, 2-Propyl	0.77
Benzene, 1,2-Dimethyl	2.46
Dodecane, 2,7,10-Trimethyl	1.78
Pentadecane	0.60
Acetic Acid	17.77
1-Decanol, 2-Ethyl	0.51
2-Furaldehyde	0.07
Benzaldehyde	0.73
Butanoic Acid	0.53
Acetophenone	1.46
Napthalene	3.21
Hexanoic Acid	0.50
Phenol	1.26
Octanoic Acid	0.45
1,2-Benzenedicarboxylic Acid Diisonyl Ester	5.3

Table 17. Number of fruits examined and infestation of mango pulp weevil/mango seed weevil in Region IVB (May 2007)*.

Province	Target no. of fruits to be examined**	No. of fruits collected and dissected	Mango pulp weevil	Mango seed weevil
Oriental Mindoro	65,508	65,508	0	0
Occidental Mindoro	16,392	16,524	0	0
Marinduque	15,780	17,113	0	0
Romblon	21,888	23,184	0	0
Palawan	21,384	22,958	0	0
Total	140,952	145,287	0	0

** Source: Golez, H.G. 2007 Midyear Report for USDA Project- National survey of the mango pulp/seed weevils in the Philippines. ** Based on 12 fruits sampled per tree of the 5% of total flowering trees in the province.*

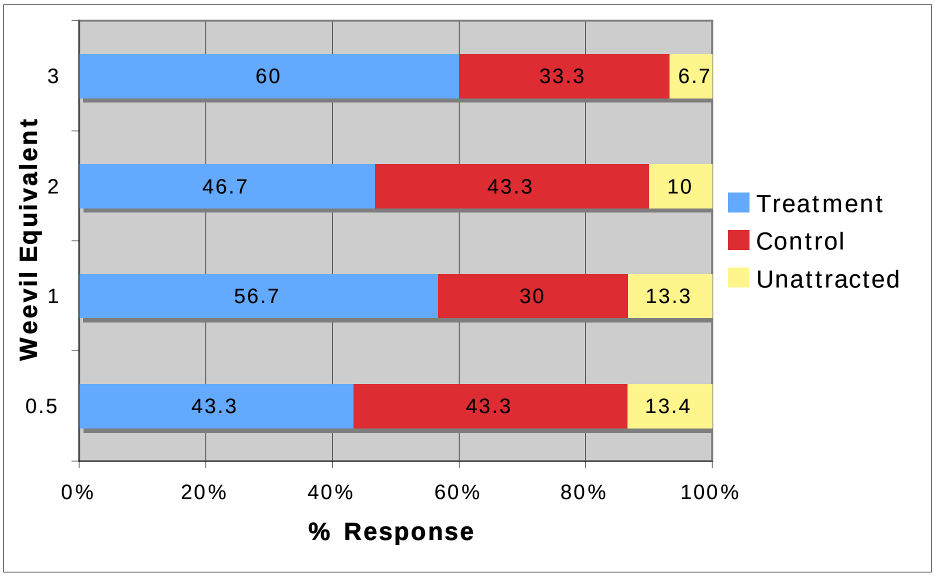

Fig 19. Response of virgin male weevils to crude extracts collected from mated female weevils in a Y-tube bioassay. X2 test, *indicates a significant preference for that treatment (P<0.05); the absence of asterisks indicate no preference. The number of weevils tested was 30 for all treatments.

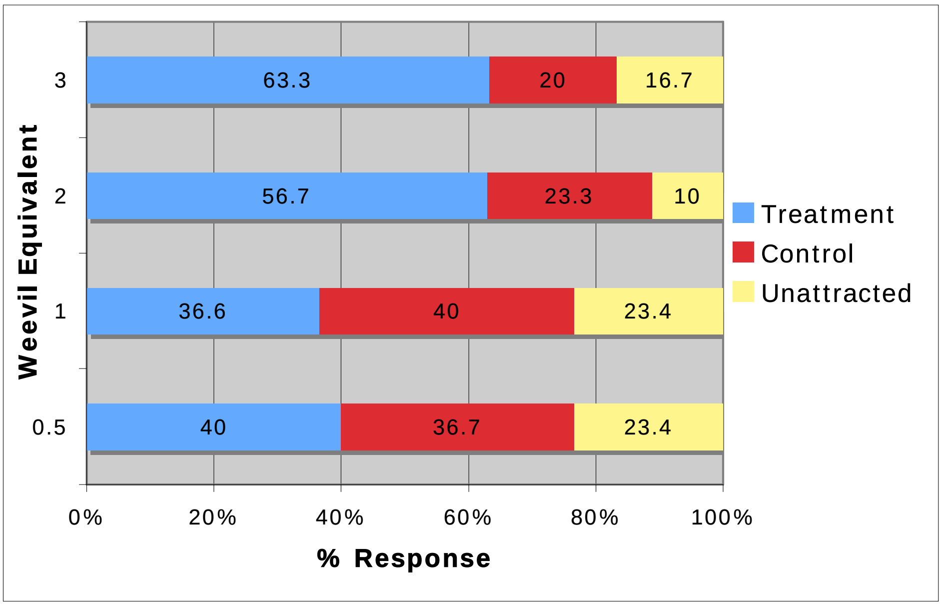

Fig. 20. Response of virgin male weevils to crude extracts collected from virgin female weevils in a Y-tube bioassay. X2 test, *indicates a significant preference for that treatment (P<0.05); the absence of asterisks indicate no preference. The number of weevils tested was 30 for all treatments.

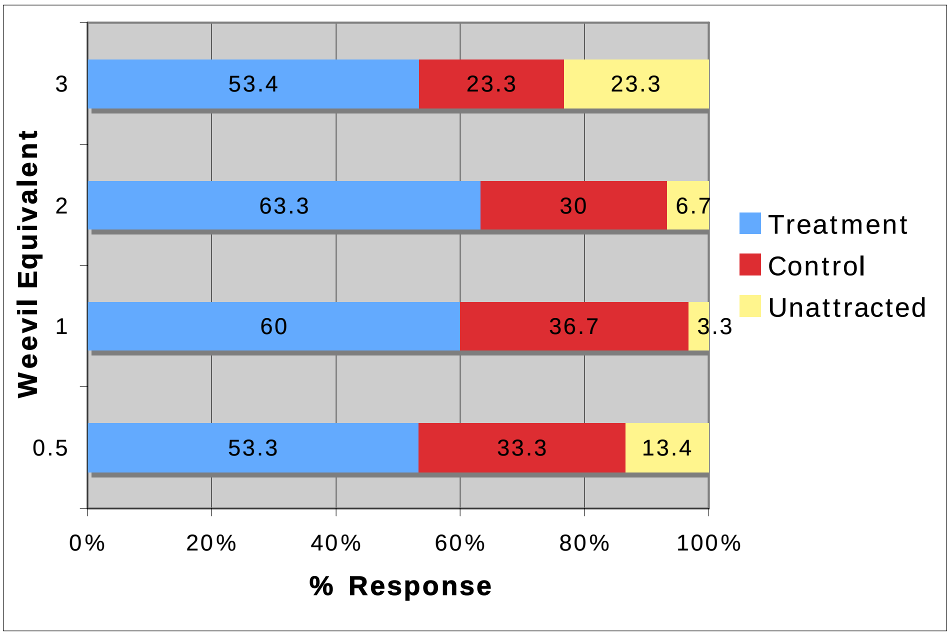

Fig. 21. Response of virgin female weevils to crude extracts collected from mated male weevils in a Y-tube bioassay. X2 test, *indicates a significant preference for that treatment (P<0.05); the absence of asterisks indicate no preference. The number of weevils tested was 30 for all treatments.

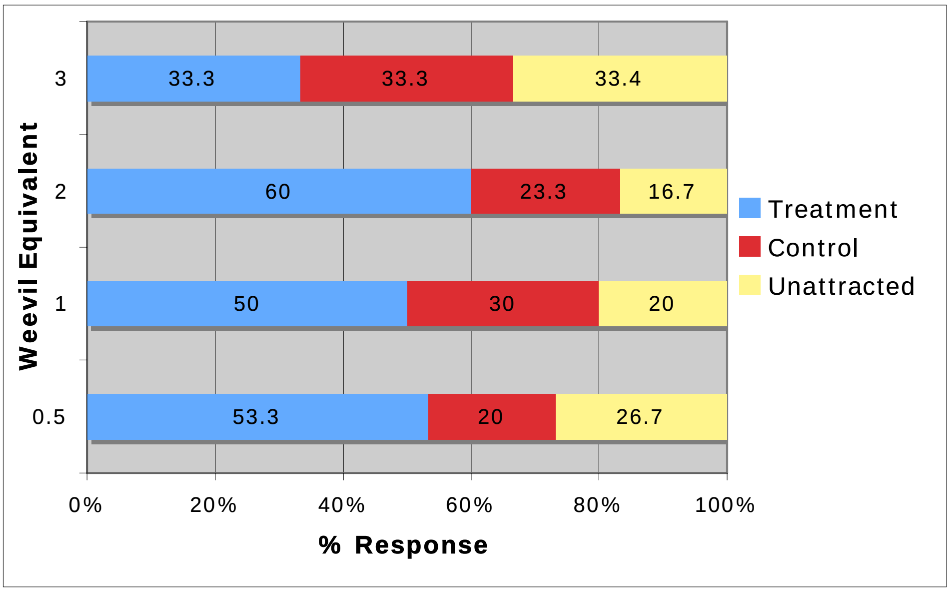

Fig. 22. Response of virgin female weevils to crude extracts collected from virgin male weevils in a Y-tube bioassay. X2 test, *indicates a significant preference for that treatment (P<0.05); the absence of asterisks indicate no preference. The number of weevils tested was 30 for all treatments.

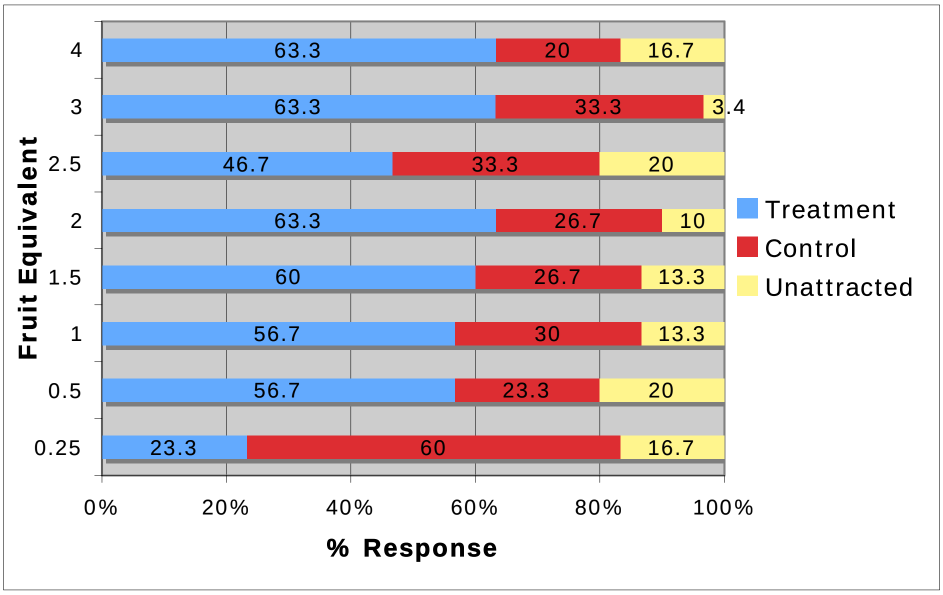

Fig. 23. Response of virgin female weevils to crude extracts collected from 70-day-old green mango fruits in a Y-tube bioassay. X2 test, *indicates a significant preference for that treatment (P<0.05); the absence of asterisks indicate no preference. The number of weevils tested was 30 for all treatments.

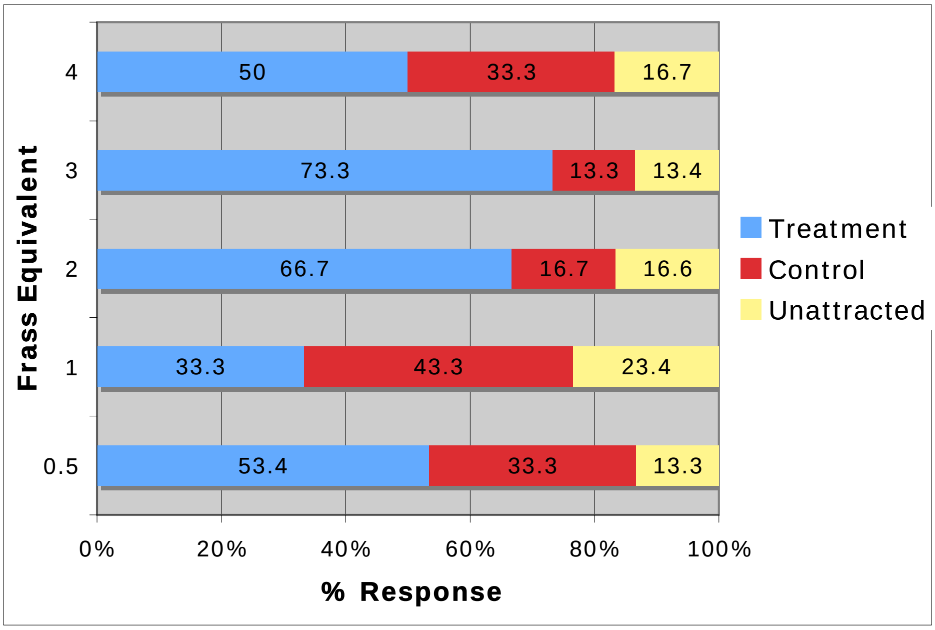

Fig. 24. Response of virgin female weevils to crude extracts collected from frass of mated male weevils in a Y-tube bioassay. X2 test, *indicates a significant preference for that treatment (P<0.05); the absence of asterisks indicate no preference. The number of weevils tested was 30 for all treatments.

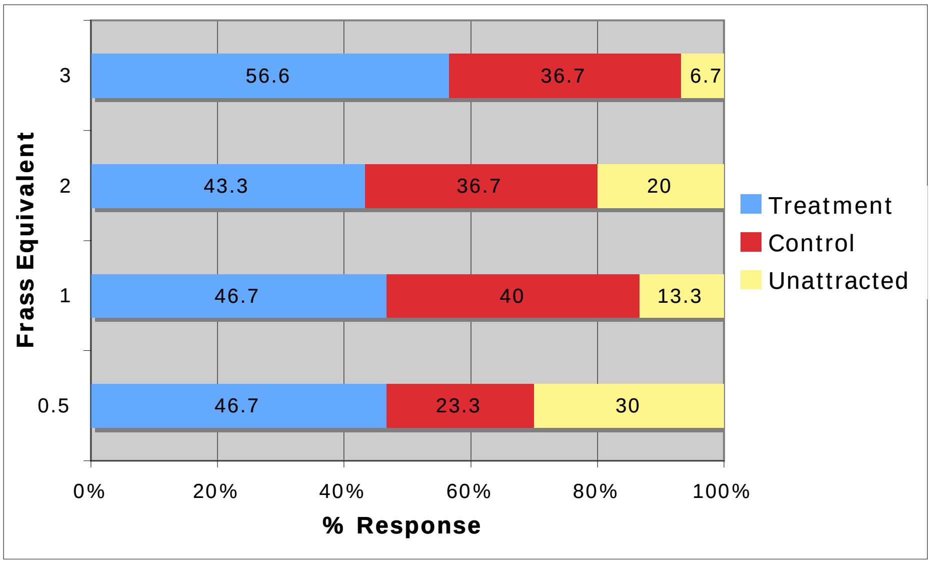

Fig. 25. Response of virgin female weevils to crude extracts collected from frass of virgin male weevils in a Y-tube bioassay. X2 test, *indicates a significant preference for that treatment (P<0.05); the absence of asterisks indicates no preference. The number of weevils tested was 30 for all treatments.

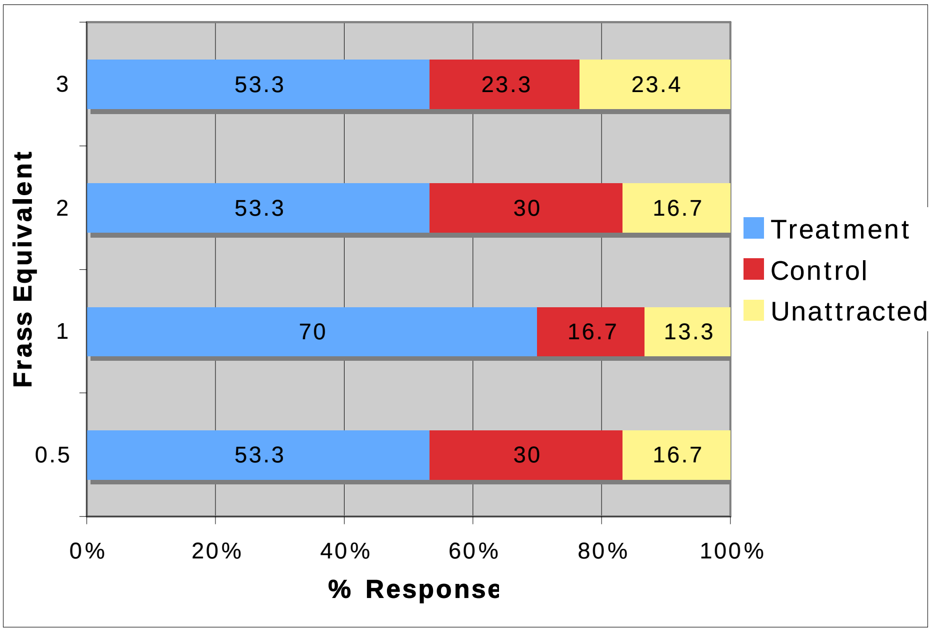

Fig. 26. Response of virgin male weevils to crude extracts collected from frass of mated female weevils in a Y-tube bioassay. X2 test, *indicates a significant preference for that treatment (P<0.05); the absence of asterisks indicate no preference. The number of weevils tested was 30 for all treatments.

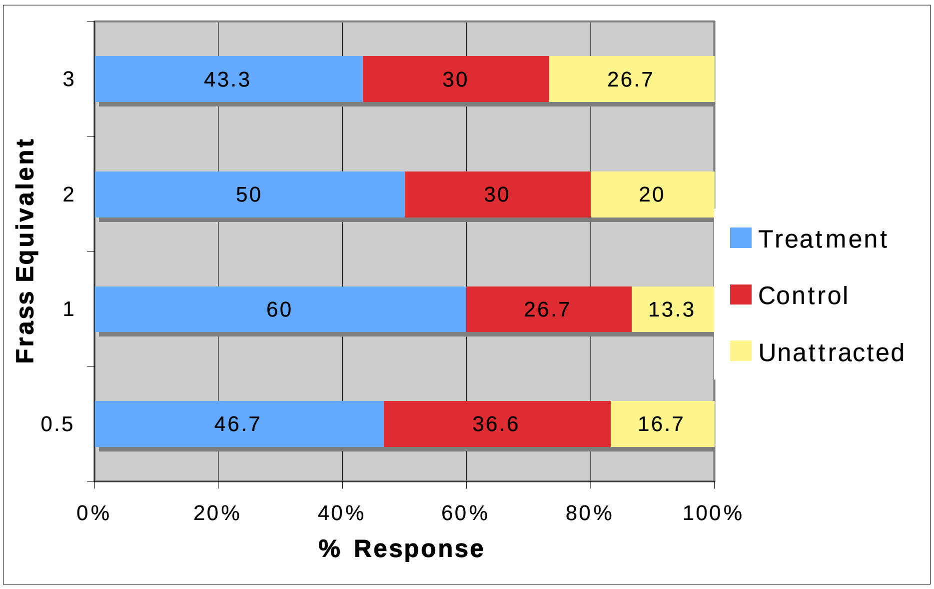

Fig. 27. Response of virgin male weevils to crude extracts collected from frass of virgin female weevils in a Y-tube bioassay. X2 test, *indicates a significant preference for that treatment (P<0.05); the absence of asterisks indicate no preference. The number of weevils tested was 30 for all treatments.

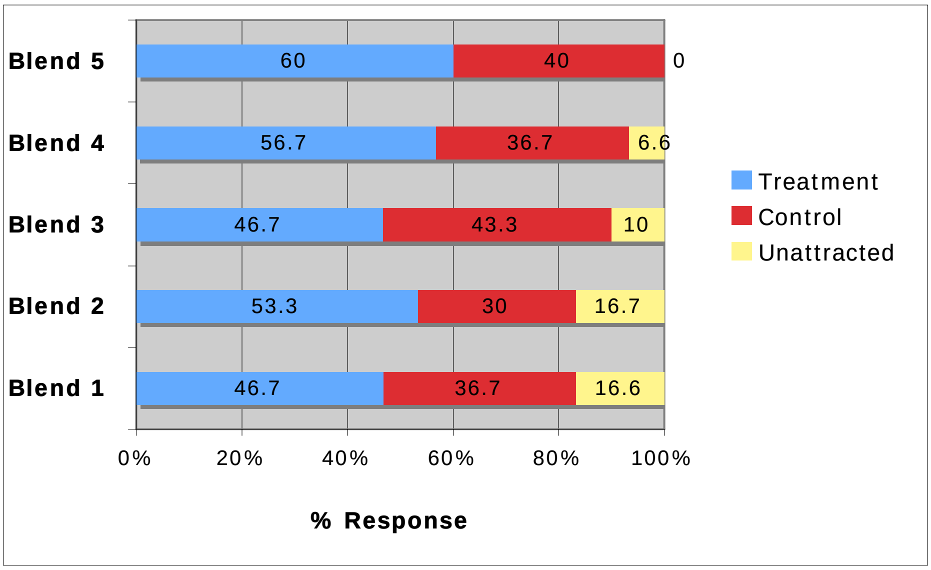

Fig. 28. Response of virgin female weevils to blends of crude extracts collected from frass of mated male weevils and mango flowers in a Y-tube bioassay. X2 test, *indicates a significant preference for that treatment (P<0.05); the absence of asterisks indicate no preference. The number of weevils tested was 30 for all treatments.

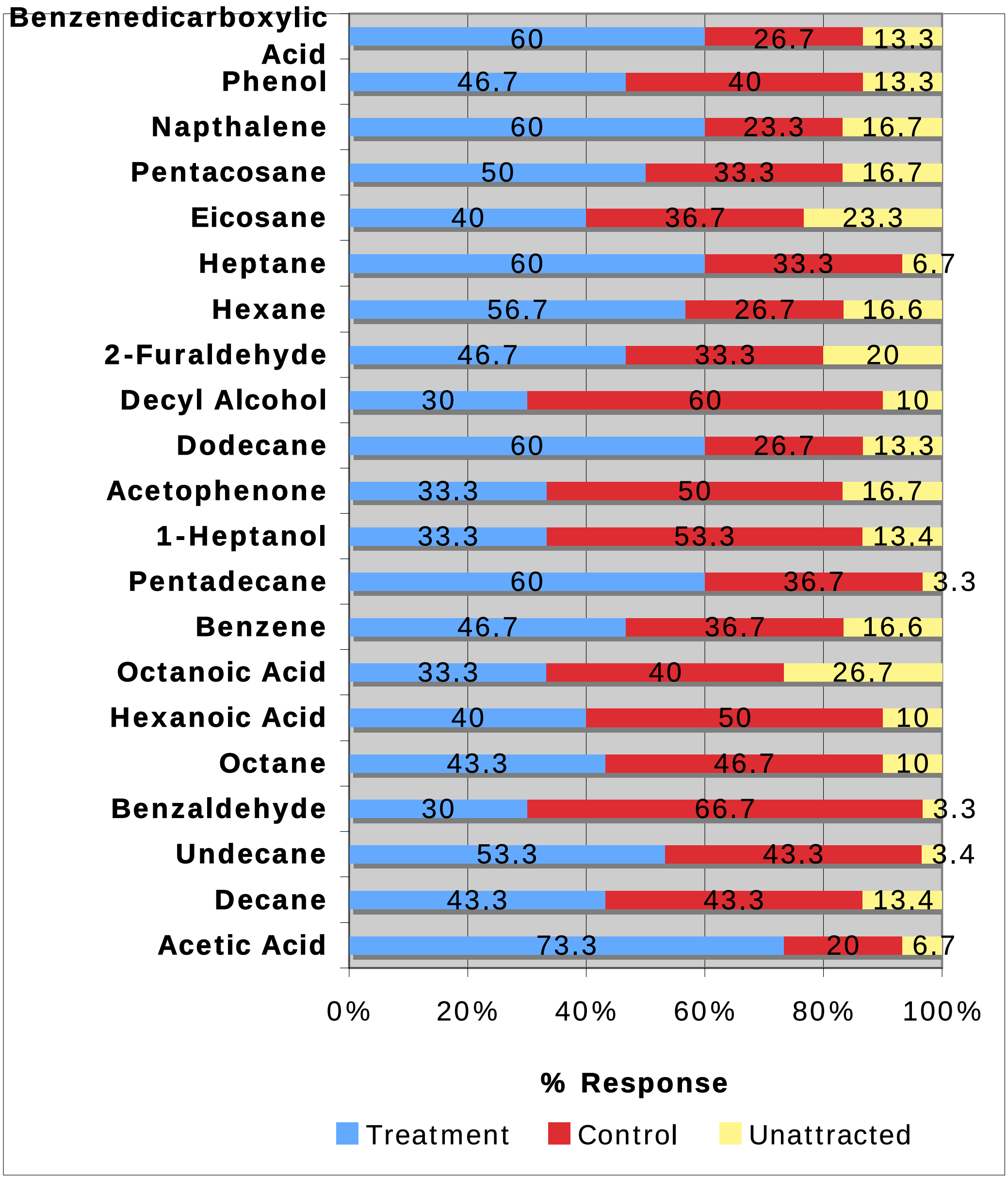

Fig. 29. Response of virgin female weevils to components of frass of mated male pulp weevils in a Y-tube bioassay. X2 test, *indicates a significant preference for that treatment ($P<0.05$); the absence of asterisks indicate no preference. The number of weevils tested was 30 for all treatments.

2.8 Conclusions and recommendations

The following conclusions and recommendations are given on the current pest status of fruit spotting bugs and alternative control strategies of pests in mango.

2.8.1 IPM development and pesticide reduction

The present study produced very useful information concerning insect pest control and judicious used of pesticides for the production of mango. Five mango insect pests identified namely cecid fly, mango leafhopper, blossom thrips, mango seedborer, and mango fruit fly. After testing the different insect pest control in various locations in Davao del Norte it was found out that IPM interventions such as regular sanitation, pruning, balanced fertilization, pest monitoring and identification, need-based chemical applications, white/yellow sticky and light traps, early bagging, use of insect pheromone, wrapping of impregnated plastic around the trunk greatly reduced the pest population and proved to be better in calendar chemical spray alone and on to no control at all. IPM interventions reduced the chemical spraying from 13 to 6 cycles with lowest infestation of only 4.78% and gave significant yield of 139.59 kilos per tree with quality fruits as compared to farmer's practice which gave 7.49% fruit damage and yield of 50.77 kilos per tree.

On the cost and return analysis study proved that there is bigger return of investment (164%) when IPM interventions is used for insect pests control. An increment of 99.50% was found over that of farmer's practice (chemical spray alone). Further the study proved that actual show casing of the result of the study is an effective tool in technology information, dissemination and adoption.

Based on the above major findings the following are recommended:

Mango growers should take into consideration of knowing the pests, its biology and life cycle within the host, timing of chemical application through pest monitoring and apply as need-based and consideration of integrating various control strategies either direct or indirect control and not to be dependent on chemical control alone. Foremost, it is recommended that mango growers must follow appropriate cultural management practices to be successful. They should be keen observant to every growth and development of the crop brought about by environmental changes.

2.8.2 Mango Pulp weevil

Adult weevils stay up to the main branches of mango trees at quiescent stage. The IPM work plan consisting of cultural, physical and chemical control and pest monitoring was able to reduce MPW population to 2%. Physical control (bagging) enabled the reduction of spray application to 5 times throughout the fruit production period.

Mated male frass at 3 frass equivalents elicited the highest attraction (73.3%) to virgin female weevils. Twenty-four components were identified by GC-MS from mated male frass and acetic acid, one of the components is able to elicit the same percentage attraction.

Survey in northern Palawan has shown that the area is still free from MPW.

The IPM strategy has shown that MPW population in the field can be effectively managed. Insecticide applications can be kept low up to 5 times only. This strategy should be used in the entire southern Palawan island so that all mango growers can still benefit from their mango trees and at the same time they can help in containing the pest in the area by keeping the population level at a minimum. Quarantine measures should be set in place so that northern Palawan could maintain weevil-free status.

Having tested all possible sources of attraction to MPW females, the finding that acetic acid can elicit 73.3% attraction is very important because now we could proceed with developing bait traps. Acetic acid will be used as the main component of the bait trap for MPW.

2.8.3 Communication and dissemination activities

Information on the progress and the results of the research and activities carried out in the pest management project was extended to growers and interested persons by workshops and industry newsletters and conference presentations.

2.8.4 IPM recommended practices

- Technical staff trained on IEC materials for effective technology dissemination
- Reproduced/distributed IPM manual during Techno Forum (11 clusters)
- Conducted 11 clusters group presentations composed of 46 barangays farmers
- Organized 11 clusters mango growers association federated into "Samal Mango Growers Association
- Organized Mango technology demonstration- 4 sites: 3 in Samal; 1 Panabo City coupled with season-long hands –on training on interested mango growers. Effective technology adoption. Activities to be replicated in their own mango farm with ongoing farmer training workshops in developing the practice of IPM strategies developed in the current ACIAR project.

2.8.5 Mango pulp weevil

Control recommendations are being showcased now in the Farmer's Field Schools being conducted by technicians of the Local Government of the towns of Brooke's Point and Narra, Palawan. These schools will be ongoing to help ensure farmer adoption of the recommended control practices for the mango pulp weevil.

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3 IPM Australia

Objective 1: Pest management research in mango in Australia.

Objective 2: To improve control and detection of mango seed weevil in Australia.

Co-authors/ contributors/ collaborators

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Bruce Nastasi – Diamond Star Farms, experimental site

Osca and Janet Gallina – experimental site

Don Lavers – experimental site

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Paul and Peter Le Feurve - Corrick Plains, experimental site

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3.2 Executive summary

Pest management research in Australia set out to evaluate the pest status of fruit spotting bugs, Amblypelta nitida Stal and Amblypelta lutescens lutescens (Distant) (Hemiptera: Coreidae) and to understand the pests biology and ecology in mango. Studies were also conducted on the semiochemistry of fruit spotting bugs and mango seed weevil, which is a major pest of quarantine importance. Alternative pesticide application methods were also evaluated for insecticide reduction strategies to promote the potential development of future biological control systems in mangoes in Australia.

As a result of studies carried out on the biology and ecology of fruit spotting bugs, the mango industry will be able to selectively control these pests where they occur in orchard hot spots. Monitoring orchard hot spots will assist in pesticide reduction strategies for managing this pest. The pest status of fruit spotting bugs is now better understood. Although these pests are infrequently seen over the growing season fruit loss studies have shown they have the potential to be economically important because peak seasonal insect activity and feeding damage occurs during flowering to fruit set. At fruit set feeding by bugs results in premature fruit drop as the fruit panicles discard damaged fruit. Also bug feeding sites on the flower panicles act as entry points for disease development (Anthracnose). This can result in complete flower panicles being destroyed and some trees not setting any fruit in areas when fruit spotting bug activity is high.

Studies conducted to evaluate alternative pesticide application methods using systemic insecticides applied either as a tree injection or basal bark trunk spray showed positive results. The best results were achieved under low to medium pest pressures at the single dose rates tested against the major pest spectrum in mangoes. All treatments performed as well as the industry standard insecticide (methidathion) but were not as effective against pink wax scale, plant hoppers and flower/fruit eating caterpillars under high pest pressure. The basal trunk treatment should be investigated further as the treatment is not as labour intensive as the injection method. The dimethoate tree injection treatment was the most effective at all pest pressures and trial sites compared to the other systemic pesticides at the dose rate tested (3g ai / tree).

Semiochemistry studies on fruit spotting bugs and mango seed weevils have also progressed. There is now reasonable confidence that all the major components of the male sex pheromone of A. lutescens have been identified. The previously unknown 220 MW compound is evidently an

epoxide, an observation consistent with the finding for A. nitida. Once reconfirmed, combinations of pheromone components can be evaluated in the laboratory and then assessed in the field as both monitoring and control tools. Near pheromone compounds derived from plants in combination with certain common plant volatiles appear to elicit some response from adult bugs in the field, but this needs to be explored further by refining the mixes of compounds and rates of emission. There is no clear evidence yet that mango seed weevil produces a pheromone. However, with appropriate input from an organic chemist there is an opportunity to more thoroughly examine the components of aerations collected from adult weevils. In addition, weevils may respond to mango-specific compounds and this should be an avenue of future study.

3.3 Background

Fruit spotting bugs

The fruit spotting bugs, Amblypelta nitida Stal and Amblypelta lutescens lutescens (Distant) (Hemiptera: Coreidae) are native insects which are major pests of economic importance in many commercial fruit and nut trees as well as some vine crops in Australia. Some of these include avocados, custard apples, macadamia nuts, cashews, papaya, guavas, lychees, passionfruit, pecans, citrus, rambutan, mango and longans (Astridge et al. 2000).

Fruit spotting bugs have a very wide host range. Amplypelta lutescens lutescens is the more dominant of the two species and is known to feed on at least 111 host plant species belonging to 51 families. Amblypelta nitida is recorded on 56 host species belonging to 30 families (Waite and Huwer, 1998). They are sap feeding insects which feed on new flush growth, flower panicles and developing fruit. Feeding on new flush terminals and flower panicles can result in lesions developing around the feeding sites leading to severe wilting and death of the new shoots. Feeding sites on the fruit form dark sunken spots. As the fruit continues to develop the feeding sites on the fruit will often crack. In some crops fruit feeding can result in premature fruit drop especially during fruit set. In lychees, fruit spotting bugs have been responsible for up to 98% of the damage in fallen fruit (Waite 1990).

Growers with a lower level of awareness respond to damage sightings, by which time much of the crop is lost. Damage has been known to reach 50% of a crop despite control measures, and losses of tens of millions of dollars annually across industries are not unrealistic estimates (Waite et al. 1993). Control of fruit spotting bugs in many crops is achieved prophylactically, with successive applications of pesticides. There are 26 crops in Queensland that have an approved use for endosulfan to control fruit spotting bugs. While endosulfan is an effective insecticide against these pests, it has an uncertain future as an agricultural chemical and is under threat of being withdrawn. Together with environmental concerns over insecticide use, urban encroachment on farming land and consumer demands for cleaner product, there is a need to improve control measures for pests such as fruit spotting bugs.

Very little has been known about the pest status of fruit spotting bugs in mango. Although known to feed in mango fruit spotting bugs are perceived by many growers as being a minor pest. This is because they are seen infrequently over the growing season and also because there has been little research conducted to establish their economic importance. Over the past few seasons growers have reported poor fruit set in some orchards. Yield also varies significantly between different orchards of similar age and variety (7-20 cartons/tree). There is therefore a need to evaluate the pest status of fruit spotting bugs and to determine their economic impact in mangoes.

Recent research on various components of the mango pest complex in Australia has been completed for the mango industry by entomologists of the Queensland Department of Primary Industries and Fisheries. This research was aimed at learning more about the ecology of a major pest, mango scale, in preparation for the import and release of an exotic parasitioid (Aphytis chionapsis) from South Africa.

The challenge in Australia then is to develop an integrated pest management strategy for mango pests which accounts for the escalating pest status of plant feeding bugs while reducing the chemical load in the environment to establish potential biological control systems. This strategy needs to have minimal or no impact on the proposed scale parasitoid, and should consider the possible arrival of mango leafhoppers and redbanded mango caterpillar in production areas.

Pest monitoring should form the basis of control decisions, and the appropriate selection of insecticides or alternatives and their proper application will be critical to both the level of control, maximising the exploitation of biological agents and counteracting the expected upsurge in new pests. More than half of the Queensland mango crop is grown within river catchments that impact on the Great Barrier Reef. Reductions in the chemical load applied to the crop will thus have a positive impact on the long-term health of the reef.

For fruit spotting bugs, semiochemicals using pheromones or plant kairomones appear to offer the best chance of developing practical systems for orchard monitoring and may provide additional opportunities for controlling these pests through mating disruption or mass-trapping. Work started on the identification of sex pheromones in Amblypelta more than 15 years ago by Aldrich et al. (1993) and Waite et al. (1993). Pheromones are produced by the males and appear to consist of a number of compounds, some of which are complex (Moore et al., 1999). This complexity has slowed progress in obtaining a practical mix to test in the field.

For Amblypelta lutescens, (-)-(3R)-(E)-nerolidol, α-farnesene and an unidentified compound (Molecular Weight = 220) appear to be the main pheromone components, with the possibility of some components of the Amblypelta nitida pheromone being involved also. For A. nitida, a new chemical, β-ocimene-epoxide (myroxide), appears to be an important compound along with (E)-β-ocimene and linalool, with nonanal and decanal implicated also. However, there is some possibility that these last two compounds are sequestered from damaged plant tissue. Both (-)-(3R)-(E)-nerolidol and myroxide have been difficult to source for testing, but some progress has been made in this respect. As A. lutescens is the most significant species of fruitspotting bug in tropical Australia, and is particularly active in sappy plants like mango, cashew and papaya, identifying its pheromone components is regarded as a more urgent task than confirming those for A. nitida.

There are at least two approaches that could be taken to identify potential plant attractants for Amblypelta. (1) A comparison of the volatiles produced by highly favoured varieties of plants against the less favoured ones may indicate whether there are specific compounds which are responsible for the enhanced attractancy of fruitspotting bugs. Favoured varieties are known for carambolas, heliconias and cassava. The chemical profiling would be seeking some commonality of compounds across the different species. (2) The preferred hosts of fruitspotting bugs and the stage at which these plants are preferentially attacked offers some guide to unravelling the chemicals responsible for bug attraction. A similar approach could be taken to that adopted in past research for fruitpiercing moth, in which general chemical compounds common to a range of fruits at a particular stage of ripeness were identified in the literature and formulated into blends for various forms of testing. A scan of the literature on preferred fruitspotting bug hosts suggests compounds such as β-caryophyllene, α-pinene, α-copaene and 3-carene might be involved in their attraction. Green leaf volatiles, such as trans-2-hexenal, may also be important. It is also possible that pheromone components, such as α-farnesene and nerolidol, which are found in many bug hosts, could be sequestered from plants. The huge host range of fruit spotting bugs implies that compounds common to a wide range of plants should be involved in their attraction and should be investigated.

Mango seed weevil

The mango seed weevil Sternochetus mangiferae (Fabricius) (Coleoptera: Curculionidae) is native to Australia and is also widely distributed in Africa, Asia, the Pacific Islands and the Caribbean (McComie and De Chi, 1994). In Australia it is recorded in Queensland, the Northern Territory and New South Wales (Cunningham, 1989)

Newly hatched mango seed weevil larvae bore into the fruit to the seed after emergence from the egg destroying the cotyledon inside the seed. Tunnelling through the fruit to the seed is not discernable in the flesh at fruit maturity. In Australia the mango seed weevil is considered a minor pest of economic importance as yield and fruit quality is not affected by weevil infestation (Cunningham, 1989).

Mango seed weevil has become an important pest of Australian mango because they infest the fruits seed which makes them a pest of quarantine importance for growers wishing to export to specific markets (Day and Pande 1987). A non-invasive technology is needed to enhance quarantine monitoring of mango seed weevil in Australia. Monitoring the presence or absence of mango seed weevil in mango orchards is critical for determining farm freedom and the potential for exporting fruit to quarantine-restricted markets such as China and the USA. Currently this can only be done by cutting open fruit at harvest to ascertain infestation levels. Pheromones or plant kairomones could provide the means to monitor weevil activity without the labour intensity and time involved in fruit cutting. There has been no previous work done on pheromones of mango seed weevil or the Cryptorhynchinae group in which mango seed weevil belongs.

Project Aims

Even though endosulfan is regarded as being relatively ‘soft’ on beneficial organisms and of real value in IPM systems, it is extremely toxic to fish and aquatic organisms. As a result of earlier research into the behaviour and ecology of fruit spotting bugs, recent findings in relation to avocados suggest that broad-scale application of insecticides for fruit spotting bug control, at least in larger orchards, is probably unnecessary, and that a concentration on relatively compact bug hotspots both for monitoring and targeted control, is possible. This approach will be tested in mangoes because it offers the opportunity to reduce the frequency of chemical sprays, and the area that is subjected to those sprays.

Because fruit spotting bugs are infrequently seen over the growing season, studies to evaluate the pest’s population dynamics will be conducted to determine their peak seasonal activity periods. Identifying the bugs peak activity periods in mango will assist in the timing of monitoring and control strategies to reduce bug damage and pesticide applications.

While fruit spotting bugs can breed in fruit crops if sprays are not applied, the bugs that cause most crop damage migrate into the crop continuously from external breeding areas that consist of both native and exotic host plants (Waite et al. 2000). Even though the hotspot strategy may work generally, there might still be occasions when the whole orchard requires treatment. Effective insecticides that have minimal environmental impact and are non-disruptive to natural enemies, especially of the scale parasitoids, are required for this. Alternatives, which include compounds such as imidacloprid (Confidor®)and thiamethoxam (Actara®) will be tested, along with others that might be identified as further research is conducted. Some of the above compounds maybe equally useful against other important mango pests such as plant and leaf hoppers and the mango seed weevil and should be investigated.

The other key areas of the project will examine different spray application methods to reduce the chemical load in the environment to help promote the development of biological control systems. Extension training will also be carried out through a new extension project called “Deliverance” in Australia to help train growers and other industry personnel in the areas of insect identification, monitoring procedures and pest management decision-making.

In addition to practical aspects of fruit spotting bug management, research already underway that is attempting to develop chemical-based (pheromones and host volatiles) monitoring systems for fruit spotting bugs and mango seed weevil, will be continued. This will involve collecting active compounds of these insects from aerations to identify and verify pheromone components and explore other potential attractants for use in monitoring and trapping.

3.4 Objectives

To improve integrated field management of mango pests in Australia

The objectives of the studies in Australia will be to research aspects of the biology and ecology of fruit spotting bugs (A. nitida and A. lutescens lutescens) and mango seed weevils (Sternochetus frigidus) to develop targeted pest management strategies. New pesticide application methods will be evaluated using systemic pesticides applied as an injection or basal bark application to the tree trunk. The main objective is to reduce the pesticide load applied to mango crops to help conserve natural enemies and promote an environment conducive to the development of biological control.

Research will also be conducted to try to indentify the pheromones of fruit spotting bugs and mango seed weevil which can be used in IPM strategies. These studies will provide opportunities to develop more effective monitoring and management systems for pesticide reduction and the promotion of biological control systems.

Hypotheses – Australia

An investigation of fruit spotting bug behaviour in mango crops, including their occurrence in hotspots, will provide useful information for developing monitoring strategies and targeting control options.

Alternative fruit spotting bug control options employing less disruptive treatments and application methods using systemic insecticides will promote better opportunities to develop biological control systems. The alternative treatments will be compatible with the IPM system developed to manage other pests, including those that may reach production areas in the future (such redbanded mango caterpillar and mango leafhopper)

The active compounds collected from fruit spotting bug and mango seed weevil aerations can be identified and attraction can be demonstrated through electroantennogram experiments, and potential attractants explored for use in field traps.

3.5 Methodology

3.5.1 Population dynamics and field management of fruit spotting bugs

Seasonal population dynamics of fruit spotting bugs

Fortnightly surveys were conducted from July 2005 – July 2007 at four orchards in the Burdekin region (Farm 1, 19°36’ 11” S, 147° 08’ 02” E; Farm 2, 19° 35’ 51” S, 147° 08’ 53” E; Farm 3, 19° 23’ 20” S, 146° 57’ 05” E and Farm 4, 19° 35’ 51” S, 147° 08’ 53” E; and four orchards on the Atherton Tableland (Farm 1, 17° 01’ 81” S, 145° 47’ 26” E; Farm 2, 17° 09’ 92” S, 145° 44’ 10” E; Farm 3, 17° 15’ 88” S, 145° 23’ 26” E and Farm 4, 17° 12’ 48” S, 145° 26’ 46” E) regions.

Orchard selection was based on distribution through each growing region and common production of the Kensington Pride (KP’s) and R2E2 varieties. These varieties were selected for evaluation because they are the two major commercial plantings produced by the Australian mango industry. The two varieties were also selected because of the need to evaluate possible varietal susceptibility to fruit spotting bug feeding.

Two random tree blocks were chosen from each orchard (1 x KP and 1 x R2E2) with 30 trees randomly selected in each block using a random number generator. Each row and tree was numbered and 4-5 branches were flagged with tape for intensive sampling during each survey period. A static sampling plan was used for each fortnightly survey period and insect activity was recorded over the season and compared to the crops phenology for each region. All data were averaged over the month and pooled for each region and each variety to get mean percent orchard infestation levels for each variety grown in each region. This was also done to evaluate regional susceptibility to fruit spotting bug attack.

Estimating premature fruit drop caused by fruit spotting bugs

A study over the 2005-2007 growing seasons was carried out to determine the level of fruit drop caused by fruit spotting bugs feeding at 4 orchards in the Tablelands growing region. Ten trees were selected from each orchard (5 from each variety of KP and R2E2) with known fruit spotting bug infestation. Premature fruit dropped underneath each tree canopy was raked and collected during each end of month sampling period. One hundred fruit were counted from each tree variety at each orchard (total 4000 premature fruit from 4 orchards) and the percentage of fruit with visible fruit spotting bug feeding damage was recorded.

At harvest, the mean total number of fruit per tree was counted from 4 trees with known fruit spotting bug activity (recorded during flowering and fruit set) and compared to the mean total number of fruit counted from 4 trees with no fruit spotting bug activity. This was done to compare any yield differences caused by bug feeding damage during flowering to fruit set. All trees were the same age and variety in the same orchard blocks where fruit spotting bug activity was recorded.

Statistical analysis

Data were pooled for all orchards and each variety and the mean fruit drop caused by fruit spotting bugs was recorded. Statistical analysis was conducted on the mean monthly fruit drop caused by fruit spotting bugs against each variety using ANOVA (Genstat version 9.2). A t-test was used to compare the fruit yields of trees infested or not infested with fruit spotting bugs for two varieties (KP's and R2E2) over two seasons (2005-2007).

Evaluation of tree injection and basal trunk application using systemic insecticides

Two systems of insecticide tree injection were originally chosen for evaluation. These included the Sidewinder® tree injection system and the ChemJet® syringe injectors (Figure 1). After testing the Sidewinder® a precise measured dose of chemical could not be delivered into the mango trees and this system was discarded from the trial. The potential for using tree injection of systemic pesticides to control the major pests of mango was carried out using the 20 ml ChemJet® tree injectors.

Three farms sites (Farm 1, 17° 01' 81" S, 145° 47' 26" E; Farm 2, 17° 09' 92" S, 145° 44' 10" E; Farm 3, 17° 15' 88" S, 145° 23' 26" E) were selected for conducting replicated trials in the Tablelands region. Each trial site represented different levels of whole farm pesticide use (Farm 1 = high pesticide use [14-16 applications of pesticides], Farm 2 = medium pesticide use [8-10 applications], and Farm 3 = no pesticide use). The farms were also selected to evaluate the effect of different natural pest pressures against the treatments dose rate and efficacy.

A randomised complete block trial design was used to block for non-uniform soil types, water, nutrition and pest pressures. Each treatment was replicated 4 times at each trial site and applied to mature Kensington Pride (KP) mango trees around 3-4 m in height. There was a one tree buffer between each treatment (Table 1).

A basal bark trunk treatment using thiamethoxam and PentraBark® was included as an extra treatment in trial site 2. The basal bark treatment was not included in trial sites 1 and 3 due to the lack of product available at the time of testing. Only one systemic insecticide was tested using the basal bark trunk spraying method at 5 g ai per tree in 2 L of water.

Photo 1. Showing the ChemJet™ syringes and the Sidwinder™ tree injection systems

Table 1. Showing the treatments, supplier, formulation, application method and rate tested.

Treatments	Supplier	Formulation	Application	Dose rate (a.i.)
Control (water and Agral®)	-	-	Canopy/foliar spray	1ml/L
Thiamethoxam	Syngenta	250g/kg WG*	Injection	3g in 80ml/tree
Pentra-Bark® &Thiamethoxam †	Syngenta and Agrichem	250g/kg WG	Trunk spray	50ml and 5g in approx 2L water/tree
Imidacloprid	Bayer	350g/L SC**	Injection	3g 80ml water/tree
Experimental 1 (Exp1) neonicitinoid	Bayer	EC Confidential	Injection	3g 80ml water/tree
Experimental 2 (Exp2) neonicitinoid	Bayer	EC Confidential	Injection	3g 80ml water/tree
Dimethoate	Nufarm	400g/L EC***	Injection	3g 80 ml water/tree
Methidathion & Agral® (ISI)	Syngenta	400g/L EC	Canopy/foliar spray	12.5ml/10L (Label) & 1ml/L

** Wettable granules, **Suspension concentrate, ***Emulsifiable concentrate, IS = industry standard insecticide, †Treatment applied only at farm site 2*

Teatment application methods

All treatments were applied at around 50% peak flowering in early September 2007.

Tree injection

Injection of insecticide treatments were applied by drilling four holes into each tree with a ¼ inch drill bit from a battery operated cordless drill. Each hole was drilled slightly offset to the centre and four 20ml ChemJet® injectors where threaded into the holes for each tree replication for each treatment. Each injector was then released under spring loaded pressure and checked every 3-6 hours until all treatments were empty and recollected after use.

Basal trunk spray

The rate used was 50mls of PentraBark® and 20g of thiamethoxam (5 g ai) in approximately 2 litres of water/tree. This solution was then spray applied at low pressure using a Swissmex™ backpack sprayer (hollow cone nozzle) to the entire tree trunk from ground level up to approximately 2 meters or to the first scaffolding limbs until runoff.

Canopy sprays

The control and industry standard insecticides were canopy applied with a Solo™ backpack mister. Methidathion was applied at the label rate of 125ml/100L of water. Spraying was repeated over the growing season for each farm trial site based on monitoring of insect pest populations within each tree replication for each farm site.

Harvest assessments and insect damage ratings

Fruit quality assessments for insect damage were conducted using an insect damage rating index applied to the external fruit surface (Table 2). Thirty fruit where randomly selected from each tree replicate for all treatments and the mean insect damage to the fruit skin was recorded for each treatment at each farm site. Insect damage to the fruit was recorded for fruit spotting bugs, flower/fruit eating caterpillars, plant hoppers, mango scale and pink wax scale.

After fruit surface damage assessments were carried out the fruit were then destructively sampled for the presence of mango seed weevils. A knife guillotine was used to cut each fruit splitting the seed in two to check for mango seed weevil presence. Larvae, pupae and adults where combined in the counts for each fruit sampled. The number of weevils per fruit were then counted and the mean percentage weevil infestation per treatment was recorded for each trial site.

Table 2. Fruit damage ratings used in the fruit quality assessments at harvest to rate insect damage.

Fruit skin damage rating	Area damaged	Type of damage
1	$1mm^2$	S = sucking
2	$2mm^2$	SS = sucking and sooty mould
3	$3mm^2$	C = chewing
4	$4mm^2$	WE = weevil eggs
5	$5mm^2$	SC = scale blemish
6	$6mm^2$	
7	$7mm^2$	
8	$8mm^2$	
9	$9mm^2$	
10	$10mm^2$	
11	less than $100mm^2$	
12	100 to $400mm^2$	
13	400 to $1600mm^2$	
14	over 1600 mm^2	

Statistical analysis

All treatments where compared to a control and industry standard insecticide by using fruit damage ratings against the major pests of economic importance. Statistical analysis was conducted on the mean insect damage per plot (fruit) that were analysed for three individual sites (Farm1, Farm2, Farm3) using analysis of variance (ANOVA). Where a significant main effect of treatment was identified, pairwise comparisons were performed using the 95% LSD.

3.5.2 Semiochemistry of fruit spotting bug and mango seed weevil

Fruitspotting bug

Pheromones - The focus of work on bug pheromones has been the identity of the MW = 220 compound for A. lutescens and verification of the other pheromone components recognised in previous work. Male bugs collected from the field were confined in an aeration chamber with fresh green beans in the laboratory. The intake line to the chamber contained a charcoal filter and a flow regulator. The out-take line had a capsule containing Super Q Porapak absorbent powder closest to the bug chamber and leading out to a vacuum tap. Silicone tubing was used to connect the glassware, collector and filter to form a continuous system. Air was drawn through the bug chamber and absorbent trap for four days, during which time any dead bugs were removed and beans replaced if necessary. At the completion of this period the absorbent powder was flooded with hexane to extract any volatiles trapped during the aeration. These procedures were repeated on a number of different occasions.

The hexane extracts were analysed using gas chromatography (GC) and mass spectrometry (MS). Verification of pheromone peaks was attempted through combined GC-EAD (coupled gas chromatography - electroantennographic detection) using freshly excised female bug antennae. The mass specs of relevant compounds were determined by searching chemical libraries, comparing with those reported in the literature and using other information (e.g. NMR data) where appropriate. For the MW = 220 compound this required a certain amount of deduction, experience and knowledge supplied by Chris Moore (ex DPI&F) and Jeff Aldrich (USDA).

Plant kairomones – A range of plant compounds common to many bug hosts or those close to the known pheromone components were procured from different chemical suppliers for testing in the field. The chemicals were dispensed into 1.5 ml centrifuge tubes with avocado oil. These tubes each had a glass microcap placed in the lid to emit the treatment odour. There were three replicates of each treatment indicated in Table 1 below. Each treatment tube was attached within a hole cut in the centre of a plywood panel (30 x 25 cm), which was painted avocado green and covered in birdstop. Panels were deployed through an organic avocado orchard (Figure 1), placed singly in trees (at 2.5 to 3 m height) that were selected for possessing a minimal quantity of set fruit. The panels were exposed for a period of over one month, and inspected weekly for the presence of spotting bugs and other insects.

Table 3. Various plant kairomones, their combinations and rates assessed as fruitspotting bug attractants in the field.

No.	Treatments and rates
1	Control (oil only)
2	Trans-nerolidol (7µl)
3	Linalool (25µl)
4	α-farnesene (10µl)
5	Trans-nerolidol (7µl)+β-caryophyllene (100µl)
6	Linalool (25µl)+β-caryophyllene (100µl)
7	α-farnesene (10µl)+β-caryophyllene (100µl)
8	Trans-nerolidol (7µl)+Linalool (25µl)+α-farnesene (10µl)
9	Trans-nerolidol (7µl)+Linalool (25µl)+α-farnesene (10µl)+β-caryophyllene (100µl)
10	α-pinene (100 µl)+3-carene (100 µl)+α-copaene (50 µl)+β-caryophyllene (100µl)

Mango seed weevil

Solid-phase microextraction (SPME) field collectors were used to trap potential pheromones of both mango seed weevil (Australia) and mango pulp weevil (Philippines). In Palawan, collections were made individually from males and females, and also from mating pairs of mango pulp weevil. In Mareeba, collections were made separately from males and females, from males and females together and separately from male, female and male plus female frass of mango seed weevil.

Collections were made over a 24 h period. The exposed SPME collectors (Figure 2) were sent to the Organic Chemistry lab at Indooroopilly for analysis by GC-MS. The identity of the major peaks were ascertained by Chris Moore (former DPIF Chemist), but no assessment of the minor peaks has yet been possible. There has been no evaluation yet of the response of mango seed weevil to mango specific compounds in the laboratory or field.

3.6 Achievements against activities and outputs/milestones

Objective 1: Integrated field management systems and judicious pesticide use

no.	activity	outputs/ milestones	completion date	comments
1.1	Develop pest monitoring kits to enhance the collection of data	Workshop books distributed at regional workshops	2007 - 2008	Pest monitoring workshop booklets completed for pest monitoring workshops. Monitoring field guides completed
1.2	Run training workshops in pest monitoring	Training workshops completed	2007	10 Monitoring workshops completed in Darwin, Kununurra, Katherine, Mareeba, Burdekin, and Sth Qld and Bundaberg, through the project “Delivering mango technology” MG06007. workshops will be ongoing until 2010
1.3	Acquire relevant biological data on target insects (Helopeltis spp., scale, leaf hopper) (A,P)	Biology and seasonal history recorded	2007	Season histories of mango scale., leafhopper and Helopeltis sp recorded in separate projects including “Mango plant protection – phase 1 (FR02050)
1.4	Investigate fruitspotting bug hotspot occurrence and consistency in mangoes (A)	Fruit spotting bug hotspot phenomenon confirmed in mangoes. Data on seasonal bug activity collected and analysed	2007	Field distribution confirm that bugs are not uniformly spread throughout the orchard but tend to occur in hotspots
1.5	Crop monitoring and data interpretation of fruit spotting bugs	Seasonality studies completed	2007	Critical bug infestation periods in mango are from flowering to early fruit set. Bugs can cause economic loss if numbers are high.
1.6	Alternative control options tested and compatibility with IPM determined	Trials complete and assessment of best treatments made	2008	Initial studies using different application methods of systemic pesticides using injection and basal bark and irrigation have been completed.
1.7	Identification and testing of active volatiles	Identification and testing complete	2008	Initial testing completed need chemical ecologist to interpret results
1.8	Development and testing of region specific variations to IPM system and judicious pesticide use for target pests scale, leaf hopper and Helopeltis spp. (A,P)	Trials complete and assessment of best treatments made	2008	Training in pest monitoring and pesticide application trials completed under different pest pressures
1.9	Transfer technologies and information to users across all sectors of industry for selected regions	Information packages prepared and meetings with farmer groups and extension personnel completed	2006-2008	Technology transfer through Deliverance workshops, conference presentations and industry new letters

P=Philippines, A=Australia

Objective 2: To obtain further knowledge on the ecology, behaviour, pheromones and control options for mango seed and pulp weevils

no.	activity	outputs/ milestones	completion date	comments
2.1	Acquire additional behavioural, ecological and distribution data on pulp weevil (P) and literature information on seed weevil (A)	Good understanding of the life system of the pest, revisions of distribution data, updating of knowledge base	2007	Distribution studies completed in Australia in project HORT 2007 032
2.2	Investigate field control of pulp weevil (P) and seed weevil (A), including chemical application efficiency	Trials to test alternative controls complete	2007	Chemical control and other control strategies evaluated in project HORT 2007 032
2.3	Determination of accuracy of X-ray techniques for detecting pulp weevil (P) and seed weevil (A)	Data on detection performance collected and analysed	2007	Work carried out in the Philippines but applicable to Australia
2.4	Transfer technologies and information to users across all sectors of industry for selected regions	Information packages prepared and meetings with farmer groups and extension personnel completed	2007-2008	Technology transfer through Deliverance workshops, conference presentations and industry new letters

P=Philippines, A=Australia

3.7 Key results and discussion

The following results were recorded for work carried out against fruit spotting bugs in mango.

3.7.1 Population dynamics and field management of fruit spotting bugs

Seasonal population dynamics of fruit spotting bugs

Regional survey results for the 2005-2006 growing season indicate that the highest fruit spotting bug activity in the Tablelands and Burdekin regions is occurring from August through to December. Orchard infestation levels of fruit spotting bugs peaked in September in the Burdekin at around 17% for both varieties. In the Tablelands, orchard infestation level peaked in October at 23% for KP's and 20% for R2E2's (Figure 1). After the September and October peaks, the fruit spotting bug populations declined rapidly and remained low for the rest of the season in both regions.

Similar seasonal trends in the population dynamics of fruit spotting bugs have been recorded for the second survey season (2006-2007). Mean regional orchard infestation levels of fruit spotting bugs began rising in August in the Burdekin and peaked at 13% in September for R2E2's and 10% for KP's. On the Tablelands fruit spotting bug populations began rising in mid-September and peaked at 17% for R2E2's and 13% for KP's. Population levels were lower on all farms than the previous season.

Viewing the seasonal fruit spotting bug population activity according to crop phenology cycles between both regions and varieties, revealed that peak population increases were occurring just after peak flowering through to early fruit set. After this period, as the fruit continued to develop (past duck egg size) the populations rapidly declined in all farm sites in each region for both varieties for the rest of the growing season. Pesticides were applied at most farm sites after fruit set and could have been influencing population decline for most of the season but similar trends of population decline were also occurring across the control sites where no pesticides where applied (Figure 2). All fruit spotting bug population levels at all farm sites had peak population levels during flowering to early fruit set. This was possibly due to no sprays being applied during the flowering to fruit set period on all survey sites over both growing seasons and the preference of fruit spotting bugs to feed on immature fruit (Huwer 1996). The control sites where no pesticides were used indicated the fruit spotting bug populations were naturally declining after the flowering to fruit set period in mango.

Studies in the past have suggested that fruit spotting bugs may not get all their nutritional requirements from just one crop and migration to other crops might be necessary (Huwer 1996). The migration of fruit spotting bugs into crops that are flowering is a similar trend observed by Waite (1990) in lychee where heavy fruit drop was also recorded. This could explain the high populations of fruit spotting bugs populations in mango particularly during the flowering to fruit set periods and then the rapid population declines across the two different growing regions over two seasons as indicated in the unsprayed orchards. Fruit spotting bug does not seem to have a significant preference between the varieties (KP and R2E2) tested and the two main mango production regions (Tablelands and Burdekin).

Figure 1. Mean percent orchard block infestation of fruit spotting bugs in the Tablelands and Burdekin regions for R2E2 and KP mango varieties from 2005-2007. Infestation data are pooled for both growing regions across 8 orchards.

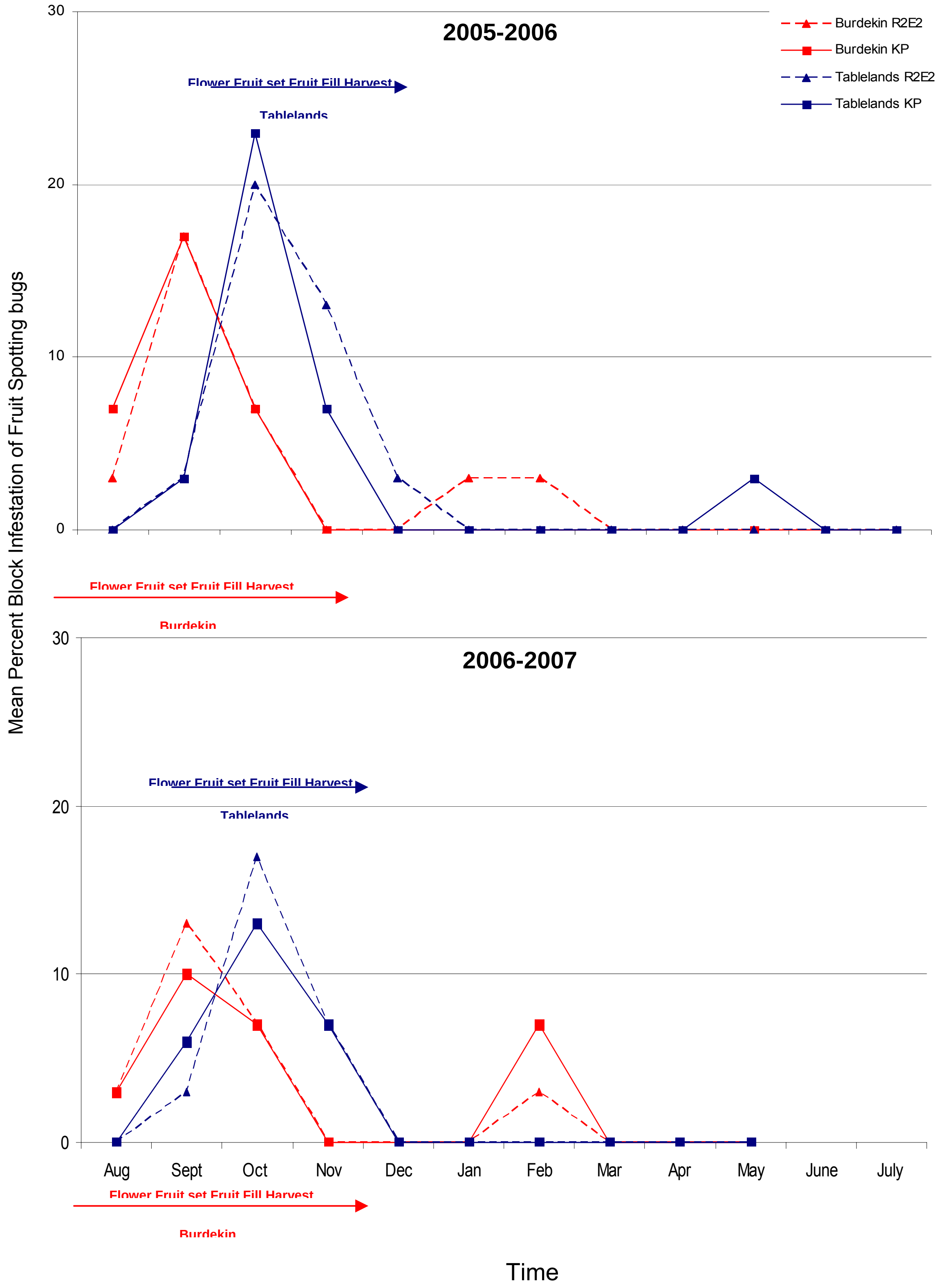
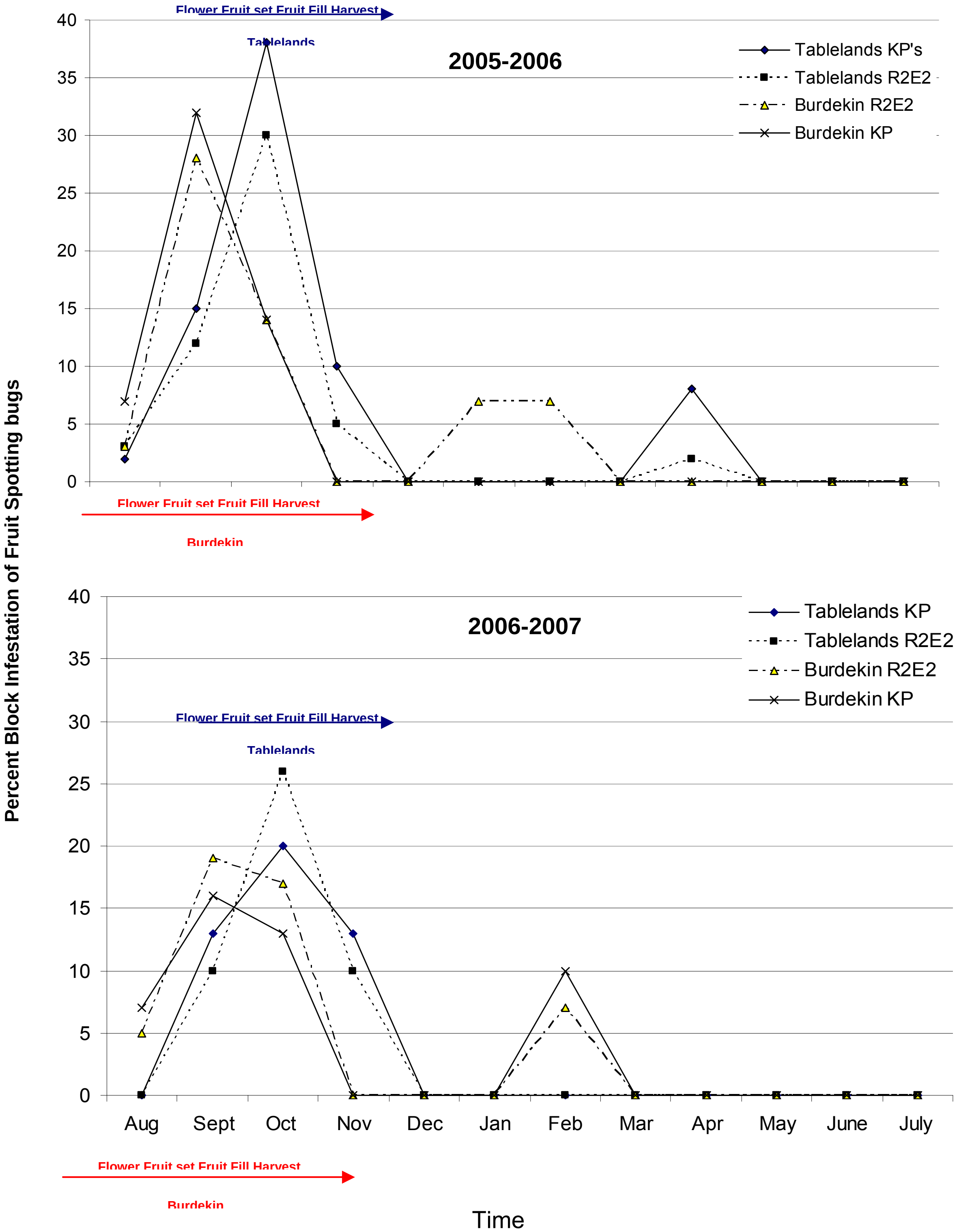


Figure 2. Mean percent orchard block infestation of fruit spotting bugs in two unsprayed orchard blocks in the Tablelands and Burdekin regions for R2E2 and KP mango varieties from 2005-2007.



Estimating premature fruit drop caused by fruit spotting bugs

Although fruit spotting bugs are infrequently seen for most of the growing season in mango, their migration from other locations into mango orchards commence at critical times in the crop's phenology (flowering to fruit set). During this period the bugs were observed actively feeding on the developing flower and fruit panicles and also on developing fruit up to duck egg size. Primary feeding sites on the flower panicles caused by fruit spotting bugs were observed being infected with anthracnose. The disease spread throughout the panicle resulting in no fruit setting and panicle death. As fruit set approached the bugs were observed actively feeding on the fruit panicles and developing fruit. This was resulted in pre-mature fruit drop.

Some trees and areas where fruit spotting bug activity was high resulted in no fruit set. These studies confirm the theory that fruit spotting bugs tend to come in from other areas during critical times in the crops phenology in mango and accumulate in hot spots rather than being uniformly spread throughout the orchard. During fruit set fruit spotting bugs were feeding on developing fruit panicles. Feeding damage resulted in premature fruit drop with many panicles losing 100% of their fruit. Fruit collected and counted under trees associated with premature fruit drop in the Tablelands in 2005-2006 revealed that 48% of R2E2's fruit and 40% of KP fruit were lost in October due to damage caused by fruit spotting bugs feeding activity. November sampling was also high showing 32% of R2E2 and 35% of KP fruit drop was associated with fruit spotting bug feeding (Figure 3).

During the 2006-2007 seasons the fruit spotting bug populations and fruit damage decreased. Premature fruit drop was lower than the previous season during the flowering to fruit set period. Mean fruit drop caused by fruit spotting bug feeding for October was 17% for R2E2 and 21% for the KP varieties. In November fruit drop was 15% for R2E2 and 10% for KP.

Fruit spotting bug damage was relatively high especially during the 2005-2006 growing season considering these results do not take into consideration unmarked fruit where feeding may have taken place on fruit panicles causing the fruit to drop unblemished. These results also do not consider the amount of fruit lost from fruit spotting bugs feeding during flowering and the loss of flower panicles and potential fruit set. There was no significant differences ($p<0.05$) in variety preference of bug damage between the KP and R2E2 mango varieties (Figure 3).

The highest fruit spotting bug populations were recorded during the 2005-2006 growing seasons. In the KP variety the fruit spotting bug infested trees mean fruit counts at harvest were 48% lower (120 fruit / tree) compared to the control trees where no fruit spotting bug activity was recorded (230 fruit /tree). The R2E2 variety also suffered considerable yield decline during this season. The mean fruit counts per tree for R2E2 infested trees (during flowering to fruit set) was 47% lower (77 fruit /tree) compared to trees that had no fruit spotting bug activity (145 fruit /tree) during flowering to fruit set. During the 2006-2007 harvest season the fruit spotting bug activity was lower than the previous season. For the KP variety fruit harvested from trees infested with fruit spotting bug were 32% lower (177 fruit / tree) compared with trees that had no fruit spotting bug activity (262 fruits per tree). The R2E2 variety also suffered yield loses compared to the control trees where no fruit spotting bug was recorded. The R2E2 variety was 34% (105 fruit / tree) lower than control trees (159 fruit / tree). Trees infested with fruit spotting bugs had significantly lower yields ($p<0.05$) than trees not infested with fruit spotting bugs during flowering to fruit set for both varieties over two seasons (Figure 4).

Photos 1-2. Fruit spotting bug feeding on a newly emerging mango flower panicle (top). Flower panicles were marked with flagging tape and observed over the next few weeks. The feeding sites caused by fruit spotting bugs became infected with anthracnose resulting in complete flower panicle death and no fruit set (bottom).

Photos 3-4. Fruit spotting bug feeding directly on the fruit panicle during fruit set (top photo 3). Premature fruit drop caused by fruit spotting bug with typical feeding symptoms from direct fruit feeding (bottom photo 4)

Figure 3. Mean percent fruit drop (2005-2006) caused by fruit spotting bugs feeding on KP and the R2E2 mango varieties (2005 – 2007).

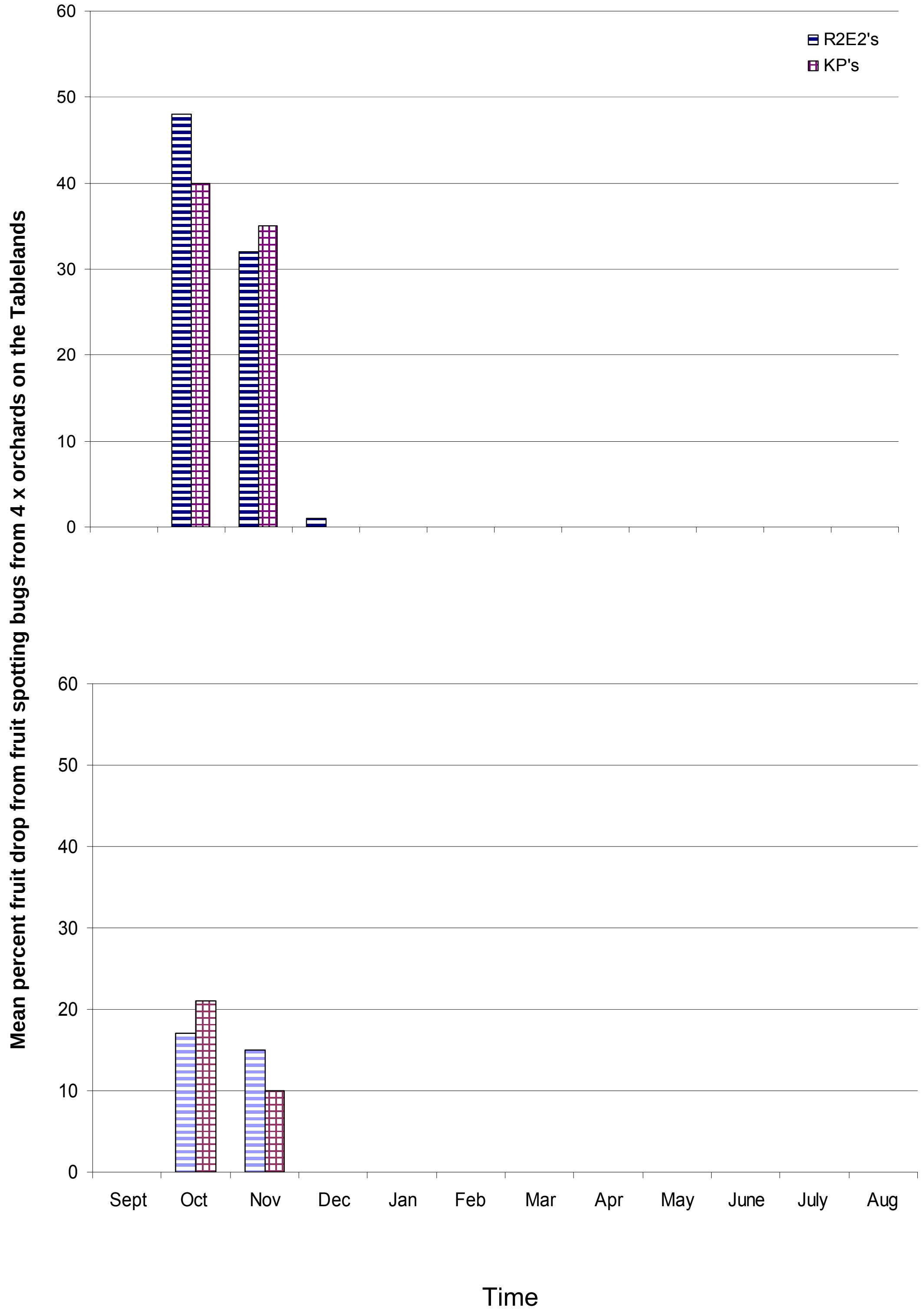
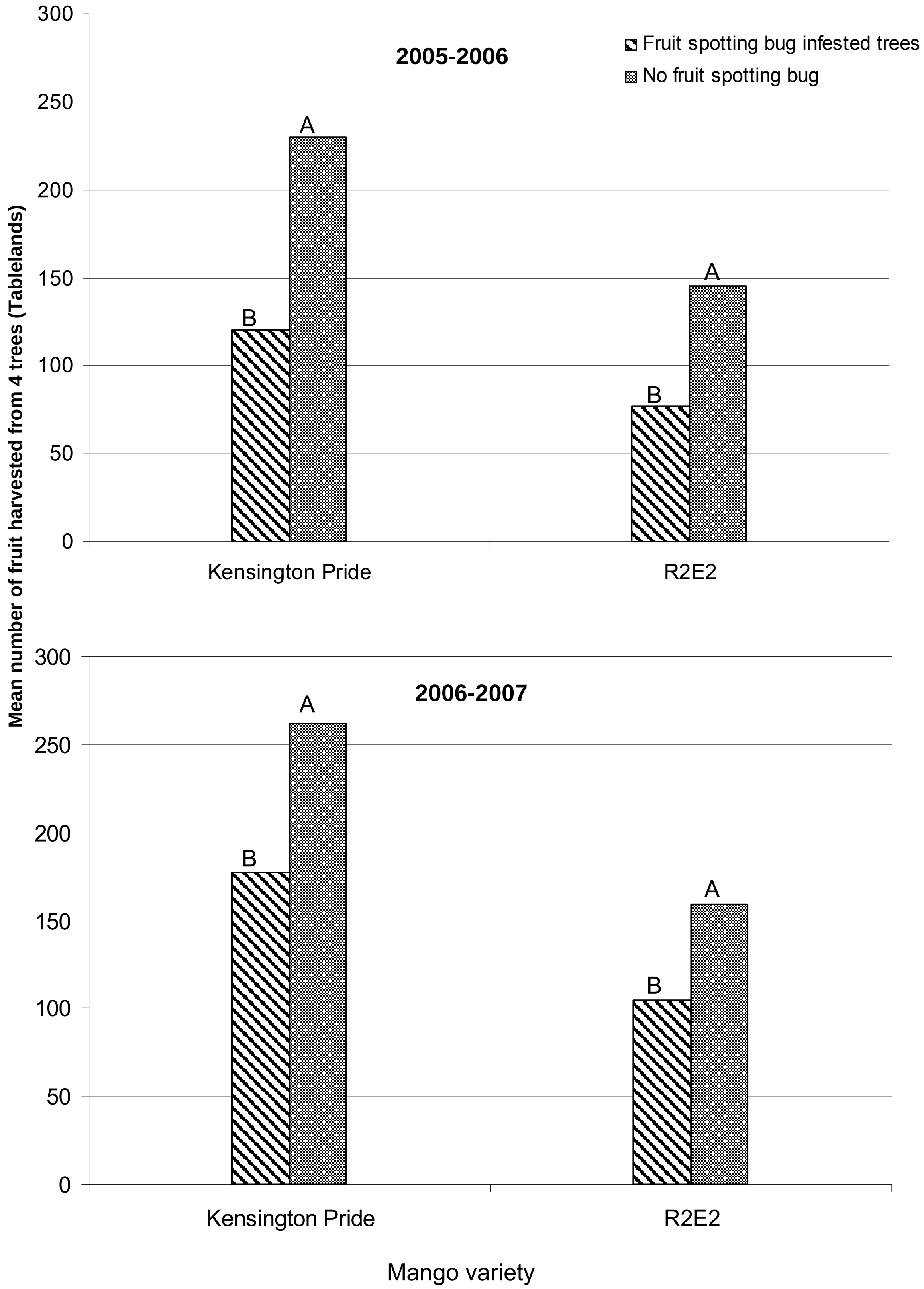


Figure 4. Mean number of fruit harvested from fruit spotting bug infested trees (during flowering to fruit set) and no fruit spotting bug trees (control) in 2005-2006 and 2006-2007 from Kensington Pride and R2E2 mango varieties. Means with the same letters in common are not significantly different (P > 0.05)



There was no varietal feeding preferences for either the KP or R2E2 varieties. The potential economic impact from fruit spotting bugs was shown to be high within orchard hotspots because peak migration and fruit spotting bug activity periods coincide with a critical phases in the crop cycle (flowering to early fruit set).

Monitoring and visual assessments of fruit spotting bug populations can be difficult when the natural population levels in the field are low because they hide behind foliage and branches when approached. Understanding the migration patterns of fruit spotting bugs in mangos during flowering to fruit set and their feeding patterns will help develop more effective monitoring strategies. Fruit spotting bug activity is a lot easier to see as they migrate onto flower and fruit panicles and monitoring for these insects during this period is achievable.

The seasonality studies show the importance of monitoring fruit spotting bug populations during flowering to fruit set in mango. During this period the bugs damage is revealed in flower panicle wilting and death and premature fruit drop and fruit damage during early fruit set.

The level of physical damage caused by these insects (feeding symptoms from damaged flower and fruit panicles, damaged fruit and premature fruit drop) can be an indication of the presence of fruit spotting bug populations within hotspot areas in the orchard. These symptoms and understanding the migration patterns of fruit spotting bugs in mango will assist monitoring and control of this pest for the mango industry.

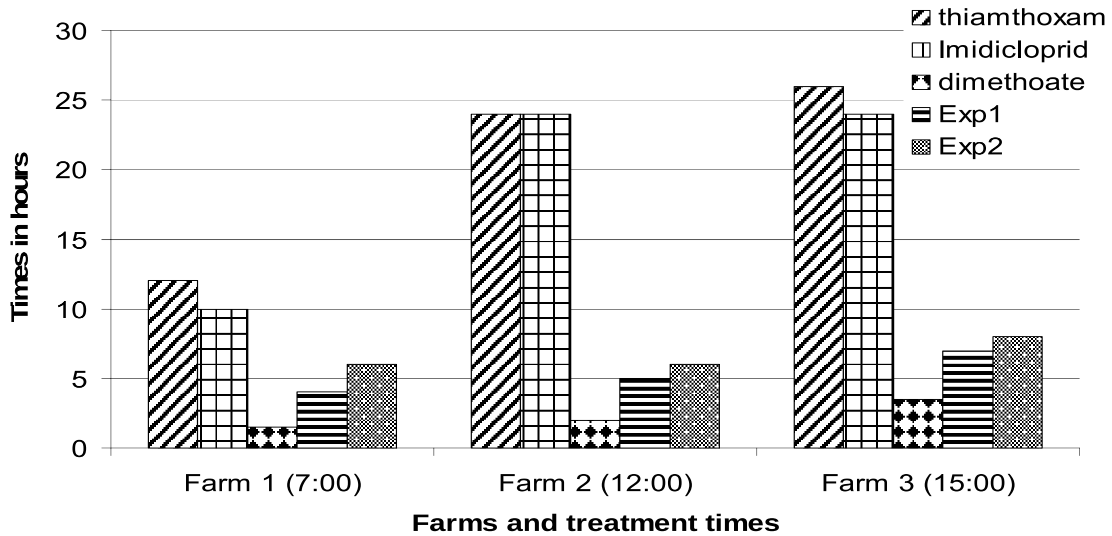
Careful observations in hotspot areas, especially during the cooler times of the day (morning and late afternoon) will reveal the presence of these insects. Control measures should be carried out in hotspot areas within the orchard at the first signs of fruit spotting bug activity during flowering to fruit set in mango orchards.

Evaluation of tree injection and basal trunk application of systemic insecticides

Uptake of the systemic insecticides applied as tree injection treatments with ChemJet® tree injectors varied across the formulation of pesticides being used and the time of day applied (Figure 5). The uptake of all insecticides was achieved after 26 hours within a temperature range of 19° - 32° C.

The uptake of all systemic insecticide treatments into the plants was observed to be quicker when applied during the early morning compared to being applied at midday and mid-afternoon. Within treatments the uptake of the insecticides varied between formulations. The EC formulations had the quickest uptake into the trees ranging from 2-7 hours across all farm sites depending on the time of application. The WP and SC formulations were slower (10-26hrs).

Figure 5. The recorded uptake of systemic insecticides applied as tree injection treatments to Kensington Pride mangos of similar ages and heights at three different times of the day at three different farm sites



Fruit damage assessments

At harvest (January), the fruit were stripped from each tree replicate and were randomly selected and rated for insect damage to the fruit surface. After fruit assessments were carried out the fruit were destructively sampled for the presence of mango seed weevil.

Fruit damage assessments for tree injection treatments under low pest pressure (trial site 1)

This farm site had high whole farm pesticide use patterns and low natural pest pressure. The following damage results were recorded for fruit spotting bug, Helopeltis sp, flower/fruit eating caterpillars, plant hopper, mango scale, pink wax scale and mango seed weevil (Table 3).

Fruit spotting bug damage

Although most of the fruit damage caused by fruit spotting bugs occurs during flowering to fruit set, we wanted to evaluate the level of damaged fruit at harvest. Fruit spotting bug populations were lower than the previous two seasons across all farm sites and the level of damaged fruit at harvest was not significantly different to the control ($P>0.05$) and the industry standard insecticide at this trial site. The industry standard insecticide was also not significantly different to the control treatment.

Helopeltis sp.

No Helopeltis bug damage was recorded at this trial site.

Flower/Fruit eating caterpillar damage

No damage was recorded to the fruit surface from flower and fruit eating caterpillars for all treatments including the control and industry standard insecticide. The pest pressure from these insects was not high enough to measure treatment effects at this trial site.

Plant hopper damage

All insecticide treatments performed significantly better then the control treatment. There was no significant difference ($P>0.05$) comparing the industry standard insecticides to the other injection treatments. This being said the natural pest pressure of plant hoppers was low over the growing season at this farm location possibly due to the higher frequency of whole farm pesticide use.

Mango scale

All pesticide treatments performed significantly better then the control treatment and were not significantly different to the industry standard insecticide treatment ($P>0.05$). All injection treatments had no scale damage to the fruit except for the injection treatments Exp1 and Exp2. The industry standard foliar treatment also had no scale damage to the fruit.

Pink wax scale / sooty mould

All pesticide treatments had significantly less damage to the fruit when compared to the control treatment. Damage was recorded only on the Exp2 and industry standard treatments but these were not significantly different to the other pesticide treatments ($P>0.05$).

Mango seed weevil counts - destructive fruit assessments

There were very low populations of mango seed weevils collected from all fruit from this trial site (3.8% natural infestation collected from untreated fruit). All pesticide treatments performed significantly better ($P<0.05$) than the control treatment and were not significantly different to each other. Only the industry standard methidathion and the injection treatment Exp1 had a small level of seed weevil present in the fruit.

Fruit damage assessments for tree injection and basal trunk spray treatments under medium pest pressure (trial site 2)

This farm site had medium whole farm pesticide use and had the basal trunk spray treatment of PentraBark® and thiamethoxam included in the trial. The following damage results were recorded for fruit spotting bug, Helopeltis sp, flower/fruit eating caterpillars, plant hopper, mango scale, pink wax scale and mango seed weevil (Table 4).

Fruit spotting bug damage

All pesticide treatments including the basal trunk sprays of thimethoxam had no fruit spotting bug damage and performed significantly better than the control treatment. Only a small level of fruit damage was recorded in the control treatment at this farm site as fruit spotting bug populations where low during the season.

Helopeltis sp.

No Helopeltis bug damage was recorded at this trial site.

Flower/Fruit eating caterpillar damage

Very little damage was recorded to the fruit surface from flower and fruit eating caterpillars for all treatments including the control and industry standard insecticide. There were no significant differences recorded between all treatments and the control and industry standard insecticides.

Plant hopper damage

No plant hopper damage to the fruit was recorded at this trial site.

Mango scale

The mango scale population was high at this trial site. The best performing treatment was the Exp2 injection treatment which performed significantly better ($P<0.05$) at this site than all the other treatments for suppressing mango scale. The next best treatment was the thiamethoxam injection treatment which performed better than the industry standard pesticide (methidathion) and the control treatment. The thiamethoxam injection treatment was not significantly better than the basal bark trunk treatment, imidacloprid injection, dimethoate injection and Exp1 treatments which where equally effective. The basal bark trunk treatment, imidacloprid injection, dimethoate injection and Exp1 treatments were significantly more effective than the control treatment for suppressing mango scale and were equally as effective as the industry standard pesticide.

Pink wax scale / sooty mould

No pink wax scale and sooty mould damage to the fruit was recorded at this trial site.

Mango seed weevil counts - destructive fruit assessments

There were very low natural populations of mango seed weevil found at this trial site (5% natural infestation collected from untreated trees). The basal trunk treatment of thiamethoxam as well as the thiamethoxam, imidacloprid, dimethoate injection treatments had no mango seed weevil present in the fruit at this trial site. The industry standard insecticide was not significantly different when compared to the control and other treatments but did have some mango seed weevil present in the fruit. Both Exp1 and Exp 2 had some seed weevil present in the fruit but was significantly lower than the control and not significantly different to the other treatments.

Fruit damage assessments for tree injection treatments under high pest pressure (trial site 3)

This farm site had no pesticides used for 4 years and high natural pest pressure. The following damage results were recorded for fruit spotting bug, Helopeltis sp, flower/fruit eating caterpillars, plant hopper, mango scale, pink wax scale and mango seed weevil (Table 5).

Fruit spotting bug damage

There were low levels of fruit spotting bug damage on mature fruit at this trial site. The thiamethoxam, imidacloprid, dimethoate, Exp1 and Exp2 injection treatments had no damage caused by fruit spotting bug feeding to mature fruit. Although these treatments had no damage caused by fruit spotting bug they where not significantly different to the control and industry standard insecticide (methidathion). As the seasonal fruit spotting bug population levels were too low to assess pesticide and application efficacy these studies will need to be repeated to evaluate their effects on fruit spotting bugs in mango.

Helopeltis sp.

No Helopeltis bug damage was recorded at this trial site.

Flower/Fruit eating caterpillar damage

Caterpillar fruit damage was reasonably high at this location because of no pesticide use. As expected the dimethoate injection and industry standard pesticide were the best treatments and were significantly more effective ($P<0.05$) than the other treatments and the control. All other treatments were not significantly different to the control treatment.

Plant hopper damage

A high number of plant hoppers were present at this trial site. All the injection treatments were not significantly different from each other but only the Exp1 and Exp2 treatments were significantly more effective then the control treatment ($P<0.05$) under high pest pressure. The industry standard pesticide was the best performing treatment.

Mango scale

The natural mango scale populations during this trial were high. All pesticide treatments were equally effective when compared to each other and the industry standard insecticide methidathion. All injection treatments were significantly more effective ($P<0.05$) in reducing scale populations when compared to the control treatment.

Pink wax scale / sooty mould

A moderate population of pink wax scale was present during this trial. All pesticide treatments performed significantly better than the control ($P<0.05$). The thiamethoxam, imidaclorprid, dimethoate and Exp2 injection treatments had no pink wax scale and sooty mould on the fruit at this location. All injection treatments had significantly lower populations than the industry standard pesticide methidathion.

Mango seed weevil counts - destructive fruit assessments

There was a high natural population of mango seed weevil present at this trial site (36.3%). All pesticide treatments were equally effective compared to the industry standard pesticide methidathion and had significantly lower populations of weevils in the fruit ($P<0.05$) when compared to the control treatment.

Table 3. The results summarised are the treatment insect damage means at trial site 1 (high pesticide use), the F-Probability associated with the main effect of treatment, 95% least significant difference (LSD) and the residual degrees of freedom. Where a significant main effect of treatment was identified, pairwise comparisons were performed using the 95% LSD.

Trial site 1 high whole farm pesticide – low natural pest pressure	Fruit Spotting Bug Damage	Helopeltis bug damage	Flower/Fruit Eating Larvae Damage	Plant Hoppers	Mango Scale	Pink Wax Scale/Sooty Mould	Mean % seed weevil infestation per treatment sample
Control	0.113 a	-	-	0.275 a	0.225 a	0.375 a	0.038 a
Thiamethoxam - inj	0.000 a	-	-	0.000 b	0.000 b	0.000 b	0.000 b
Imidacloprid - inj	0.000 a	-	-	0.000 b	0.000 b	0.000 b	0.000 b
Dimethoate - inj	0.000 a	-	-	0.000 b	0.000 b	0.000 b	0.000 b
Exp1 - inj	0.000 a	-	-	0.000 b	0.025 b	0.138 b	0.013 b
Exp2 - inj	0.000 a	-	-	0.000 b	0.075 b	0.000 b	0.000 b
Methidathion – fol *	0.075 a	-	-	0.000 b	0.000 b	0.138 b	0.013 b
F-prob	0.147	-	-	<0.001	<0.001	0.002	0.033
95% LSD	0.1028	-	-	0.0362	0.0794	0.1797	0.0239
df residual	18	-	-	18	18	18	18

*Means in the same column with a letter in common are not significantly different (p > 0.05). * Industry standard insecticide*

Table 4. The results summarised are the treatment insect damage means from trial site 2 (Medium pesticide use), the F-Probability associated with the main effect of treatment, 95% least significant difference (LSD) and the residual degrees of freedom. Where a significant main effect of treatment was identified, pairwise comparisons were performed using the 95% LSD.

Trial site 2 medium whole farm pesticide – medium natural pest pressure							
	Fruit Spotting Bug Damage	Helopeltis bug damage	Flower/Fruit Eating Larvae Damage	Plant Hoppers	Mango Scale	Pink Wax Scale/Sooty Mould	Mean % seed weevil infestation per treatment sample
Control	0.025 a	-	0.175 a	-	0.675 a	-	0.050 a
Thiamethoxam - inj	0.000 b	-	0.100 a	-	0.262 c	-	0.000 b
Imidacloprid - inj	0.000 b	-	0.075 a	-	0.312 bc	-	0.000 b
Dimethoate - inj	0.000 b	-	0.000 a	-	0.312 bc	-	0.000 b
Exp1 - inj	0.000 b	-	0.175 a	-	0.312 bc	-	0.013 b
Exp2 - inj	0.000 b	-	0.125 a	-	0.112 d	-	0.013 b
Methidathion – fol *	0.000 b	-	0.000 a	-	0.375 b	-	0.025 ab
Thiamethoxam and PentraBark®	0.000 b	-	0.125 a	-	0.312 bc	-	0.000 b
F-prob	0.024	-	0.118	-	<0.001	-	0.017
95% LSD	0.0150	-	0.1461	-	0.103	-	0.0289
df residual	21		21	-	21	-	21

*Means in the same column with a letter in common are not significantly different (p > 0.05). * Industry standard insecticide*

Table 5. The results summarised are the treatment insect damage means from trial site 3 (no pesticide used), the F-Probability associated with the main effect of treatment, 95% least significant difference (LSD) and the residual degrees of freedom. Where a significant main effect of treatment was identified, pairwise comparisons were performed using the 95% LSD.

Trial site 3 No whole farm pesticide – high natural pest pressure							
	Fruit Spotting Bug Damage	**Helopeltis bug damage**	**Flower/Fruit Eating Larvae Damage**	**Plant Hoppers**	**Mango Scale**	**Pink Wax Scale/Sooty Mould**	**Mean % seed weevil infestation per treatment sample**
Control	0.113 a	-	0.312 a	0.462 a	0.800 a	0.525 a	0.363 a
Thiamethoxam - inj	0.000 a	-	0.312 a	0.312 ab	0.312 b	0.000 c	0.025 b
Imidacloprid - inj	0.000 a	-	0.250 a	0.312 ab	0.400 b	0.000 c	0.025 b
Dimethoate - inj	0.000 a	-	0.000 b	0.312 ab	0.450 b	0.000 c	0.025 b
Exp1 - inj	0.000 a	-	0.250 a	0.250 b	0.462 b	0.138 c	0.050 b
Exp2 - inj	0.000 a	-	0.250 a	0.250 b	0.312 b	0.000 c	0.025 b
Methidathion – fol *	0.075 a	-	0.000 b	0.062 c	0.462 b	0.312 b	0.075 b
F-prob	0.165	-	0.044	0.016	0.010	<0.001	<0.001
95% LSD	0.1054	-	0.2447	0.1871	0.2454	0.1426	0.0647
df residual	18	-	18	18	18	18	18

*Means in the same column with a letter in common are not significantly different (p > 0.05). * Industry standard insecticide*

Across site evaluation of tree injection treatments

Across the three trial sites, the tree injection treatments received higher fruit damage in farms that had lower whole farm pesticide use. This was an indication in general of a higher natural pest populations being present.

The overall efficacy and the potential for using tree injection as a method for controlling the major mango pests worked effectively where pest populations where low to moderate (8-14 insecticide applications over the season) at the dose rate tested. The efficacy of the dose rate tested over the three trial sites for all treatments reduced as the natural pest pressures increased for most pests evaluated during these trials but were in general more effective than the control treatments. Under high pest pressure (Trial site 3) the injection treatments were less effective and sometimes where not as effective as the industry standard insecticide, indicating that further research is needed to determine optimal dose rates (Table 5).

With possible higher dose rates needed per treatment for high pest pressures and the high labour costs associated in treating every tree with injection, it could be argued that this application method might not be economically viable. This would depend on the efficacy duration of the injection treatments under high pest pressures, the optimal dose rates required and the frequency of normal pesticide applications.

Basal bark trunk treatment

Overall, this treatment performed equally as effective as the industry standard insecticide under low pest pressures at the single trial site tested. Further trials are required to evaluate this treatment further. If this application method can be shown to be as effective as the industry standard insecticide under a larger trial with higher pest pressures, then it would be a preferred pesticide application method compared to tree injection. This is because of the lower costs and less labour associated with application. It is recommended that this method be further evaluated for potential use.

3.7.2 Semiochemistry of fruit spotting bugs and mango seed weevil

Fruit spotting bug

Pheromones - The 220 MW compound was present in a number of aeration samples taken from male A. lutescens and analysed by gas chromatography. However, in some of the samples not immediately analysed this compound apparently oxidised and was not detectable. This was a phenomenon experienced previously with this particular compound.

After considerable discussion on the mass specs of the 220 compound, some false leads and considerable deduction, it was concluded that it must be a particular epoxide. Its precise identity is not being revealed at this stage because of uncertainty about the commercial value of any IP. This epoxide, which is known from numerous plants but not from insects, was formulated in Jeff Aldrich's laboratory in the US and subsequently matched to the compound observed in a recent aeration taken from A. lutescens males. This now needs to be repeated to confirm the presence of all the suspected pheromone components in the one aeration sample. The makeup of the pheromone for A. lutescens appears to follow a similar pattern to that for A. nitida. And even though the actual pheromone components are different there are clear chemical (structural) relationships between the two pheromones.

After final verification of the identity of the 220 MW compound GC-EAD testing of single and multiple pheromone components and rates can be undertaken. Once completed, the results will guide testing of combinations and rates of components in the field. Depending on the amounts of material required for field trials the services of a synthetic chemist capable of producing difficult or pure compounds may be required. Close collaboration with the USDA should maximise our knowledge of the compounds and their deployment. If the effectiveness of the synthetic pheromone as a monitoring tool can be determined then the possibility of employing them in a control capacity can be assessed. This might include looking at mating disruption, enhancing egg parasitoid activity or using pheromone-chemosterilant combinations to significantly reduce bug populations at the local level. Rationalising the number of pesticide applications would be the most fundamental gain from the acquisition of an effective pheromone.

Plant kairomones – None of the single compounds listed in Table 3 attracted spotting bugs to the panels. However, where near pheromone components were combined with β-caryophyllene a small number of adult bugs were captured. The three treatments that caught bugs were trans-nerolidol + β-caryophyllene, α-farnesene + β-caryophyllene and trans-nerolidol + linalool + α-farnesene + β-caryophyllene. The overall ratio of ♂♂:♀♀ captured was 3:1. Various other insects were caught on the panels but there was no significant association between particular attractants and the other fauna.

As near pheromone components in combination with other plant compounds offer a certain level of response from bugs, the combinations of these compounds need to be refined and rates of emission varied to see whether higher levels of attractancy can be achieved. Synergism between pheromone components and plant kairomones may be fundamental to the attraction of bugs. This may explain bug preferences for plants such as Murraya paniculata, which possess pheromone relatives like trans-nerolidol (Olawore et al., 2005).

Photo 5. Panels emitting various plant volatiles to test attractancy to fruitspotting bugs.

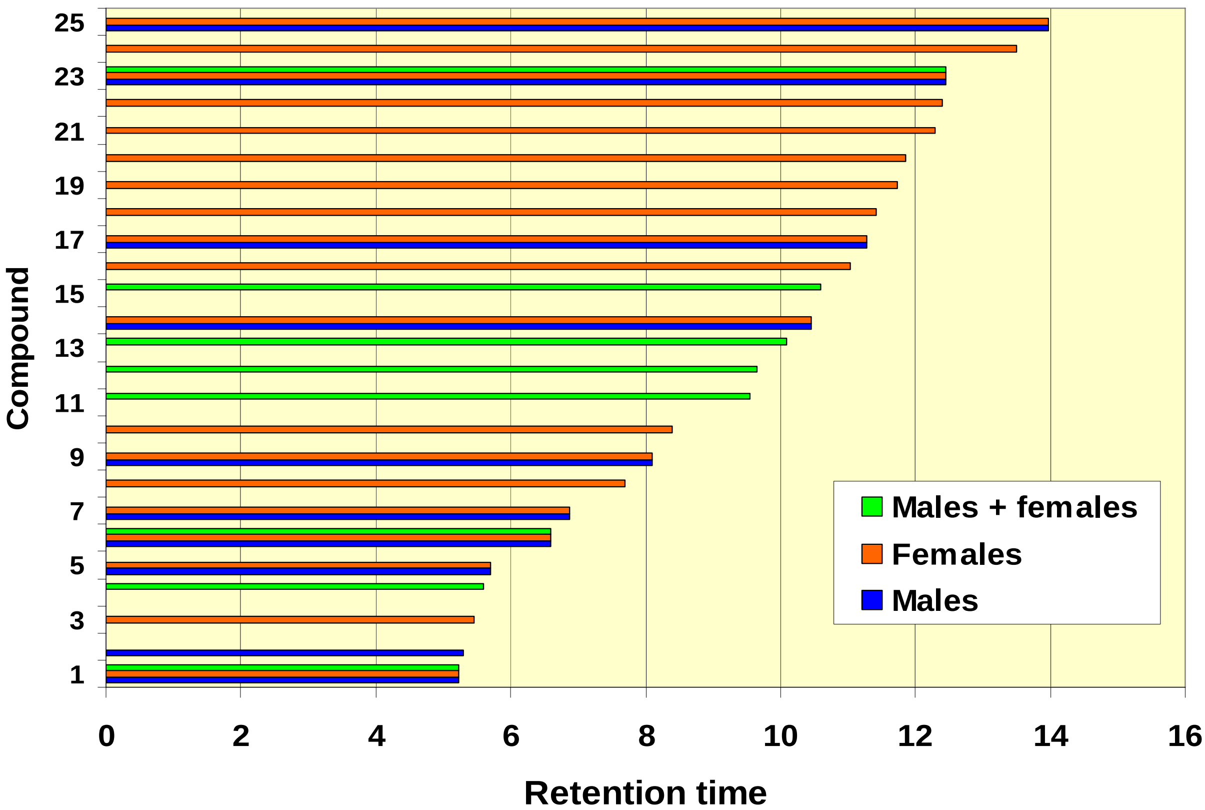
Mango seed weevil

Good GC profiles were obtained for all the SPME collections taken, with numerous peaks in the sector where chemicals likely to be pheromones might be expected. There appeared to be many peaks common to both males and females of each individual species, as well as some unique ones. The peaks displayed by the two species appeared to be largely different, although a few common to both are suggested. For mango seed weevil there appeared to be no significant peaks that weren't mango-derived compounds. Prominent peaks (see Figure 3) included several straight-chain and many mono- and sesqui-terpenes. The latter appear to be particularly common.

The major compounds collected from male, female, or male and female mango seed weevils or their frass appear to be mango compounds, but whether they are sequestered for pheromone production or play some role in weevil attraction is not yet known. These types of compounds are not typical of weevil pheromones but mango seed weevil belongs to a group in which the pheromones are poorly known. Specific mango compounds may play an important role in weevil attraction and these need to be part of the focus of future work. Examining the minor peaks in the GC profiles for pheromone-like compounds remains a task for an experienced organic chemist and it is hoped that this will be completed within the next 12 months. The successful identification of significant compounds could determine whether an effective monitoring tool for mango seed weevil is achievable

Photo 6. SPME samplers collecting mango seed weevil volatiles.

Figure 6. The major GC peaks from SPME samples taken from mango seed weevil pooled for a number of sampling occasions



3.8 Conclusions and recommendations

The following conclusions and recommendations are given on the current pest status of fruit spotting bugs and alternative control strategies of pests in mango.

3.8.1 Conclusions

Pest status of fruit spotting bugs

The seasonal pest population levels of fruit spotting bugs can be variable from season to season. This being said the bugs peak seasonal activity periods for both the Kensington Pride and R2E2 varieties in both production regions in Qld (Burdekin and the Tablelands) was during the flowering to fruit set periods. Consequently, fruit spotting bug activity occurred during critical phases in the crop's phenology. The bugs were observed actively feeding on newly emerging flower panicles. The feeding sites caused by the fruit spotting bugs were tending to act as entry points for disease development (Anthracnose) after just 1 week of feeding.

At fruit set the bugs were observed actively feeding on the fruit panicles and the developing fruit. This was resulting in high levels of premature fruit drop. High infestation levels of fruit spotting bugs on some trees were resulting in no fruit set on infested trees at some locations within the orchard. The studies confirm the hot spot theory that migration of the bugs from other areas is occurring from flowering to fruit set. After this period the bug populations were low for the rest of the growing season. Even though the bugs were confined to hot spots within the orchards surveyed their ability to cause economic loss on infested trees was demonstrated.

Monitoring for fruit spotting bug orchard hotspots should be carried out during flowering to fruit set (up till duck egg size fruit). Being able to treat hot spot areas within the orchard as opposed to complete orchard sprays should help reduce the chemical load in the environment. This should help reduce the frequency and volume of pesticides needed to control fruit spotting bugs in mango. Although infrequently seen over the growing season, fruit spotting bugs should be considered a major pest of economic importance if present during flowering to fruit set in mangos. Control of fruit spotting bugs within orchard hot spots during flowering to fruit set should be conducted to reduce economic loss.

Alternative control options for mango pests

The systemic insecticides evaluated for tree injection at the single dose rate tested (3 g ai/tree) were shown to be effective for controlling most of the mango pests when compared to the control and industry standard pesticide under low pest pressures. Under high pest pressure the treatments became less effective at the dose rate tested with the industry standard pesticide performing better then the injection treatments for some insects (pink wax scale, plant hoppers). All injection treatments except for the dimethoate injection treatment were not effective in controlling flower and fruit eating caterpillars and other control measures would need to be in place to control these insects. Overall, the most effective tree injection treatment would be dimethoate as it covered most of the pest spectrum in these trials but at the dose rate tested was not as effective under high pest pressure for some insects when compared to the industry standard insecticide.

A lot of work is still required before tree injection could be recommended for use in mangoes. Although shown to be partially effective against some insect pests under low pest pressure, optimal dose rates need to be established so that control failures do not occur under high pest pressures. Studies should include fruit and leaf residue analysis over time, further insecticide efficacy studies based on new dose rates, pesticide formulation development for better tree uptake and treatment application timing. These studies will need to be replicated in different regions and climates to examine the effects of chemical efficacy and biodegradation.

Basal trunk spraying systemic insecticides with PentrBark® should be further investigated. Although this treatment was only carried out on one trial site under low pest pressure it was as effective as all the tree injection treatments and the industry standard insecticide. As the treatment was only evaluated at one trial site, it needs to be tested in larger field trials against higher pest pressure. If shown to be effective the basal trunk treatment using systemic pesticides would be a preferred pesticide application method because application is less labour intensive than tree injection.

Semiochemistry -Fruit spotting bug

There is now reasonable confidence that all the major components of the male sex pheromone of A. lutescens have been identified. The previously unknown 220 MW compound is evidently an epoxide, an observation consistent with the finding for A. nitida. Once reconfirmed, combinations of pheromone components can be evaluated in the laboratory and then assessed in the field as both monitoring and control tools. Near pheromone compounds derived from plants in combination with certain common plant volatiles appear to elicit some response from adult bugs in the field, but this needs to be explored further by refining the mixes of compounds and rates of emission.

Semiochemistry -Mango seed weevil

There is no clear evidence yet that mango seed weevil produces a pheromone. However, with appropriate input from an organic chemist there is an opportunity to more thoroughly examine the components of aerations collected from adult weevils. In addition, weevils may respond to mango-specific compounds and this should be an avenue of future study.

3.8.2 Recommendations

Pest status of fruit spotting bugs

Industry should use the findings on hot spots to refine control strategies of fruit spotting bugs in mango. Monitoring for fruit spotting bug should be carried out during flowering to fruit set looking for damage symptoms and within orchard hotspots.

Within orchard hotspots should be treated immediately if fruit spotting bugs are present during flowering to fruit set in mango to reduce economic loss.

Monitoring for the presence of fruit spotting bugs is an ongoing concern. In addition to attempts to develop a visual monitoring system for these pests during flowering to early fruit set, research should continue into the chemical ecology of the bugs

Alternative control options for mango pests

Basal bark applications of systemic pesticides should be further evaluated as a potential treatment for reducing the chemical load in the environment to help promote biological control systems

The potential use of the biopesticides Beauvaria bassiana and Metarhizium anisopliae should be tested for efficacy against fruit spotting bugs and other pests in mango. This could be used as a soft alternative to broad spectrum pesticides during flowering to fruit set which is a critical phase in the crop’s phenology.

Semiochemistry –Fruit spotting bug and mango seed weevil

The identity of the 220 MW compound in the A. lutescens pheromone needs reconfirmation together with the other pheromone components. GC-EAD responses to single and combined pheromone components then need to be determined to refine combinations and rates for field testing.

Further exploration of near pheromone compounds in combination with specific plant volatiles as attractants for spotting bugs should be undertaken through electroantennogram studies and in the field research.

The minor peaks in the GC profiles taken from mango seed weevil adults need to be evaluated by an organic chemist to determine whether prospective pheromones are present.

The response of mango seed weevil adults to a range of mango-unique volatiles needs to be ascertained in the laboratory or field.

3.8.3 Communication and dissemination activities

Information on the progress and the results of the research and activities carried out in the pest management project was extended to growers and interested persons by workshops and industry newsletters and conference presentations.

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3.9.2 List of publications produced by project

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4 Mango Supply Chain Management Philippines and Australia

Objective 3: Improvements to current practices and conditions for managing mango supply chains.

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4.2 Executive Summary

Philippines

Optimizing post-harvest and agribusiness systems to maintain fruit quality and improve marketing efficiency is one of the key strategies of PCARRD/UPLB/ACIAR project, “Integrated Pest Management and Supply Chain Improvement for Mangoes in the Philippines and Australia”. The main objective of the supply chain improvement component is to identify and trial improvements to current practices and conditions for managing mango supply chains.

Improvement measures were tested to optimize the supply chain for mangoes in the Philippines. Such measures were identified after a thorough analysis of the supply chain which is the first phase of the project. Among the problems identified were low productivity, poor fruit quality, logistics-related constraints, poor chain coordination, and market inefficiencies.

Problems on low productivity and poor fruit quality were evident from low yield and recovery of quality fruits. Quality further deteriorates along the chain due to rough and repeated handling leading to mechanical damage and onset of diseases primarily, anthracnose and stem-end rot. Farmers were clustered and the application of Integrated Crop Management (ICM) was promoted to address these problems.

Product distribution along the chain was traced and documented covering the upstream (farm level) all the way to the downstream (export market) supply chain nodes. Salient findings on where quality and quantity losses occur were discussed with supply chain champions (exporter-cooperators). Adoption of hot water treatment (HWT) was promoted to control postharvest diseases and was demonstrated in actual field trials. A detailed business plan for the integration of HWT in packinghouse operation was also proposed to potential investors.

Traders or exporters who source mangoes from Mindanao, particularly Davao, are faced with the problem of limited air freight capacity. Mangoes are regarded as filler load and are often bumped–off from loading especially during periods when the volume of premium load (e.g. tuna) is high. To address these logistics-related issues, the viability of sea shipment using ventilated van as an alternative to air transport was explored.

Input cost has increased several folds during the last ten years while the price of mango practically remained the same if not even lower in real terms. Rough farm-to-market road is also a concern since it contributes to losses due to mechanical damage notably compression (called bumps by the traders/procurement agents) and abrasion. These logistics-related constraints require policy interventions that will provide adequate facilities to better distribute commodities especially for those coming from Mindanao.

Poor chain coordination and inefficient market were prevailing constraints along the chain. Disparity in quality standards along the different distribution points and unclear responsibility

centers in transit were manifestations of poor chain coordination. A multi-layered trading/marketing system was an evident source of market inefficiencies as the chain involves some players performing redundant functions. Information asymmetry also causes inefficiencies as some players (e.g. locator/dicer) have greater access to certain market information. Adversarial marketing exists as farmers sell their mangoes to the highest paying trader even when there were prior arrangements with another trader, i.e. 'pole-vaulting' tactic.

Relational marketing was promoted between farm clusters and exporter-cooperators aimed at building trust between these key players and developing a more long term business relationship. Initial attempt at direct market linkage was unsuccessful as the farmers tend to "pole-vault" once offered with a higher price by other traders. Such "pole-vaulting" practice erodes whatever trust has been gained initially and undermines the relationship being established.

Australian Component

Optimizing post-harvest systems to maintain fruit quality and improve marketing efficiency was one of the key strategies of the Australian component of; "Integrated Pest Management and Supply Chain Improvement for Mangoes in the Philippines and Australia". The main objective of the supply chain improvement component is to identify and trial improvements to current practices and conditions for managing mango supply chains.

While improvements to domestic supply chains for Australian mangoes has been a high priority or over two decades, problems with export supply chains and a need to take advantage of new export protocols to China was highlighted in industry strategic plans. This project was a pilot program to establish export supply chains for direct market access into China. A participatory approach was used to generate and transfer information to build the knowledge and capacity of Australian businesses to capture this market opportunity.

A whole of chain approach led to team involvement in arrange of activities including advice on orchard management including seed weevil control /inspections where necessary, advice and training on managing quality from harvest to the retail shelf design of export packaging and monitoring of practices, conditions and quality from harvest to retail shelf and independent inspections and reports on outturn quality for each consignment. This work complimented market research and product launches and economic analysis of the profitability of export supply chains. A major focus was the communication activities which focused on reporting and the development of information products for collaborators and industry.

The project successfully supported four consignments of mangoes exported to China. All 5 collaborators gained experience in preparing export consignments.

Significant quality loss occurred during handling in the supply chain for each consignment. The causes of quality loss were, physical damage, sapburn and skin browning during harvesting, poor temperature management from the packhouse to the VHT facility and to the importer in Shanghai, resulting in fruit being too ripe and delays due to incorrect documentation resulting in fruit being too ripe.

These issues were addressed with improved temperature management during treatment, transport and conditioning and improvements in harvesting and handling.

Evaluation of project activities with project collaborators were regarded as useful The following activities were the most useful:

- Support for orchard inspection for freedom from quarantine pests
- Provide advice and training on managing quality from harvest to retail shelf
- Monitoring practices, conditions and fruit quality from harvest to retail shelf
- Consumer focus group research
- Communication of information

4.3 Background

Supply chain management (SCM) simply refers to the management of the entire set of production, distribution and marketing processes by which a consumer is supplied with a desired product. Folkers and Koehorst (1998) as cited by Woods (2004) define a supply chain as a set of interdependent companies/entities that work closely together to manage the flow of goods and services along the chain in order to realize superior customer value.

Supply chain management is a systems approach and draws contributions from various disciplines. Areas for SCM improvement may be categorized into three: (1) improving economic efficiency; (2) improving business relationship; and (3) improving operational efficiency. Transaction cost economics and agency theory constitute the theoretical underpinning of improving economic efficiency. The former refers to the cost associated with the exchange of goods and services, including the cost of acquiring information and the costs of negotiating and enforcing contracts, among others. The latter is concerned with defining the most appropriate contract which strikes the best balance between firms in relation to information asymmetry, uncertainty of outcomes and risk aversion. Network theory and relationship marketing are the fundamental basis in improving business relationship. Network theory underscores the interdependence (directly and indirectly) of firms and the benefits of working cooperatively. Relationship marketing is the best example of this, where firms move away from adversarial buyer-seller relationship to cooperative/collaborative marketing strategy based on commitment and trust. Finally, operations management and logistics provide the conceptual and analytical tools in improving operational efficiency (Woods, 2004).

In agri-business products, an agri-food chain is nothing more than a supply chain which produces and distributes an agricultural or horticultural product and where product flows and information flows takes place simultaneously (Bijman 2002 as cited by L. Armayan et al 2005). Agri-food supply chains differs from other supply chain due to the following: (1) the nature of production, which is partly based on biological processes, thus increasing variability and risk; (2) the nature of the product, which has specific characteristics like perishability and bulkiness that require a certain type of supply chain; and (3) the societal and consumer attitudes towards issues like food safety, animal welfare and environmental pressure.

In response to the evolving agriculture, an adoption of a new approach to agribusiness management is inevitable. The whole research and development (R&D) system has to adopt supply chain as a framework if it intends to remain relevant. The adoption of supply chain management framework and methodology can help improve the production, distribution and marketing processes to meet consumers' requirements in terms of quantity, quality and price of the products. Supply chain research implies managing the relationship among primary producers and the traders for more competitive business venture and efficient flow of goods and services.

In the Philippines, industry clustering is the closest concept to supply chain management (SCM). Industry clustering was introduced to SMEs in 1999 through the Philippine Export Development Plan which mandated clustering as the main strategy for SME development. It is defined as the grouping of firms, allied business and buyers - all operating under an environment shaped by the government, the physical and cultural heritage and available infrastructure. It is also the grouping of interrelated or interlinked activities composed of industries, suppliers, required support services, infrastructure and institutions (Tablizo 2001).

Supply chain management (SCM) is still an emerging concept and a new approach for R&D in the Philippines. Existing literatures can be categorized into two: (a) SCM related and (b) SCM studies. The former are those that have been done using other frameworks (e.g. marketing) but generated information related to supply chain analysis. The latter refers to studies which adopted supply chain management as a conceptual framework. These studies considered both the horizontal and vertical alliances in the chain.

There are a number of studies using other frameworks but generated supply chain –related information. One of these was the PCARRD implemented project on, " Marketing of agricultural commodities by producer groups in the Philippines". The project covered various commodities and focused on smallhold farmers. It traced the flow of various agricultural products, documented the activities and processes involved and examined the efficiency with which the small farmers themselves can carry out these activities. A more recent project, "Development of Innovative Marketing Strategies for Small-hold Banana Growers" was funded by PCARRD/DOST conducted a thorough assessment of the distribution system for banana in Mindoro and Quirino provinces. Although the framework was marketing in nature, the study generated a lot of information related to the supply chain maps for banana in these provinces. Other supply chain related studies were those which evaluated the logistical system of Philippine Agriculture (Ordoñez, 2005), while others examined contractual arrangements in production, such as the institution of agricultural contracts in abaca (Lumayag, 1979), mango (Brown, 1992), vegetable seed (Frando, 1998), cavendish banana (Duritan, 1998) and poultry operation (Mabesa, 2000).

The only existing studies on SCM in the Philippines are those funded by the Australian Centre for International Agricultural Research (ACIAR). The first study, entitled, "Improving the efficiency of the agribusiness supply chain and quality management for small agricultural producers in Mindanao" has been completed recently. The objectives were to (1) understand the various production and marketing systems being practiced by the farmers; b) examine efficiency of the agribusiness supply chain for vegetables; c) identify the extent to which the farmers are able to satisfy the needs of the market intermediaries and vice versa; d) identify the extent to which agricultural marketing cooperatives can improve farmer's income; e) facilitates greater adoption of quality management systems; and f) suggest appropriate policies and strategies.

Optimization of the technical postharvest and agribusiness systems to maintain fruit quality and improve marketing efficiency is one of the key strategies of the current ACIAR/PCARRD/UPLB program (PHT/2003/071) entitled, "Integrated Pest Management and Supply Chain Improvement for Mangoes in the Philippines and Australia." The supply chain project component of this program requires a thorough assessment of existing supply chain for mango with the view of working with selected mango supply chains to identify and test areas for improvement. The supply chain component uses product quality monitoring as a mechanism for engaging with and creating links between chain members.

The Australian Mango Industry Association (AMIA) in their 2004-2009 strategic plan identified as one of their objectives "to support the development of new export markets and maintain and further develop existing markets". The long term trend indicates that production is growing at 8% per year, with production likely to double within nine years. The amount of mangoes exported has remained static at 5% of total production. With future increases in supply over the next decade, export markets must be developed to maintain profitability for producers and their supply chain partners.

Key constraints to industry development related to export identified in the AMIA strategic plan are: variability in fruit quality, cost and availability of air freight and difficulties with sea freight. Two actions recommended to achieve export development are (1) commission a "Better Mangoes" cool chain project and (2) coordinate an integrated export marketing trial in selected markets targeting wholesale and retail sectors to build functional systems that provide sustainable markets. A major focus of the industry is to improve exports to Hong Kong and China. This was supported by an early project visit which identified in common with the Philippines, the supply chain for Australian fruit to Hong Kong is also disjointed with little communication between supply partners about fruit condition and there are real issues with poor handling conditions on arrival. The high transaction costs associated with these exports reflect the disjointed chain. Efforts to lower costs using sea freight have been hampered by poor systems before and after sea freight.

The air freight option using passenger airline services is limited by cost and available freight capacity. The use of sea freight overcomes the capacity constraint but introduces other problems. Sea freight is used for mangoes to a limited extent throughout the world and mostly with variable success. Where sea freight is used, the varieties are typically 'Tommy Atkins' and other green/red skin varieties which are known to have longer green life than Australian varieties. Exporters in both Australia and other countries have reported their experiences to the authors, with most lacking confidence in the process.

China/ Hong Kong currently imports approximately 41 000 tonnes of fresh mangoes, with the main countries supplying mangoes being Philippines, Taiwan, Australia, Thailand and Indonesia (AgEcon Plus Ltd). Australia is a minor supplier with 831 tonnes exported in 2004/05 (2% of total imports).

Australian mangoes have been sold in China for many years by unofficial trade through Hong Kong. However, this trade does not allow promotion and expansion of the market for Australian mangoes and the Chinese Government are also threatening to close this trade route. Direct market access to China has recently been gained through a quarantine agreement between the Chinese and Australian Governments. The detailed protocols are described in the "Work Plan Australian Mango Export to China".

Recent visits to China by exporters and representatives from AMIA and DPI&F Queensland had confirmed that the opportunities for market development were substantial but that were specific supply chain and marketing issues.

These were addressed by a project team with support from this ACIAR supported project "Integrated Pest Management and Supply Chain Improvement for Mangoes in the Philippines and Australia."

The purpose of this project was to assist supply chain businesses to export mangoes directly to China under the protocols described in the China Mango Export Work Plan.

4.4 Objective

To identify and trial improvements to current practices and conditions for managing mango supply chains.

The expected outputs are:

- Qualitative and quantitative baseline data on where and why product quality is lost in targeted supply chains. Philippines & Australia
- Spatial, temporal and linkage maps and analysis reports of supply chains and strategies, technical improvement trial plans. Philippines & Australia
- Information on product quality; price differentials and handling requirements for targeted markets. Philippines & Australia
- Evaluation data and recommendations for improvement of practices and systems that will enhance benefit flows to farmers in targeted supply chains. Philippines & Australia.

4.5 Methodology

Philippines.

The study employs the supply chain management framework. The framework consists of two phases: (1) Supply Chain Analysis and (2) Supply Chain Optimization. The former covers supply chain mapping and identification of areas for improvement, while the latter involves testing and trial runs of these interventions.

Supply chain mapping entails the identification of the members of the supply chains, flow of products, information and payments, activities and services conducted by supply chain members, critical logistic issues, key decision makers and external influences. A synthesis of relevant studies was done first to establish an overall picture of the industry in the study sites. Surveys as well as key informant interviews were then conducted to validate secondary information and to answer more specific questions related to supply chain mapping. A set of questionnaires was formulated for this purpose and was designed to answer the following key questions, among others:

1. Who are the key customers and what are their product requirements (especially quality standards)?
2. How do product, information and money flow through the supply chain?
3. What are the activities and services provided at each step in the supply chains?
4. Who are the key players and what are their respective roles?
5. What are the critical logistic issues?
6. What are the external influences?

Series of field visits to major mango supply areas in the country such as Davao del Sur, Guimaras/Iloilo, Abra and Cebu were made. Product flow was traced from the farm to assembly areas, to buying stations, to processors, to local retail and supermarkets, to the exporter's warehouse, and to Hong Kong wholesale and retail market. While tracing the flow of products in the chain, key supply chain players such as farmers, contract growers, wholesaler/assemblers, procurement agents, processors, retailers, supermarket consigners, exporters and importers were interviewed

The focus of the analysis is to identify impact on product quality of current practices. For each supply chain, at least one shipment from the product source to the ultimate destination was traced to: (1) validate/verify all information in the supply chain map initially drawn; (2) monitor and document all practices at each stage of the chain; (3) determine and quantify all costs and margins associated with such practices; and (4) changes in product volume and quality along the chain.

After the supply chain map had been validated and the impact of various practices along the chain was established, areas for improving the supply chain were identified. Supply chain champions were then identified to spearhead the identified interventions. Among others, identification of supply chain champions took into consideration the structure of power along the chain and the relative interest of members with regards to improvement in the chain. Participatory approach was employed as much as possible to achieve consensus in identifying the needed interventions. It must be recognized that any change in the existing chain will affect certain interest of members and may bring about issues, which the chain members alone can resolve.

Improvement measures were guided by the six principles of successful SCM: (1) a focus on customers and consumers; (2) the chain creates and shares value with all its members; (3) making sure the product fits the customer's specification; (4) effective logistics and distribution; (5) an information and communication strategy that includes all chain members; and (6) effective relationship that give leverage and shared ownership.

Purposive sampling was used since the chain has to be traced from the source farm to the ultimate market. Primary data were gathered from interviews of the various players from producers, traders, exporters and logistic suppliers, among others. Key informant interviews were also conducted to validate some important information. Secondary data were obtained from related literatures and statistics primarily published by the Bureau of Agricultural Statistics (BAS). The study employs simple financials tools (e.g. cost and return, partial budget, etc) to assess the financial impact of identified interventions. Gross margins along the chain were also examined in relation to the assessment of the efficiency of the various activities and processes in the chain.

In assessing losses in quality and quantity of fruits in the chain, data on quality profile of fruits at harvest and the causes of rejection (both for the export and domestic markets) were obtained at selected points in the supply chain, particularly where re-sorting and re-packing were done. The proportion of downgraded or rejected fruits was obtained and again the causes of rejection were identified.

Australia

The project was a pilot program to establish export supply chains for direct market access into China. A participatory approach was used to generate and transfer information to build the knowledge and capacity of Australian businesses to capture this market opportunity.

A critical first step was the identification of businesses that were committed to developing the legal trade into China and who were prepared to invest in the establishment of effective supply chains. An expression of interest to collaborate in the project was distributed to potential project collaborators and seven businesses pledged their support for the project. Five of the businesses provided a voluntary contribution to AMIA and the other two businesses, the VHT operators, provided in-kind contributions for their services.

An inception meeting was held with all project collaborators to introduce the research team, confirm the proposed outputs, outcomes and activities and develop an action plan. The project team then worked with the collaborators to plan, implement and review specific activities. The philosophy was to learn together in partnership.

The following activities and methods were undertaken.

1. Provide advice on orchard management including seed weevil control where necessary.

   All varieties of mangoes are permitted for export to China from any production district in Australia. The project collaborators selected three varieties of mangoes, Kensington Pride, R2E2, B74 (CalypsoTM), to source from orchards in Western Australia, Northern Territory and Queensland. Team members based in the production districts provided advice to producers to ensure compliance with all protocols and production practices to maximise fruit quality.

2. Support orchard inspection for freedom from quarantine pests and diseases – (funded by AMHI, project collaborators).

   Under the China Mango Export Work Plan, growers were required to be registered with AQIS for export to China. Their orchard had to be inspected for freedom from quarantine pests and diseases by an approved Crop Monitor. This included the cutting of approximately 5 000 mangoes per orchard for seed weevil inspection. Support was provided to each grower to help fund the costs associated with the orchard inspection and AQIS registration. The growers funded the labour costs to collect, cut and dispose of fruit for the seed weevil inspection.

3. Provide advice and training on managing quality from harvest to the retail shelf.

   Each supply chain was mapped to identify critical processes that impact on product quality. Guides providing recommendations for managing quality were provided to all businesses in the supply chain. Training sessions were delivered to importers and retailers in China on ripening, storing and transporting of Australian mangoes. The training materials were produced in both English and Chinese languages.

4. Design of export packaging (funded by HAL MG07011 and AMHI).

   The project team worked with the collaborators and AMCOR Fibre Packaging to design packaging to meet the requirements of the protocol. Two different packaging heights were required to suit the different varieties. Generic graphics were used by the collaborators with some flexibility to allow specific brand information to be included in the graphics.

5. Monitor practices, conditions and quality from harvest to retail shelf.

   Each export consignment was monitored for handling conditions and fruit quality. Temperature loggers were placed in deliveries from the orchard to VHT facility and from the VHT facility to the importer warehouse. Information was collected on handling practices and holding periods at each supply chain step.

   Fruit was sampled at harvest, at arrival and dispatch from the VHT facility, and on arrival at the importer warehouse. Fruit was assessed for external and internal quality and where possible held until eating ripe and re-assessed. The monitoring results were analysed to determine where handling practices and conditions reduced fruit quality and saleable life and to identify areas for improvement. Monitoring reports were distributed to the collaborators and the results and key findings were reviewed with them.

6. Independent inspections and reports on outturn quality for each consignment.

   A team member was based in China to assess the outturn quality of each export consignment and where possible follow consignments through to retail display. Monitoring reports were prepared for each export consignment and discussed with the collaborators. Enquiries were made to identify Produce Surveyors based in China who could be trained to do outturn inspections and prepare reports after the team member returned to Australia.

7. Market research to identify market requirements and opportunities for expansion.

   Desktop and in-market research was undertaken to assist in assessing the potential demand for Australian mangoes. Focus groups with Chinese consumers, two each in Brisbane and Shanghai were conducted, as well as in-depth interviews with importers and retailers in Shanghai. Information was gathered on the level of demand, supply periods, product specification (e.g. size, external appearance, aroma, eating quality, packaging), price structures, rationale for buying mangoes (e.g. gift giving, special treat, health reasons), perceptions of Australian mangoes compared to other imported mangoes, preferred Australian varieties, and marketing/promotional support required. The desktop and in-market research results were published in separate reports.

8. Launch of Australian mangoes to the Government and private sector in China.

   To coincide with the first exports, a product launch was held in Shanghai to promote the success of the initiative to the government and private sector. The launch was organised with support from the Queensland Government Trade and Investment Office in Shanghai.

9. Economic analysis of the costs and returns for direct market access.

   An economic assessment to determine the financial viability of direct export to China was completed. An economic export model was developed for collaborators to insert their own information to assess the financial viability of their supply chain.

10. Communication of information generated.

    Project collaborators – individual monitoring reports, personal visits, project inception meeting, planning and review meetings, progress updates by email, milestone and final project reports – information about individual business performance was confidential.

    Mango industry businesses – key findings reported in Mango Matters newsletter.

11. Project evaluation Interviews were conducted with the collaborators to evaluate the project objectives and activities, the benefits gained and their future needs for assistance to expand exports to China.

4.6 Achievements against activities and outputs/milestones

EXPECTED OUTPUT: Qualitative and quantitative baseline data on where and why product quality is lost in targeted supply chains.

No.	Activity	Outputs/ Milestones	Completion Date	Comments
1.1	Development of detailed methodology:			
	Reviewed relevant literatures to determine past and on-going R&D initiatives related to the project.	Six key questions were formulated pertinent to evaluating the existing supply chain of mango.	March 2006	
	Developed the detailed methodology consisting of two phases: a) Supply Chain Analysis; and b) Supply Chain Improvement/Optimization. Met with Terry Campbell to discuss and develop the methodology.	First to develop a more detailed approach in studying the supply chain of 'Carabao' mangoes in the Philippines.	March 2006	
1.2	Supply chain analysis involved two major activities:			
	1.2.1 Supply chain mapping of major supply and demand areas:			
	Negotiated with two exporters to serve as project cooperators or 'supply chain champions'.	Two major exporters to Hong Kong agreed to serve as cooperator or supply chain champions.	May 2006	
	Prepared a set of research instruments for the survey of all participants in the chain.	A set of questionnaires developed, pre-tested and used in the survey.	July 2006	
	Conducted field visits and surveys in Abra, Guimaras/Iloilo, Davao del Sur, Davao del Norte and Hong Kong. All of these were part of the examination of the exporter-cooperators' supply chain.	Supply chain maps developed covering the major supply and demand areas: Abra, Guimaras/Iloilo, Davao del Sur, Davao del Norte and Hong Kong.	April 2007	
	1.2.2 Data/information gathering and analysis.			
	The analysis focused on six key questions on: a) key customers and product requirements; b) product, information and money flow; c) activities and services provided at each step in the chain; d) key players and their respective roles; e) critical logistic issues and f) external influences.	Among others, it was found out that the chains being examined is plagued with the following problems: 1. Low Productivity and Quality (at harvest and along distribution channels). 2. High postharvest losses 3. Chain Inefficiencies 4. Poor Chain Coordination 5. Logistics-Related	May 2007	

EXPECTED OUTPUT: Spatial, temporal and linkage maps and analysis reports of supply chains and strategies, technical improvement trial plans.

No.	Activity	Outputs/ Milestones	Completion Date	Comments
2.1	Prepared an overview of the Philippine Mango Industry as part of the scoping activity of the project.	Overview prepared. Scope of project ascertained. Established an overall picture of the industry in the study sites.	February 2006	
2.2	Surveys as well as key informant interviews were then conducted to validate secondary information and to answer more specific questions related to supply chain mapping.	Mapped supply chains of two exporters for export and domestic markets.	April 2007	
	For each supply chain, shipments from the product source to the ultimate destination were traced to: validate/verify all information in the supply chain map initially drawn; and monitor and document all practices at each stage of the chain.	Formulated interventions based from the issues raised during surveys: direct farm-to-market linkage; adoption of ICM; HWT application; trial sea shipment using ventilated van; IEC campaign to disseminate technical and policy-related problems of the industry.		
2.3	Discussed with exporter-cooperators the supply chain problems and possible interventions. Identification of improvement measures was guided by the six key principles.		November 2007	

EXPECTED OUTPUT: Information on product quality; price differentials and handling requirements for targeted markets.

No.	Activity	Outputs/ Milestones	Completion Date	Comments
3.1	Identification of product specifications per target market.	Feedback of Hong Kong importers was sought and the need for quality was stressed.	May 2006	
		Adoption of extended hot water treatment for mangoes that are imported to mainland China as a required quarantine treatment.		
3.2	Evaluation of quality of fresh mangoes from the farm up to the retail market, both local and export.	Major contributors for quality rejection were identified and served as basis for recommendations.	July 2008	
		Recommendations on quality improvement were relayed to the supply chain champions.		
3.3	Conducted a loss assessment of the Davao-Manila local mango market to: determine and quantify all costs and margins associated with such practices; and changes in product volume and quality along the chain.	Quality and quantity losses of fresh mangoes at local retails were determined.	November 2007	

3.4	Conducted a trial comparing the effectivity of HWT and benlate dipping of locally sold mangoes in controlling anthracnose and stem-end rot.	Established effectiveness of HWT over benlate-dip treatment of mangoes to control anthracnose and stem-end rot.	November 2007	

EXPECTED OUTPUT: Evaluation data and recommendations for improvement of practices and systems that will enhance benefit flows to farmers in targeted supply chains.

No.	Activity	Outputs/ Milestones	Completion Date	Comments
Philippine Activities				
4.1	Supply Chain Improvement/Optimization			
	Implementation of improvement measures: Improving productivity and fruit quality. Adoption of ICM (Integrated Crop Management)	Farm cluster members are closely being supervised on ICM procedures. The members were informed of the said system that requires adoption of a rational and structured approach to crop planning using a combination of traditional techniques and modern technology. Technical experts regularly visited the farm.	September 2008	
	Preparation of IEC materials on production and postharvest practices.	Information, Education and Communication (IEC) materials were prepared as part of the awareness campaign to improve production and postharvest practices.	May 2007	
	HWT (Hot Water Treatment) at the exporters and traders level.	HWT (Hot Water Treatment) Detailed business plan for the integration of HWT in packinghouse operation prepared and discussed with potential investors. Sought cooperation of traders distributing mangoes for local market, particularly Tacloban and Manila in conducting HWT and rapid heat treatment (RHT) trials. Coordinated with HWT facility and service provider to conduct treatment trials at the traders' level. HWT trial scheduled and to be conducted soon for the Davao-Tacloban/Manila chain.	May 2007	
	Addressing Logistical Issues Trial shipment of ventilated van	Preliminary assessment was made on the viability of sea shipment using ventilated van as alternative to air transport.	July 2007	

	Improving Chain Efficiency Formation of farm cluster	Formed mango farm cluster where all production, postharvest and market interventions are being applied. The cluster is an informal group bounded by common interests and united to work together in achieving a common goal.	January 2008	
	Direct farm-to-market linkage	Attempt to link farmers directly with the exporter was initiated. Constant monitoring of cluster activities, especially spraying schedule is being done.	September 2008	
	Enhancing Chain Coordination Improving coordination of various organic units.	The implications of each organizational issues as well as suggestions to improve the chain were pointed out to the various organic units.	January 2008	
	Improving company procedures to minimize postharvest losses and miscommunication in delivery schedules and to deal with low moral of field personnel.	Supply chain champions made aware of these problems, their magnitude and solutions needed. They expressed commitment to address said problems.	February 2007	
Australian Activities				
	Develop common methodology for analysing supply chains based on methods in use (A,P) focus of approach will be to identify impact on product quality of current practices	Project team members agree on methodology for analysing supply chains	Completed after travel to Philippines March 2006	
	Identify two supply chain groups and map product and information flow	Two supply chains mapped for product and information flow	Completed October 2007 with five industry collaborators	
	Working with each supply chain Monitor at least one consignment for each supply chain for quality and handling practices and conditions to targeted market	Preliminary data collected on impact of handling practices and conditions on product quality	Completed January 2008 with four consignments monitored.	
	Review results, identify areas for improvement	Improvement plans developed by two supply chain groups		
	Conduct workshop and personal visits to present progress results, invite participation and develop improvement plans with other supply chain groups	Improvement plans developed by extra supply chain groups	Completed November 2007	
	Conduct market research in Hong Kong/ China markets on quality and handling requirements of customers	Information collected on product quality and handling requirements for Hong Kong/ China markets	China research completed November 2007	

	Review monitoring and market research results, identify areas for improvement, refine improvement plans with supply chain	Improvement plans refined by supply chain groups	Completed March 2008	
	Communicate key findings to wider mango industry through appropriate activities	Farmers and supply chain businesses informed about key project findings	Completed March 2008	
Other Accomplishments				
	Attendance to symposia.			
	The 1st International Symposium on Improving the Performance of Supply Chains in the Transnational Economies, Chiang Mai, Thailand, 19-30 July 2005.	Recent developments on supply chain management were obtained from the presentations of other participating countries. The participation to the said symposium strengthened the team's technical capacity on supply chain management.	July 2005	
	The 'International Symposium on Fresh Produce Supply Chain Management' in Chiang Mai, Thailand, 6-10 December 2006.	The symposium provided the venue for the presentation of the initial results of the project. The project team prepared and presented a paper entitled 'Supply Chain Improvement for Mangoes in the Philippines' at the 'International Symposium on Fresh Produce Supply Chain Management' in Chiang Mai, Thailand. The final paper was submitted to Agricultural and Food Marketing Association for Asia and the Pacific (AFMA) and the Food and Agriculture Organization (FAO). The paper appeared on the symposium proceedings.	December 2006	
	Conducted literature review of supply chain management studies in the Philippines.	Completed a publication entitled, "State of the Art: Supply Chain Management in the Philippines". The publication is currently in press for printing and reproduction. The publication contained comprehensive review of all supply chain researches and even related literature which may be useful to those who intend to do supply chain studies in the country.	June 2008	

4.7 Key Results and Discussion

The main objective of this project component is to identify and carry out trial improvements to current practices and conditions for managing mango supply chains. The expected outputs are: (1) qualitative and quantitative baseline data on where and why product quality is lost in targeted supply chains; (2) spatial, temporal and linkage maps and analysis reports of supply chains and strategies, technical improvement trials plans; (3) information on product quality; price differentials and handling requirements for targeted markets; and (4) evaluation data and recommendations for improvement of practices and systems that will enhance benefit flows to farmers in targeted supply chains.

4.7.1 Philippines Results & Discussion.

Qualitative and quantitative baseline data on where and why product quality is lost in targeted supply chains.

A detailed methodology for this project component was developed which featured the supply chain management framework consisting of two phases: (1) Supply Chain Analysis and (2) Supply Chain Optimization. The former covers supply chain mapping and identification of areas for improvement, while the latter involves testing and trial runs of these interventions. An overview of the Philippine mango industry was prepared to ascertain the scope of the study. A set of research instrument was also developed as an aid in supply chain mapping.

The inherent characteristics of the existing supply chain make it difficult to apply complete participatory approach. Instead the project worked with 'supply chain champions' who spearheaded the application of improvement measures. Supply chain champions served as reference points in mapping the supply chain. The chain was then traced from the source farm to the ultimate market.

Two agribusiness companies exporting fresh mangoes to Hong Kong and China cooperated in the study. Each firm is the principal player in its respective supply chain. Both procure fresh mangoes from the major production areas in Luzon (from January to June) and from Davao (in Mindanao) for the off-season (July to December). As Mindanao is the priority area for the project, this made them as ideal cooperators and 'supply chain champions'. The strategy to work with major players/decision makers is crucial to ensure that measures to improve the supply chain will be co-owned by the supply chain members. The firms were covered by confidentiality agreements which prevent disclosure of their identities. This, however, has little adverse impact on the project.

Supply chain maps were developed using the exporters as reference points. Field studies were conducted in Abra, Guimaras, Davao del Sur and Davao del Norte, to trace and validate the project cooperators' supply chain map and identify areas for improvement. Industry players from the different levels (production, post-production and marketing) of the supply chain were interviewed. Data and information gathered were: a) key customers and product requirements; b) product, information and money flow; c) activities and services at each step in the supply chain; d) critical logistic issues; e) major decision makers or drivers in the supply chain; and f) external influences affecting the performance of the supply chain. A field study was also conducted in Cebu to assess the fruit processing industry as part of the downstream chains. The project team also examined the Hong Kong market for fresh mangoes as an integral part of the mango supply chain.

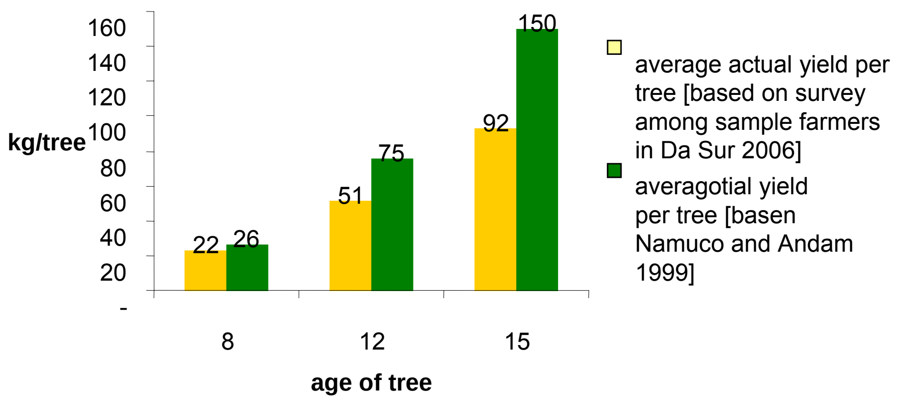
Supply Chain Analysis

After a thorough examination of the chain, it was found out that the chains being examined are plagued with the following problems:

Low Productivity

Actual and potential yield gap per tree remains extremely high (Figure 4.7.1.1) indicative of the considerable production-related challenges faced by farmers. Actual yield is typically just half of potential yield in most areas while in some areas, actual yield was just a quarter of potential yield.

Figure 4.7.1.1. Comparison of actual and potential yield by age of tree.



Insect and disease infestation is the major cause of low productivity. The calendar method of pesticide application on which most farmers have relied on for years appears no longer as effective in combating pest and diseases the incidence and severity of which seemed to have changed drastically over time.

Poor cultural practices were evident in most farms which undoubtedly result to low productivity. Listed are the production activities employed by the farmers that needs to be improved and/or corrected:

Growth regulation. Farmers are aware that they can time their production when the price of mangoes is high with the use of paclobutrazol. This chemical when applied at proper leaf age can shorten the time between attainment of right shoot age for flower induction. Proper timing of application is not followed. Instead, paclobutrazol is applied whenever mango trees do not flower resulting to non-uniform flowering.

Pruning. Most farmers do not prune their trees while some farmers were pruning their trees incorrectlygenerating adverse rather than positive results. In one case, a farmer severely side-pruned his crowded 8-year old trees instead of doing center canopy pruning. The practice could result to longer juvenility and will take two years for the trees to be ready again for induction.

Fertilization. Although basal fertilization is practiced, most of the farmers do not know the right dosage and timing of application.

Flower Induction. The practice of chemically inducing trees to bear fruit twice a year waslaso observed especially in Southern Mindanao. This practice leads to poor vigor aggravated by the non-application of fertilizers to replenish lost nutrients. Contract growing, where contractors are responsible for actual production, appears to promote the practice of twice-a-year production with little regard to the long-term adverse implication of such practice in t6he health and vitality of trees.

Tree Shaking. This is a traditional practice of the farmers but some of them do not practice it properly. Branches are not vigorously shaken fearing that the fruits that have set might be dislodged from the panicle. This improper practice will not control disease since the dried flowers that remain in the panicle will serve as source of inoculum.

Pesticide Management. This has been the persistent problem in mango production. Traditional pesticide management program seems to be no longer effective. Under-dosing and cocktailing chemicals of the same active ingredient have been observed, thus pest and diseases are not properly controlled. Another problem is the continuous use of the same insecticide and fungicide throughout the different stages of flower and fruit development. This practice will lead to development of resistance of the pests.

Spraying. Farmers were unaware that because of the incorrectly adjusted nozzle, chemicals are wasted and target spray areas of the tree are not thoroughly covered.

Poor Quality

Quality is already lost even before harvest with an average of 50-68% of total harvest with scab insect damage, wind scars and latex burn as major problems. For example, in a particular shipment traced from Abra (Figure 4.7.1.2), from a total of 8,528kg of mangoes collected from 2 buying stations in Bangued, 68% (5,768 kg) were classified as ‘rejects’ and only 32% (2,760 kg) were export grade. Mangoes that were considered ‘export grade’ at the buying station were subjected to final inspection out of which a considerable volume (14% or 386 kg) were considered as ‘reject’. All mangoes considered as reject were transported to the processing plant (approximately 6,154 kg or 72% of the total volume purchased). The exporter handled approximately 2,374 kg of export grade mangoes, 58% (1,368 kg) were delivered to the different branches of the supermarket and 42% (1,006 kg) were intended for export until enough volume is collected from other shipments.

During an off-season harvest (November) in a farm in Buhangin, Davao City, quality profile of mangoes for local market was evaluated (Table 4.7.1.1) in which 40% of the mangoes were classified for export, 55% for local distribution and 5% rejects. Apparently, scab and latex stain are the most common defect observed, amounting to 19.4% and 8.8%, respectively, of the whole volume of harvest.

Table 4.7.1.2 shows the quality profile of mangoes delivered at the exporter’s collection center (buying station) located in Davao City (2007). Even though, the exporter-cooperator sends quality control officer at the farm during harvest and field sorting, quality inspection at the buying station level still yielded a considerable percentage of rejects. There were fruits with insect damage, latex stain and burn, and wind scars.

Mechanical damage in the form of bruises, compressions and punctures constitute 20% of the total rejections. This is a manifestation of rough handling and poor packaging in transferring the fruits from the farm to the buying station. Packed fresh mangoes are manually loaded and transported in forward (8MT capacity) or elf truck (3-5MT capacity), depending on the volume of harvest. To maximize space, packed mangoes are stacked up to 6 layers in the truck.

Table *4*.7.1.1. Quality profile of local quality mangoes at farm level: Buhangin, Davao City, 2007.

Defect	Proportion of Rejects
Scab	19.41
Thrips	9.01
Sooty Mold	7.38
Discoloration	0.75
Mishapen	0.25
Growth crack	0.08
Wind scar	0.04
Diseased	0.04
Latex stain	8.80
Bruise/mech’l damage	0.29
Other unidentified diseases	8.93

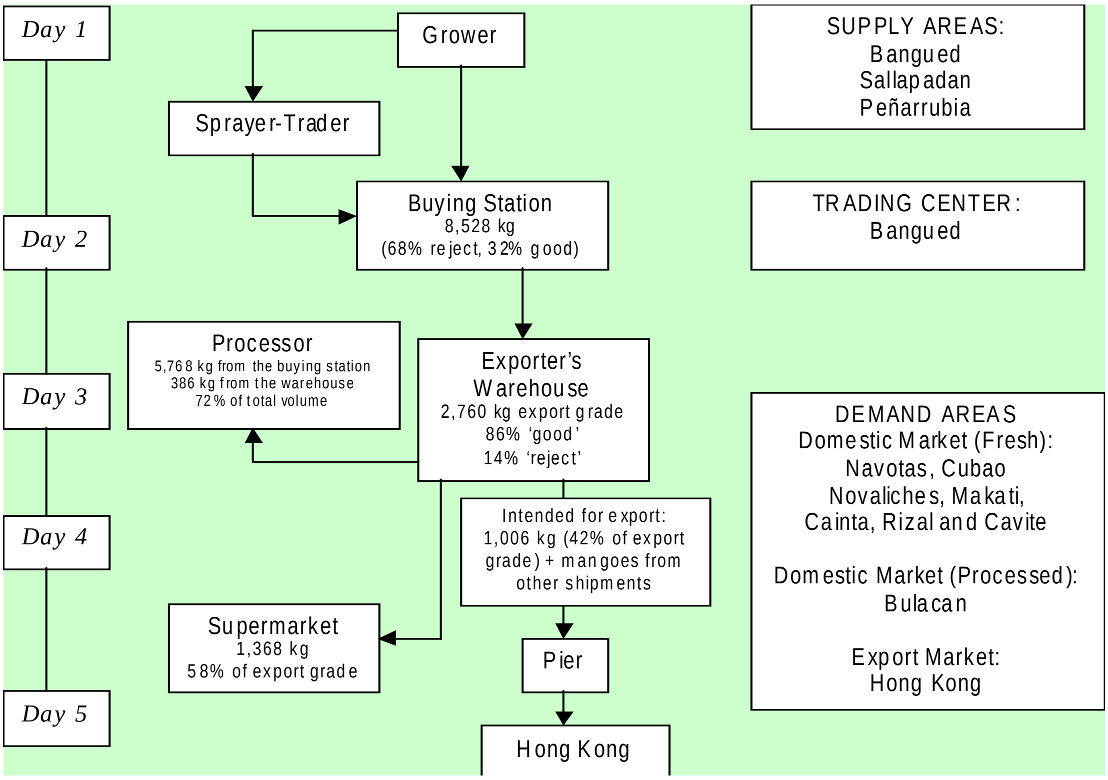


Figure *4.7.1.2*. Mango product flow and volume handled: shipment from Bangued, Abra, 2006.

Table *4.7.1.2*. Quality profile of export quality mangoes delivered at the exporter's collection center in Davao City.

Defect	Total Proportion of Rejects
Cecid fly	2.25
Ant damage	3.37
Wind scar	12.36
Lenticel spots	4.49
"Intultol"	2.25
Mishaps	5.62
Scab	1.12
Latex stain	12.36
Latex burn	16.85
Color break	8.99
Bruise	7.87
Compression damage	7.87
Abrasion	8.99
Puncture	5.62

The fruits are then transported from the buying station to the airport, mangoes are unloaded in the cargo area, subjected to x-ray machine, loaded in pallets and stays in the cargo area for loading in the plane. Upon arrival in Manila, the cartons are unloaded from the plane, delivered to the airport cargo and loaded manually in the truck for delivery to their warehouse.

At the exporter's warehouse in Manila, the mangoes undergo final inspection, re-sorting and re-packing if needed. In the warehouse, rejection after final inspection reaches up to 10%. Quality profiles of rejected mangoes are obtained at the warehouses of the two supply chain champions as shown in Table 4.7.1.3. These warehouse rejects are in turn absorbed by local buyers in Metro Manila (Figure 4.7.1.3).

Figure *4*.7.1.3. Export quality (a) and rejects (b) at the exporter's warehouse.

Figure 4.7.1.4 shows the commodity and postharvest handling practices from the farm to the warehouse in Manila. Product handling is characterized as repetitive resulting to approximately 18 handling steps. The multiple handling of mango from harvest to warehouse lead to the incidence of mechanical damage hence rejection during the final packing in Manila.

Table *4.7.1.3*. Quality profile of rejected mangoes at the exporters' warehouse in Navotas, Metro Manila.

Defects	Exporter 1 (%)	Exporter 2 (%)
wind scar	1.26	0.90
sooty mold	0.02	-
Scab	1.02	0.58
cecid fly	0.31	0.08
ant damage	0.59	0.22
color break	0.29	-
compression/bumps	0.79	1.12
latex stain	1.63	0.62
latex burn	1.50	1.68
Bruise	1.12	1.76
Cut	0.06	0.08
crack	0.03	-
puncture	0.03	-
lenticel spotting	1.17	2.56
discoloration	0.11	0.16

Anthracnose and stem-end rot are major postharvest diseases especially during the rainy months of July to November (off-season). For the local/domestic market, the problem brought about by anthracnose and stem-end rot has already driven the traders in Mindanao to use Benomyl (benlate) as a postharvest dip for mangoes sold at the local market. The efficacy of such treatment is doubtful not to mention that Benomyl is prohibited as postharvest dip.

For fruits exported to Hong Kong, about 5% of the lot exhibits the onset of the disease as early as upon arrival at the Yau Ma Tei market (Figure 4.7.1.2). Advanced deterioration is observed when the fruits are on display at the various retail outlets. The retail price in Hong Kong drops to as much as 75-85% as the disease becomes more evident. On the average, medium size good quality fruits are sold for HK$ 8-12/pc in retail stalls. This drops to as low as HK $ 1-3/pc when the disease is in advance state.

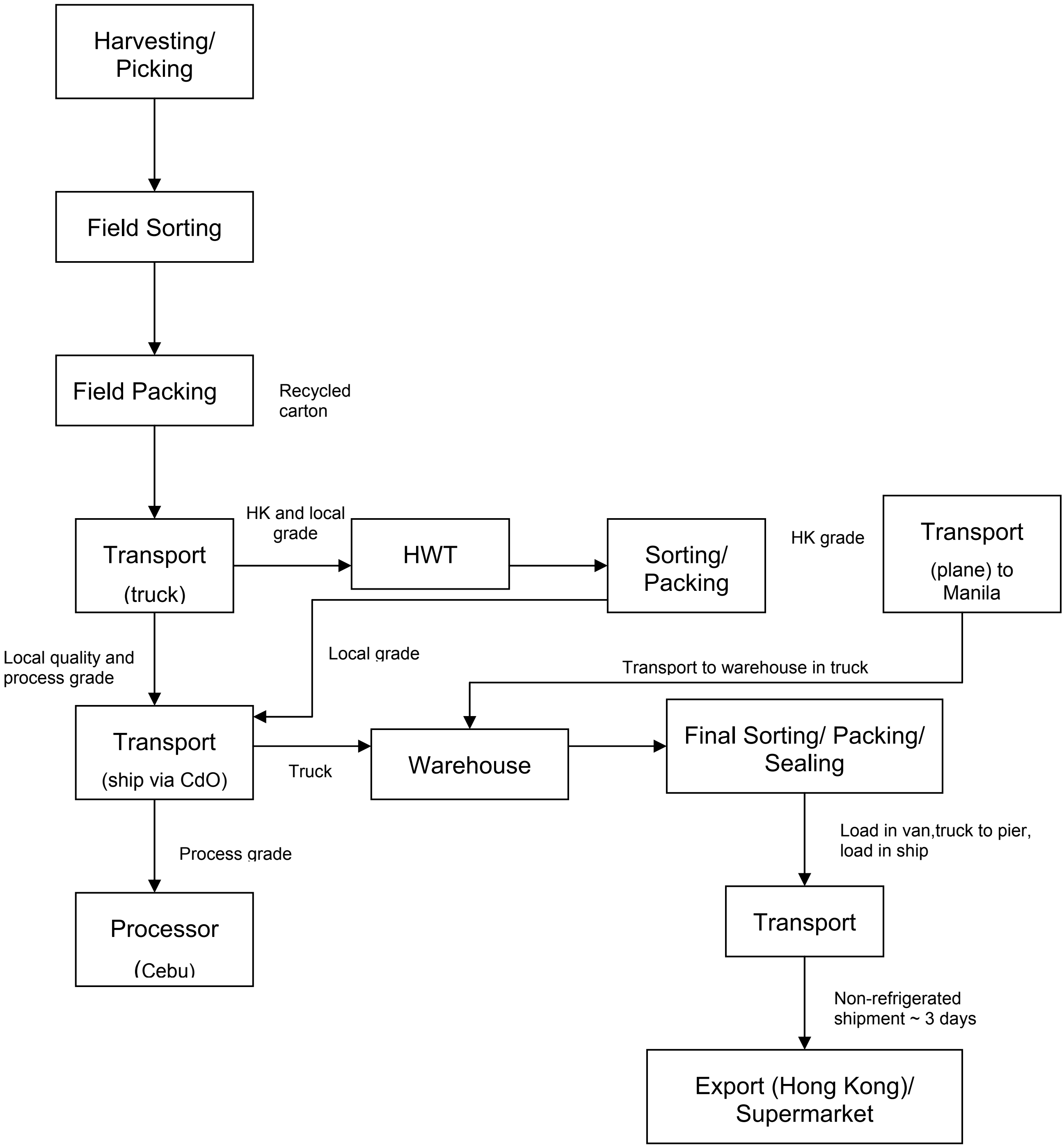


Figure *4*.7.1.4 Mango postharvest practices: Davao, 2006-2007.

During the project team's meeting with the importer in Hong Kong, the importer emphasized the need to improve more on quality. He specially noted that the mangoes decay easily and quality is inconsistent. He also mentioned about undersizing. The importer also added that a stronger packaging material is needed. When this issue was discussed with the exporter, one of the reasons cited was that bulk purchases of packaging cartons reduce his operational cost, and therefore cartons are stored for a long period of time making them less durable.

Mango fruits (PCI 4-5, more yellow than green to just streaks of green) upon arrival at the Hong Kong container yard adjacent to the wholesale market.

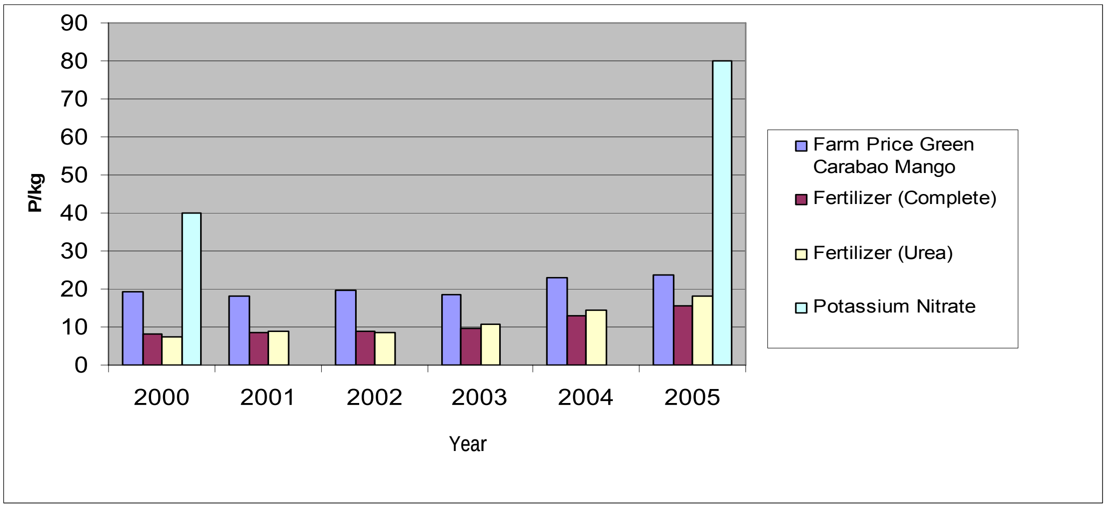
Mango fruits (PCI 5, yellow with tinge of green) on display at the Hong Kong warehouse/ Yau Ma Tei wholesale fruit market.

Mango fruits (PCI 6, full yellow to table-ripe stage) at the Hong Kong retail market.

Figure 4.7.1.5. Philippine mangoes at various retail outlets in Hong Kong (September 2006): Good quality mangoes at HK$12/pc sold at a fruit grocer (a) and at HK$8/pc sold at a retail fruit stall night market (b); Poor quality mangoes sold at HK$10 per 3-pc set (c) and HK$10 per 7-pc set (d).

Limited air freight capacity in Davao: Air freight capacity servicing the Davao-Manila route is very limited. In cases when priority cargo such as tuna, cut flowers and other fruits such as rambutan and lanzones are available in large volumes, mangoes are often off-loaded by the major airlines. Thus, even if large volume of fresh mangoes is available in Davao, the volume that can be brought to Manila and eventually to Hong Kong and other export markets is limited. Fresh mango is often considered a filler in air cargo. As such, the freight cost is much lower compared to other types of cargo. The disadvantage however, is that fresh mangoes have a lower loading priority.

Increasing cost of inputs: The price of inputs particularly KNO3 and other fertilizer have doubled over the last five years (Figure 4.7.1.6). However, the farm price of mangoes remains practically the same. Net income from mango production is only about PhP4-5/ kg on the average. Given an average yield of about 5.5 MT/ha, net income is relatively small.



Farm-to-market road: Rough farm-to-market roads contribute to losses, due to the mechanical damage sustained through compression and abrasion. Most farms are far from the buying station and fruit has to be transported by trucks or jeepneys. Compression damage is especially high when fruits are not properly packed and over stacking is practiced. The cost of transportation may also increase, especially when the roads become muddy. In such cases, mangoes have to be hauled by sleds for long distances before they can finally be loaded into the truck.

Market Inefficiencies

Inefficiencies are evident in the system which may be attributed mainly to information asymmetry. The multi-layered marketing system for mangoes involves some players which perform redundant

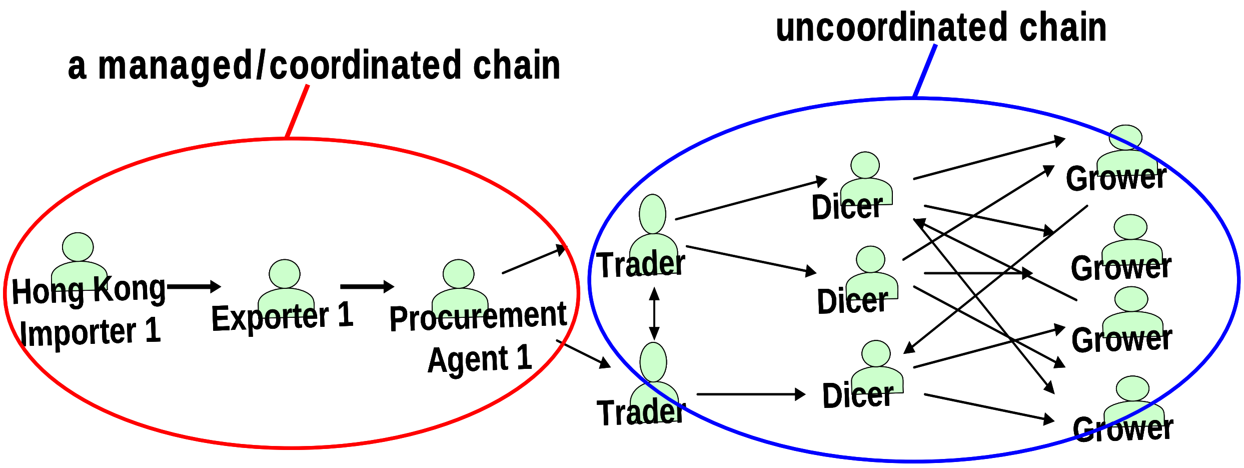


Figure 4.7.1.7. Existing mango marketing system.

functions. For example, locators (locally called as 'dicer') exist simply because they possess the information on supply source (Figure 4.7.1.7.). Farmers have limited market and technical information which constrained them from reaping larger benefits from their harvest. Adversarial marketing is evident as farmers sell their mangoes to the highest paying trader even when there were prior arrangements with another trader. This 'pole-vaulting' tactic is also common among traders when dealing with exporters.

Poor Chain Coordination

Problems related to poor chain coordination are broadly classified into: disparity in quality standards within the chain and export market; miscommunication in delivery schedules causes delayed deliveries and failure to catch-up with the original shipping schedule; organizational issues like inadequate incentive among staff and uncertain employment status.

Disparity in quality standards was evident as rejection at the exporter's warehouse is still high. Fruits that are considered good at the field buying station were paid the premium price for quality. The financial loss to the exporter is obvious when the same fruits are rejected in the warehouse not to mention that a certain transportation cost has already been incurred. However, it must be considered that the exporter-cooperator does not only suffer the direct cost of this loss but also incur an opportunity cost. The opportunity cost is what the exporter-cooperator would have earned if the volume of mangoes originally classified as export grade (at the field buying station) yet rejected due to poor quality at the warehouse were also sold as export grade.

Miscommunication in delivery schedules was caused by lack of an established responsibility center in transit. Delayed deliveries and higher rate of rejection due to ripening were manifestations of this inefficient operation.

An emerging organizational problem was discovered in the course of the study. There appears to be no sense of permanency among the key staff especially those engaged in procurement. The staff do not have company identity (I.D.), job contract or appointment hence are not sure of the status of their employment in the firm. This sense of insecurity haunts them constantly although it could not be established whether such has already been adversely affecting their performance. The meager salary and travel allowance they receive compound this problem. They would like management to recognize this problem but they would not bring it directly to management for fear of losing their jobs.

4.7.2 Spatial, Temporal and Linkage Maps

a. Product Flow

Mindanao is the traditional source of mangoes during the off-season months of June to December because its climate allows for a year-round production. Mindanao farmers schedule their harvest season in order to supply the needs of the domestic (Luzon and Visayas) and export markets during the off-season months in Luzon.

In this particular chain (Figure 4.7.2.1), fruits came from farms within the vicinity or neighboring towns of Davao City, Davao del Sur and Davao del Norte where the buying stations are located. Supply areas vary in distance from the buying stations. In the case of the Davao City buying station, supply areas are the bordering districts of Calinan, Tugbok and Toril with an estimated distance ranging from 26 to 30 kms. Other sources of fruits are the municipalities like Matanao and Bansalan of Davao del Sur which are approximately 65 to 70 kms away from the buying station. In some cases, fruits may also come from Samal Island, Davao del Norte which is just a 15-minute boat ride from Davao City.

For the cooperator's buying station located in Digos City, fruits came from neighboring municipalities, like Matanao, Malalag, Sulop, Bansalan and Padada. These municipalities are approximately 13 to 20 kms away from Digos City, respectively.

Buying stations were strategically located in the economic centers (Digos and Davao City) of the Province. The stations are actually residential houses rented or owned by the exporter's agents. These serve as packinghouses as well as a warehouse where packaging materials are stored. The stations are highly accessible to all means of land transportation vehicles in the area.

From the source farm, local quality and the processed (locally called as 'dried') grade fruits are brought to the local buying station. Fruits are then sea-shipped via Cagayan de Oro City pier when it has reached an economical volume (Figure 4.7.2.2). Local grade mangoes destined to Manila may take 32 hours travel time while processed grade fruits bound to Cebu may take 12 hours travel time.

In cases of large volume harvest, the freshly harvested export quality mangoes coming from Mindanao reaches the exporter's warehouse in Manila within 36 hours for final sorting and packing. Typically, it takes five days before an export shipment reaches the Hong Kong market.

Upon arrival, the mangoes were unloaded from the container yard adjacent to the wholesale fruit market in Yau Ma Tei. Fruits were inspected in terms of its condition and quality. Mangoes are then stored in a cold room in the importer's warehouse until it ripens. Fresh mangoes are displayed in the retail stores and supermarkets in their ripe stage.

Mangoes are also sold in other forms such as mango specialty cakes, mango puree, mango tart, ‘mango sago’ or mango shake, mango roll, mango pudding, mango pancake, mango cheese cup, and dried mango(Figure 4.7.2.3). The following are the areas where different mango products are available:

- Roadside stalls - fresh mangoes on display were on the table-ripe stage
- Cake houses - a regular-sized cake uses 4-5 pieces of ripe mangoes cut in thin slices and made as a topping along with other fruits; mango pudding is also available packed in transparent plastic cups; rolls with thinly sliced mangoes used as filling and topping are also for sale; other cake specialties available are mango tart, mango pancake
- Beverage stalls - sells fresh ripe mango juice, 'mango sago' and mango puree in retail plastic cups
- Supermarkets - fresh mangoes at ripe stage are displayed along with other fruits; the diseased (up to 10% severity) fruits are packed separately in styro packages; sometimes fresh mangoes are also included in a fruit basket package together with other fruits.

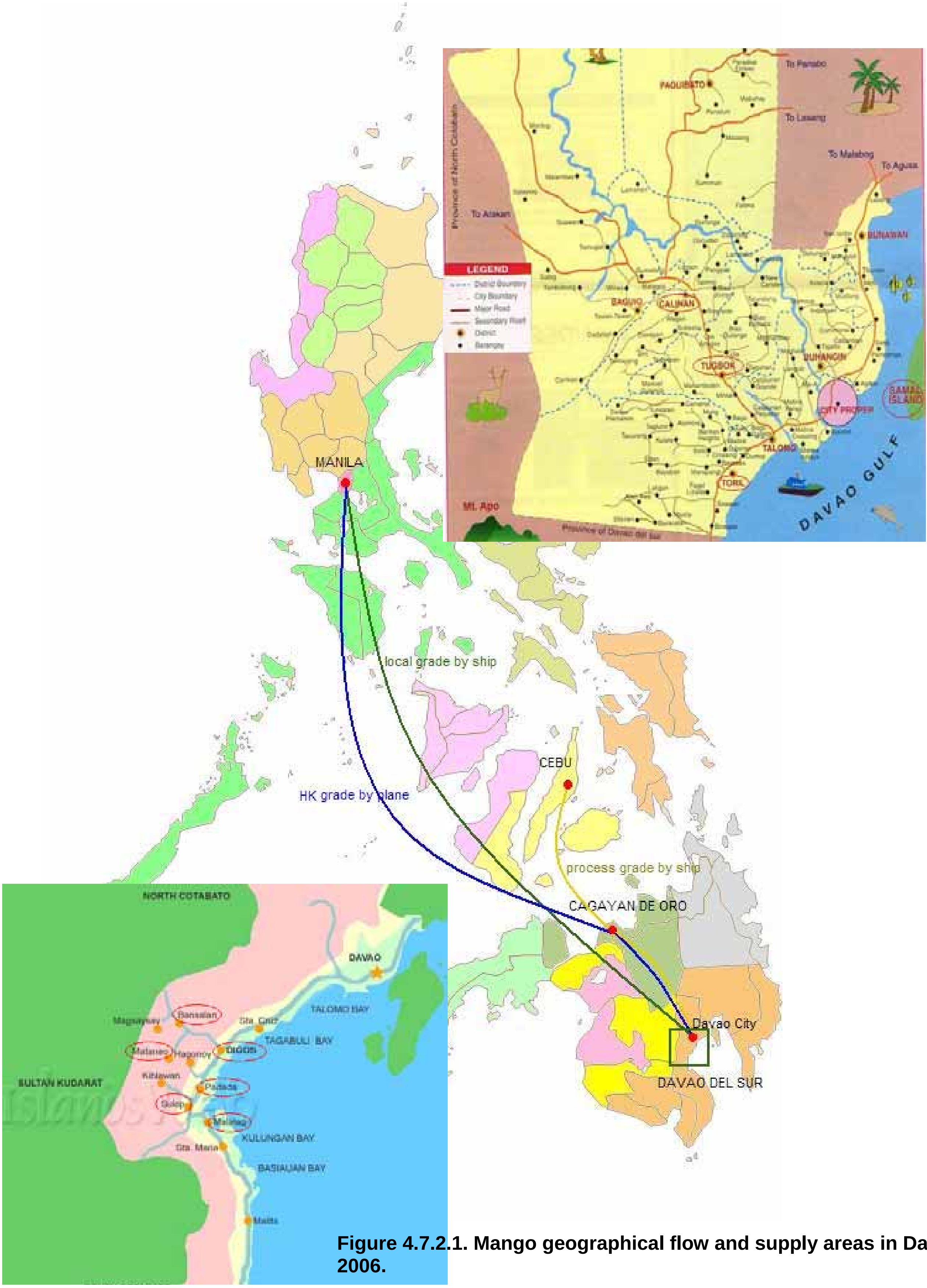


Figure 4.7.2.1. Mango geographical flow and supply areas in Davao, 2006.

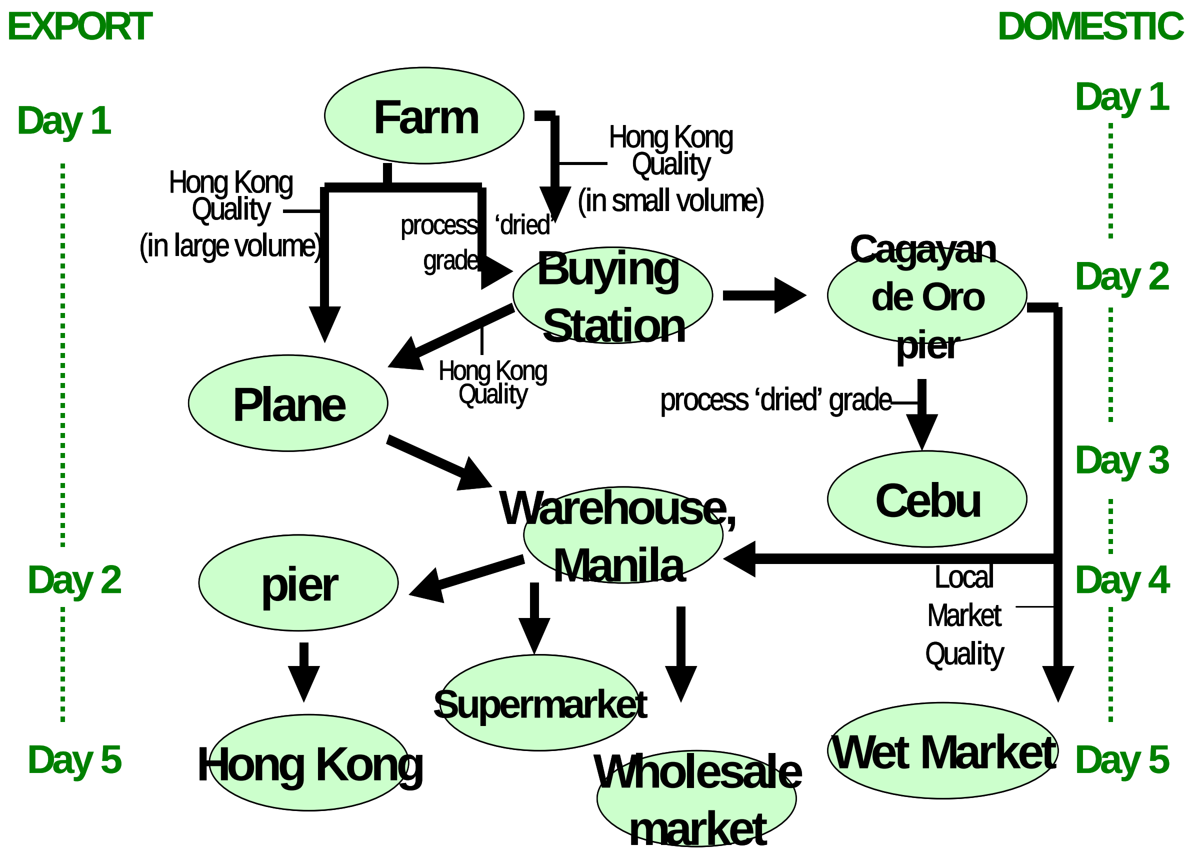


Figure *4*.7.2.2. Mango supply chain in Davao del Sur: product flow (2006).

Figure *4*.7.2.3. Other mango products available in Hong Kong fruit retail market: mango rolls (a), dried mango (b), mango tart (c), mango cake (d), mango pudding (e), and mango

b. Payment Flow

Figure 4.7.2.4 shows a typical payment flow in a mango supply chain. The procurement agents inform the exporter about the available volume of fruits. The exporter then transmits payment through a joint bank account with the agents. The procurement agents withdraw the money from the bank and use this as cash payment to fruit suppliers (e.g. growers/sprayer-traders).

The exporter provides the operating capital for the buying operations of the procurement agents. The capital provided is used for the procurement of fruits and packaging materials. Aside from the operating capital, the procurement agent based in Digos City receives a monthly salary from the exporter.

Growers usually sell their mangoes to assembler/wholesalers in entire lot basis, or locally called as “tuntong-timbang”. It is when traders buy all the harvests from the grower at a set price regardless of quality classification. However, in some cases, the owner of the farm enters into a leasing contract with the sprayer-trader.

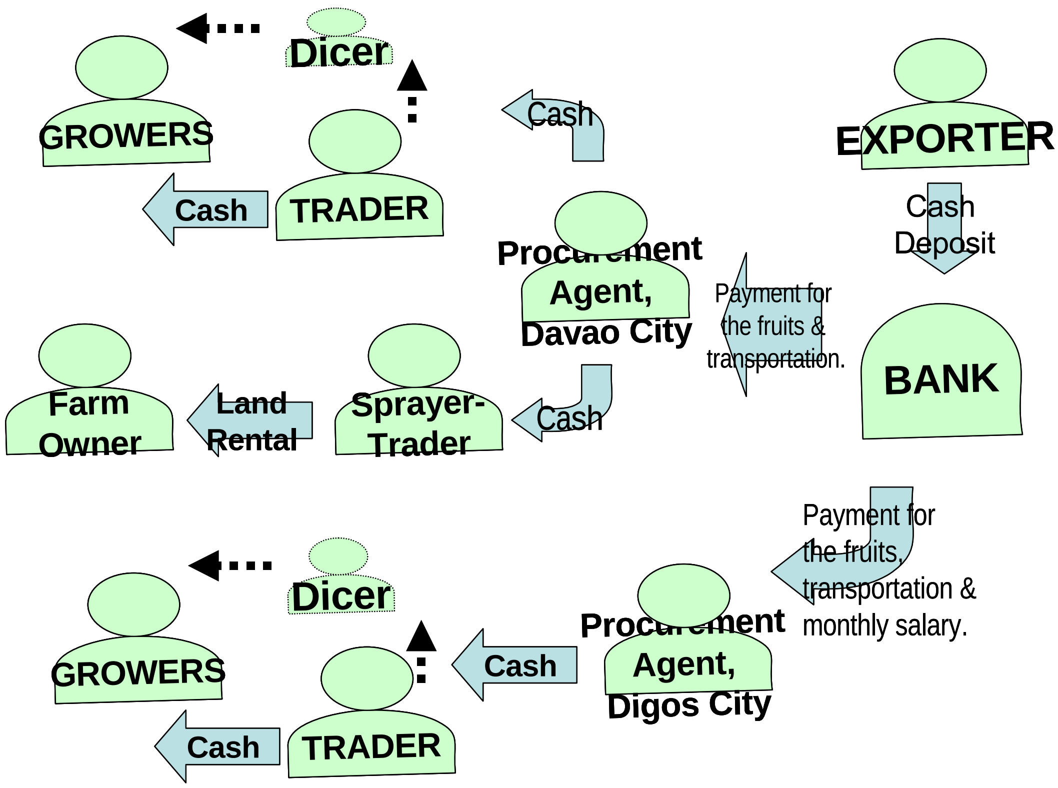
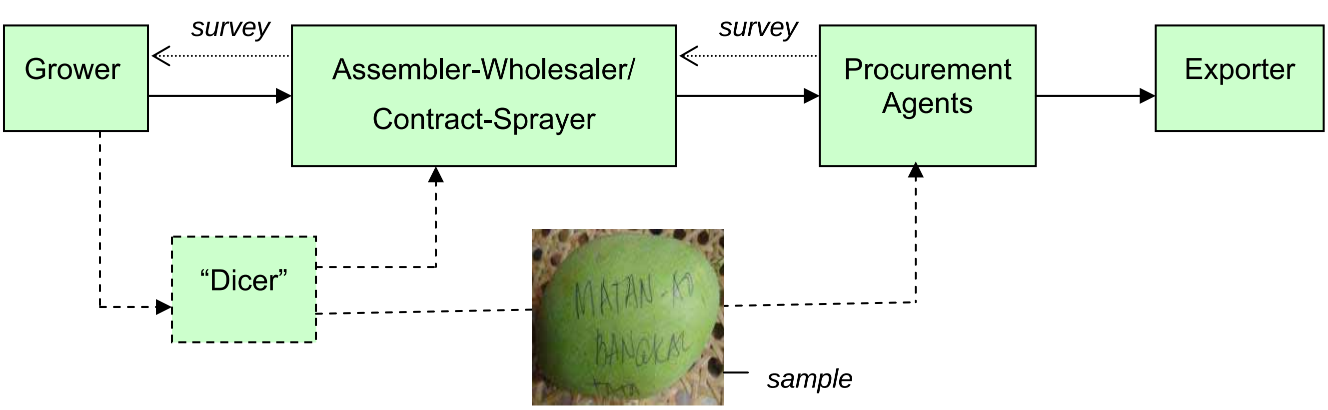


Figure 4.7.2.4. Mango supply chain in Davao del Sur: payment flow (2006).

c. Flow of Information

Information on Supply

Procurement agents obtained information on availability of mangoes from growers/sprayer-traders either through text messaging or direct communication (Figure 4.7.2.5). They also employ locator/dicer who conducts actual survey of potential sources of fruits and paid on commission basis. The agent based in Digos City also conducts actual field survey. The locator/dicer will bring a sample fruit ready for harvest to the procurement agents. The procurement agents then relay the information regarding the estimated volume of mangoes to the exporter-cooperator.



Price Information

Figure 4.7.2.5. Mango supply chain in Davao del Sur: flow of information on supply (2006).

Procurement agents are guided by the purchase price set by the exporter (Figure 4.7.2.6). Through the years, the agents have enough number of clients who would agree to sell their harvest at the prevailing market price. In cases when the set price is not competitive relative to the prevailing market price, the procurement agents request the exporter for some adjustments.

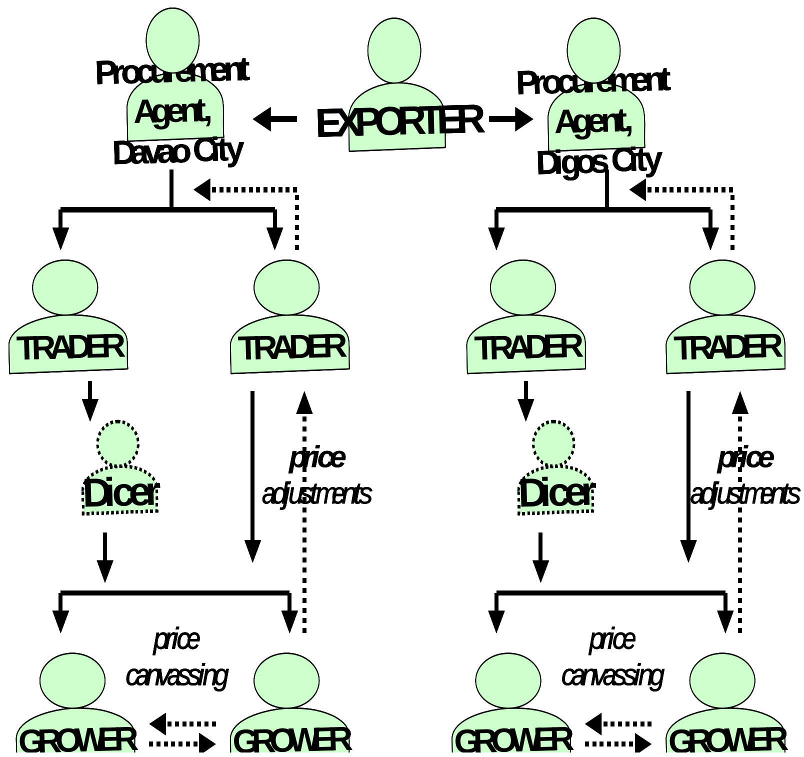


Figure 4. 7.2.6. Mango supply chain in Davao del Sur: flow of price information (2006).

Although growers are merely price takers, they also conduct price canvassing through direct communication or through text messaging to co-growers, local traders and buying stations to discover the prevailing price. In that case, growers prefer to sell their harvest to the trader with the highest buying price and pays on cash basis.

Technical Information

Majority of the growers, contract-sprayers and traders involved in this chain are old hands. They acquire knowledge on mango cultural practices through their own experience and practices of co-growers (Figure 4.7.2.7). Growers have devoted almost 10 up to 30 years in mango farming. Contract-sprayers and traders have been in mango trading for at least 5 years up to almost 30 years. They also acquire information from seminars sponsored by chemical companies and extension services conducted by the local government unit (LGU).

Basically, growers are informed about the quality standards by the classifiers sent by the procurement agents. The exporter then informs the procurement agents regarding classification and grading standards. Most farmers are unaware of the end-buyers of their mangoes but they express interest for any information that would improve the quality of their harvest.

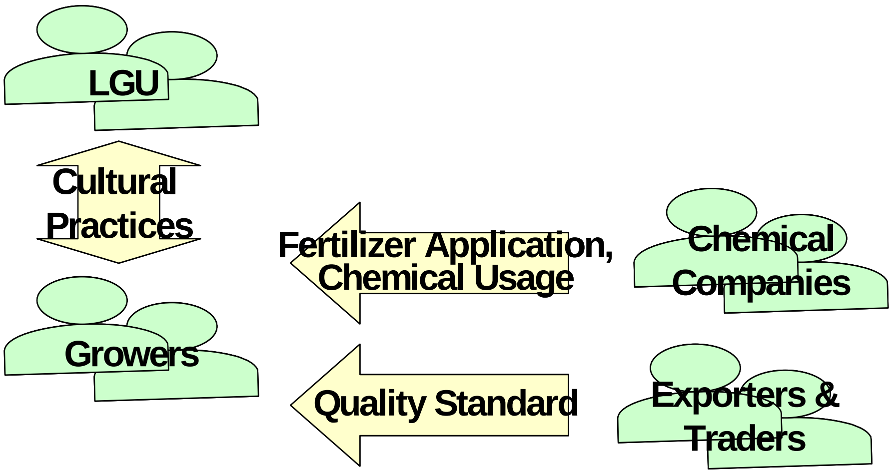


Figure 4.7.2.7. Mango supply chain in Davao del Sur: flow of technical information

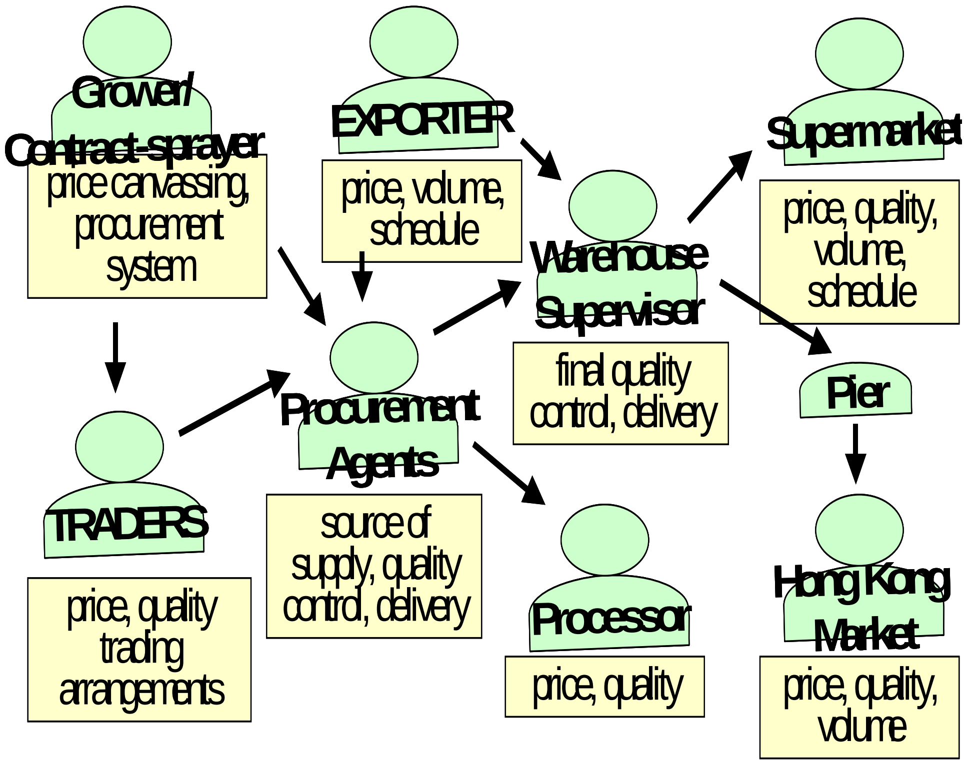


Figure 4.7.2.8. Mango supply chain in Davao del Sur: major decision makers (2006).

d. Major Decision Makers

Figure 4.7.2.8 shows the major decision makers in the mango supply chain (Davao del Sur, 2006). The exporter-cooperator is a key decision maker in the chain. Primarily, the exporter sets the purchase price, the volume of fruits to be purchased and the schedule of procurement and delivery. The volume of fruits to be purchased is based on the demand of the different customers of the exporter. The exporter largely influences the schedule of procurement. The exporter would advice the agents to stop buying mangoes when prices are too low (high supply) or when there are impediments regarding the shipment from the Manila pier to Hong Kong. In this particular field study, the exporter instructed one of the agents (Digos City) to temporarily stop buying fruits as shipments experience delays due to the presence of typhoon in Hong Kong.

In the field, the procurement agents are in charge of the procurement operation that entails identification of supply source, the implementation of quality standards and the delivery of fruits to the Manila warehouse. However, the field classifiers are held more responsible in the actual execution of quality standards since sorting and packing is done at the farm. At the Manila warehouse, the supervisor is accountable for final quality control, packing and delivery of fruits either to the pier (bound for Hong Kong) or to the supermarket.

Normally, growers/contract-sprayers have the full authority on the production operation. Growers perform price canvassing and negotiate with traders regarding what procurement system to follow. Normally, growers sell their produce to the trader who offered the highest price. However, in some cases, farm owners enter a leasing contract with sprayer-traders and therefore authorize the latter on production and marketing operations. The sprayer-trader pays the farm owner a fix land rental fee for a specific period of time.

The key customers of the exporter-cooperator are also independent decision-making units. Compliance to their requirements is a primary concern of the exporter. The processor, supermarkets, and the importer set their price, volume requirement, quality standards and schedule of delivery.

e. Activity and Cost Schedule

Tables 4.7.2.1 shows the cost incurred in every activity along chain for fruits intended for the Hong Kong export markets. This data is true for off-season mangoes sourced from Davao del Sur. The data were taken during the project team's year 2006 to 2007 field studies.

Table 7.2.1. Activity-Cost Table for 'Carabao' Mangoes for Export Market

Supply Chain Participant or Node	Cost Description	Average Cost per kg (PhP)
Grower	Crop protection	6.63
	Pruning	0.16
	Irrigation	0.23
	Fertilization	1.33
	Bagging	0.87
	Weeding	0.28
	Harvest	1.17
	Labor (Farm Maintenance)	1.04
Production node: cost/kg		**11.71**
Trader (farm)	Survey of supply source	0.08
	Harvest/Purchase Operations:	
	Labor	0.6
	Packaging	2.67
	Transport	1.00
Distribution node: cost/kg at trader's level		**4.35**
Trader (buying station)	Labor	0.27
	Packaging cost after re-classifcation	0.13
	Cost of rejects after re-classification	
	HWT	1.5
	Buying station rental	0.08
	Transport (Plane):	
	freight cost	12.65
Distribution node: cost/kg at procurement agent's level		**14.63**
Exporter	Labor and Packaging	16.67
	Transport and Container van rental	
	Fees: Proforma Bill of Loading, Export Declaration, Authority to Load (BOC), Bill of Loading	
Distribution node: cost/kg at exporter's level		**16.67**

4.7.3 7.3 Information on Product Quality, Price Differential and Handling Requirements

a. Quality Requirements

The intended markets of the exporter-cooperators are both the domestic and Hong Kong mango consumers. Quality standards are set mainly by the exporters while local markets and processors have their own quality requirements. One of the exporter-cooperators also supplies mangoes to processors in Cebu.

Table 4.7.3.1 shows the quality requirements of the different markets and which are being followed by the supply chain champion's procurement agent:

Table 4.7.3.1. Quality and size characteristics of mangoes for different markets.

Market Type	Destination	Characteristics	
		Quality	Size
Export	Hong Kong	Fresh green mangoes, mature, regular-shaped, smooth, free from diseases/insect infestation and mechanical damage	XL: ≥ 350 g L: 300 – 349 g M: 250 – 299 g
Domestic	Supermarket	Fresh green mangoes, mature, regular-shaped, smooth, free from diseases/insect infestation and mechanical damage	'Medium' size only 'Regular': < 300 g 'Premium': ≥ 300 g
	Processor	Fruits with latex stain, latex burn, irregularly shaped, abnormal in size, slight mechanical damage, and disease/insect damage like capsid bug	'Regular': ≥ 160 g 'Sapadera': < 160 g

The exporter-cooperator only purchases fruits that weigh 250 grams and above for mangoes intended for export. The reason for this is the high domestic freight cost to Manila that cannot be offset by the low selling price of mangoes classified as small (<250 g) in the Hongkong market.

The processor absorbs 'reject' mangoes such as fruits with latex stain, latex burn, irregularly-shaped, abnormal in size, slight damage evident in the appearance of the fruit and disease and insect infestation like capsid bug.

b. Price Differential

Different modes of buying were observed as enumerated below:

"Tuntong-timbang" – a local term referring to the buying scheme where traders buy all the harvests including the unmarketable rejects, i.e. fruits with cracks and severe pest damage, from the grower at a set price. Everything that is attached to the harvested fruit such as leaves, pedicel and newspaper bags are included in weighing. Mangoes are placed in bamboo baskets at 28-kg gross weight but only 25-kg is accounted for during payment, subtracting the weight of the bamboo basket. This is very common in Mindanao and most preferred by farmers since everything else is bought including the processed-grade rejects.

"All-in" – good mangoes, which includes export grade and local grade mangoes, regardless of classification, are purchased at the same price. Processed grade and unmarketable rejects are not included, but most of the time, the buyer is still the one who purchases the process grade fruits but a much lower price.

Based on classification – mangoes are classified according to size and price varies based on size, e.g. difference of 5 PhP per size. This is a common buying scheme in Luzon, specifically in areas like Pangasinan, Zambales and Nueva Ecija.

According to a procurement agent (Davao City), a ton of fruit harvest would usually yield 50-60% of Hong Kong grade mangoes and the remaining 40-50% is classified as local, dried or reject. The high rate of rejection at the field is a remarkable loss for the farmers since low quality fruits commands a lower price. Table 4.7.3.2 shows the price difference according to harvest quality. However, if the procurement system is "tuntong-timbang", the trader (who bought the fruits at a single price regardless of quality) takes the risk of high rate of rejection. Usual cause of rejection includes latex stains, "nora-nora", irregular size and shape, scars and mechanical damage.

Table 4.7.3.2. Farmgate price according to quality and size, Davao City, August, 2006.

	Quality					"Tuntong-Timbang"
	Hong Kong		Local	Dried	Reject	
	S	M, L, XL				
Farmgate Price (P/kg)	22-23	26-28	19-20	18-19	5	23

c. Handling Requirements

From the farm, export quality mangoes are packed in cartons provided by the exporter (Figure 4.7.3.1). Hong Kong grade mangoes are packed in cartons at 12-kg/pack and arranged in layers with a vertical divider at the middle of the pack. The packaging carton has an opening on both side ends serving as a handle during hauling. A label is placed outside of the carton indicating the size of mangoes inside the pack. After the final sorting at the exporter's warehouse, packed mangoes are sealed by a plastic strap, color coded based on the size of the mangoes inside the carton.

Local quality mangoes packed in the farm are commonly placed in used banana cartons at 20 to 25-kgs per pack. Mangoes are individually wrapped with newspaper, usually the same one used during bagging. Newspapers are also used as linings as mangoes are arranged in layers inside the carton. Plastic straw is used to seal the cartons.

Bamboo baskets are also used as a packaging material for mangoes, especially by the retail stalls. Retailers usually transfer the mangoes from used banana cartons to bamboo baskets lined with newspaper. Each basket may contain 30-40 kg of mangoes with newspaper wraps already removed. Calcium carbide is usually added before sealing the package to facilitate ripening.

Figure 4.7.3.1. Packaging for export (a) and local (b and c) quality mangoes.

4.7.4 Improvement Measures/Interventions

Issues and inefficiencies along the supply chain have been identified and necessary interventions were formulated and implemented.

- Aimed at improving productivity and fruit quality, interventions implemented include: application of integrated crops management (ICM), preparation and dissemination of information, education and communication (IEC) materials and conduct of hot water treatment (HWT) and rapid heat treatment (RHT) trials. Farm cluster members are closely being supervised on ICM procedure that requires adoption of a rational and structured approach to crop planning using a combination of traditional techniques and modern technology. Information, Education and Communication (IEC) materials were prepared as part of the awareness campaign to improve production and postharvest practices. For the domestic market, a HWT trial was conducted for the Davao-Manila supply chain. A follow-up field study for the Manila-Hong Kong chain is scheduled on the third year of project implementation. The field study involves temperature monitoring in transit, quality assessment at various distribution layers to finalize recommendations in an attempt to optimize the Manila-Hong Kong chain.

- To address logistical issues, a preliminary assessment was made on the viability of sea shipment using ventilated van as alternative to air transport. The team met with the logistics provider to flesh out the details of the trial.
- In order to improve chain efficiency, a mango farm cluster was formed in Matanao and Bansalan, Davao del Sur. A cluster is an informal group bounded by common interests and united to work together in achieving a common goal. All production, postharvest and market interventions are being applied to the cluster. The cluster is being linked directly with the exporter.
- To enhance chain coordination, the implications of each organizational issues as well as suggestions to improve the chain were pointed out to the various organic units. Consequently, supply chain champions expressed their commitment to address such problems.

a. Cluster Formation

The project recognizes the need for a change in perspective that productivity and efficiency can be achieved by enhancing the performance of the whole chain and not at a single point in the supply chain. A holistic approach is imperative to address a number of contributing factors on productivity such as pest management, cultural practices and postharvest handling. Hence, farm clustering was introduced.

Farm clustering was introduced to groups of farmers in Mindanao (Figure 4.7.4.1). The farmers were stimulated to form a cluster as they realize the benefit of working together to achieve a higher level of efficiency in mango production and marketing. The mango farm clusters consisted of ten closely located farms in Brgy. Bangkal, Matanao, and Brgy. Mabuhay, Bansalan in Davao del Sur.

Developing supply chains requires a lot of effort in building a cooperative relationship with farmers, especially in gaining their trust and motivating them to work together. Prior to farm cluster formation, farmers rarely practice information sharing either for lack of confidence or simply because there's no avenue for discussion. Farmers work individually to resolve problems on pest infestation. This created a strong demand for technical information and assistance among farmers and eventually becomes the major motivating factor for cluster formation. The farmers were stimulated to form a cluster as they realize the benefit of working together to achieve a higher level of efficiency in mango production and marketing. The mango farm cluster consisted of ten closely located farms in Brgy. Bangkal, Matanao, and Brgy. Mabuhay, Bansalan in Davao del Sur. To capitalize on this, the project provided technical assistance through the help of a pest management expert to gain the farmers' trust.

Figure 4.7.4.1. Farm cluster formation in Davao del Sur providing technical assistance to growers (2006).

The prevailing issue of growers and sprayers is low productivity and low quality recovery, which can be attributed to their production activities. This was one of the issues addressed in the farm cluster. After verifying the spray program of the members, it was found out that cocktailing of chemicals with the same active ingredients and under-dosed spraying of pesticide is a common practice. Moreover, farmers have inadequate knowledge regarding necessary cultural practices such as growth regulation, pruning, sanitation and fertilization.

On a regular basis, consultation meetings and field visits were conducted in order to monitor the farm cluster's activities. Consultation meetings served as an avenue to ventilate problems and issues in mango production and as a capability-building activity thru provision of technical information. Field visits were conducted to assess actual farm condition and carry out actual demonstration of proper farming techniques. Cooperation among farmers was developed as they share their production practices, success stories, problems encountered and activity plan.

b. Integrated Crop Management

An Integrated Crop Management (ICM) strategy is being promoted among farm cluster members. This involves the adoption of a rational approach to crop planning using a combination of traditional techniques and new strategies to improve productivity. Figure 7.4.2 shows the generic ICM strategies that were employed in the two farm clusters. Strict monitoring of pests and climatic conditions were highlighted as the critical activity in implementing ICM since this will determine the modifications and adjustments in pesticide management that will be implemented.

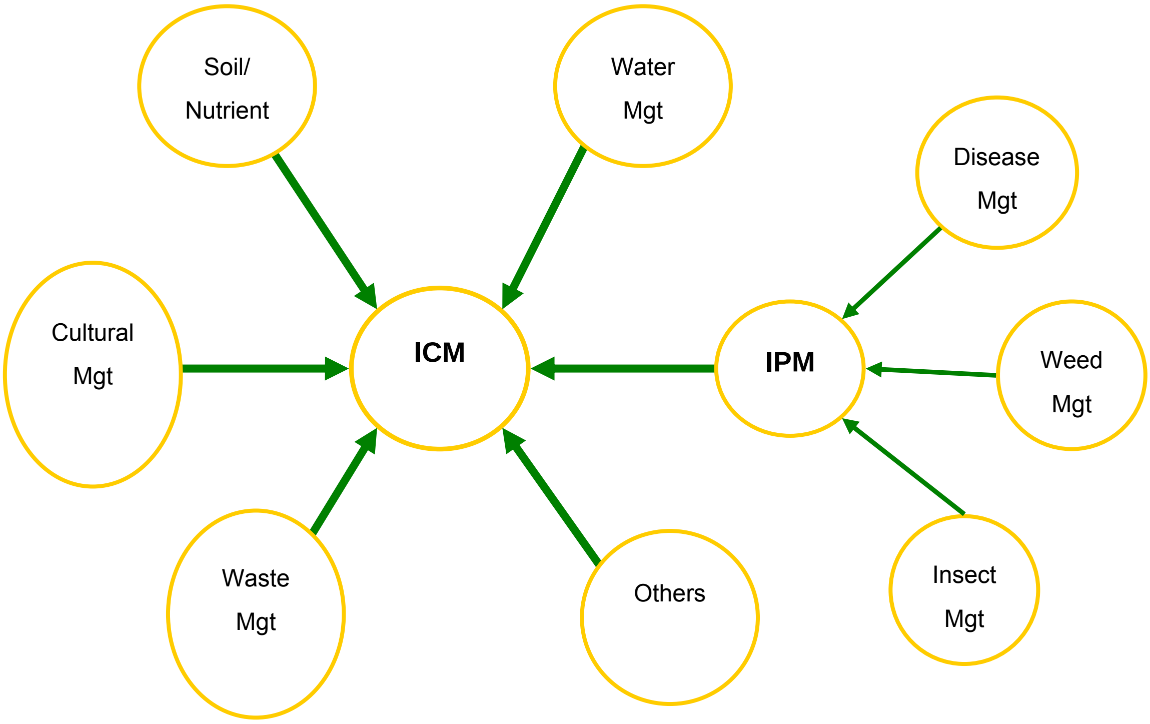


Figure *4*.7.4.2. Components of mango ICM.

The following cultural management practices were implemented and regularly monitored:

- application of growth regulators such as Paclobutrazol
- pruning especially center canopy pruning
- fertilization
- flower induction
- pesticide management

Pesticide management has been the persistent problem in mango production. All cluster members practice the so-called 'cocktailing' of pesticides and since they are in mixtures, the tendency is to underdose all the chemicals that are mixed. Moreover, they are not aware of the synergistic effects of the chemicals that they are mixing due to lack of knowledge of the chemical groupings of these pesticides. A sample spray program was given to cluster members as guide.

Table 4.7.4.2. Comparative pesticide spray program of the mango farm cluster members and the recommended spray program of IPM.

Farmer's Practice1		IPM2	
DAFI3	Chemicals Used	DAFI3	Recommended Chemicals
0	Calcium nitrate	0	Calcium nitrate
10-12	CPM + Super Cartap + Dantop	7-12	Alika + Mancozeb
18	Dantop + Caligro	13-18	Oshin + Mancozeb + (Kilabot)
23-24	Super Quick + Super Cartap + Selecron + Goldazim	21-25	Chess + Amistar + Mancozeb + (Mesurol)
28	Mesurol + Selecron + Padan	27-29	Amistar + Mancozeb
35	Foliar fertilizer + Mixed CPM	30-35	Alika + Mancozeb or Antracol + Kilabot
42	Penant + Goldazim	38-45	Cartap + (Mesurol) + Mancozeb or Carbendazim
50	Sumithion + Foliar fertilizer	45-50	Sevin + Benlate
57-60	Wokozim + Penant + Redeem	45-60	Early Bagging
90-95	Matahion	60-120	Alika or Cartap or Sevin

1 Conventional pesticide spray program followed by a representative member of the cluster
2 Recommended spray program in a worst-case scenario, i.e., major insect pests are present and weather conditions favor infestation and disease development
3 Days after flower induction

Another problem with their pesticide spray program is the continuous use of the same insecticide and fungicide throughout the different stages of flower and fruit development. This practice will lead to development of resistance of the pests. Farmers were advised of the need to alternate pesticides of different groupings as part of their resistance management strategy. A list of these pesticides and their groupings was provided for their reference. In fungicide management, differences between systemic and protectant fungicides and when should they be applied were explained. A sample spray program was distributed to the cluster similar as that in Table 4.7.4.2 (IPM) indicating the expected pest/disease at a particular period after flower induction and the appropriate chemicals to use and their correct dosage.

Table 4.7.4.3. Comparative pesticide productivity and quality before and after application of ICM of two farm cluster members in Matanao, Davao del Sur.

	Farmer 1		Farmer 2	
	Before ICM	ICM	Before ICM	ICM
Yield/tree (kg/tree)	39.06	32.39	69.44	137.41
Chemical input cost/tree	186.58	327.29	183.19	737.22
Total production cost/tree	342.14	494.53	550.13	1,025.03
Gross income/tree	976.62	1,394.68	902.83	2,791.57
Net income/tree	549.89	900.15	352.70	1,766.55
% unmarketable rejects	5.0	2.8	9.6	6.8

After adopting ICM, quality and productivity has improved as represented by two members of the farm cluster in Matanao, Davao del Sur in Table 4.7.4.3. Farmer 1 has 14-year old trees while the trees of Farmer 2 were 18-years old. Note that the total production and cost of chemical input are higher after ICM was applied. Nevertheless, it proves to be effective as reflected on the increased volume of harvest per tree of Farmer 2 by 97.87%. Quality has also improved as shown in the decreased percentage of rejects of the two farms. Farmer 1 has a greater yield per tree before applying ICM but of poor quality, thus income per tree was low. After adopting ICM, quality has improved thus mangoes were bought at a higher price and income has improved.

Some farmers, however, were unsuccessful because of some unavoidable factors such as the weather condition. Even if the recommended spray program is followed, frequent occurrence of rain has contributed to severe infestation of insects and diseases. Some trees were also "over-stressed" because trees are not allowed to rest after a fruiting cycle. It was recommended that trees be given a rest period of one year before inducing it to flower again to break the cycle.

c. Postharvest Disease Control

During the rainy months of June to December, when mangoes are primarily produced from Mindanao, postharvest diseases such as anthracnose and stem-end rot become a perennial problem. This causes almost 5% of rejects, both in Hong Kong and local markets. For mangoes exported in Hong Kong, price drops to as much as 75-85% as the disease becomes more prevalent.

In the local market, traders opted to use Benomyl to control anthracnose and stem-end rot. Fruits are dipped to a sponge soaked in water and Benomyl mixture and the practice is said to lower the disease incidence to 2-3% according to traders. Benomyl is not recommended as a postharvest dip, thus poses risk for the consumers. Exporters, on the other hand employ HWT to control anthracnose and stem-end rot.

A survey among traders at Bankerohan was carried out to determine the extent of awareness & estimate the demand for HWT prior to the pilot testing of HWT at the traders' level in Davao City. Apparently, the traders have inadequate information regarding the benefits and proper application of HWT. The survey revealed that the demand for the technology is volatile citing two major constraints: the time needed for the treatment causing delays in disposal and the added cost. A total of 10 mango traders were interviewed. On the average, each trader handles 3 tons of fruits per day during the peak season.

A business proposal was prepared and submitted to EMC Property Holdings (owner of Bankerohan) for the establishment of a common HWT facility at Bankerohan, Davao City to cater to the needs of mango traders in the area and as a better alternative to benlate-dip. The proposal provides a detailed description of the investment project including a detailed analysis of the viability of the business. The team met with EMC Property Holdings and the company finds the proposal of commercial merit provided the demand for the technology is established.

A trial comparing the efficacy of HWT against benlate dipping of local quality mangoes from Davao del Sur was initiated. Three sets of freshly harvested mango samples from Buhangin, Davao City were evaluated. One set of samples were subjected to HWT and another was dipped in benlate, few hours after harvest. The last set was not subjected to any treatment. All samples went through the postharvest handling processes typical for locally distributed mangoes.

Hot water treatment proved to be effective in controlling anthracnose and stem-end rot, with mangoes showing no disease development up to eight days after harvest. In contrast, fruits dipped in benlate exhibited high anthracnose incidence although stem-end appeared to have been controlled. Control fruits had 100% anthracnose and stem-end rot eight days after harvest. Anthracnose severity for benlate dipped mangoes was also 100% and no incidence of stem end rot was observed. Benlate dip offers some control against stem-end rot but anthracnose remains a problem. Disease severity and incidence from five to eight days after harvest is shown in Figure 4.7.4.3.

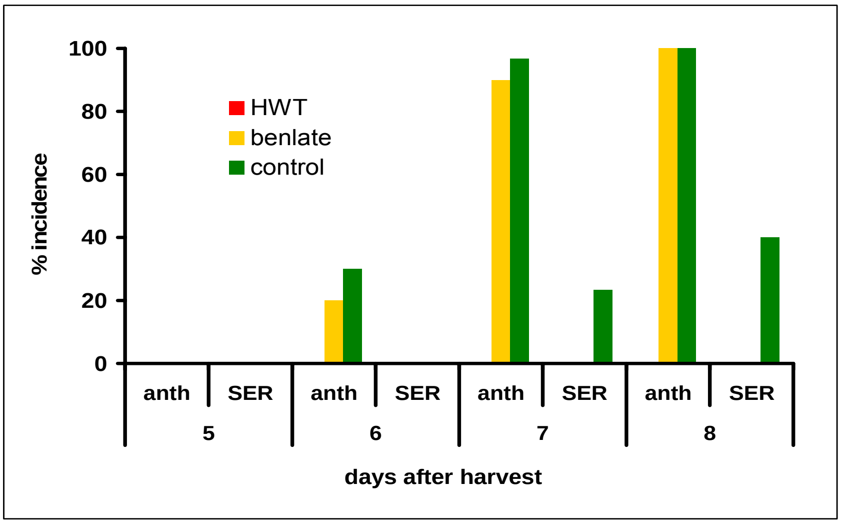


Figure 4.7.4.3. Comparison of disease incidence of local quality mango samples subjected to different treatments.

Figure 4.7.4.4. Disease incidence of local quality mangoes subjected to different treatment, 8 days after harvest

4.7.5 Development of Alternative Quarantine Treatment of Mangoes for Export to China

Through the funding from the Mango Producers and Exporters Confederation (MPEC) and collaborative research between PHTRC, DA-BPI and DOST-PNRI, the extended hot water dip (EHWD) of mangoes for export to China was developed. During discussions with Hong Kong importers, this quarantine issue was raised. Hence the supply chain project partly participated in the development of EHWD protocol particularly during evaluation of fruits' response to EHWD.

d. Information Campaign

Information, Education and Communication (IEC) materials were also prepared as part of the awareness campaign on integrated pest management and postharvest handling for farmers and traders.

e. Addressing Logistics-related Issues

Another notable problem that was observed by the project team was the limited air freight capacity servicing the Davao-Manila route. In cases when priority cargo such as tuna, cut flowers and other fruits such as rambutan and lanzones are available in large volumes, mangoes are often off-loaded by the major airlines. This sometimes causes delays on delivery and worst in cases, the mangoes are "bumped-off" and the traders resort to route it to Cagayan de Oro via sea cargo through open van.

The viability of sea shipment using ventilated van as an alternative to air transport was evaluated to address the logistics problem associated with the limited air freight capacity in the Davao-Manila route. A meeting has been set between the project team and the logistics provider (of ventilated vans) to flesh out the details of the trial. In the mean time, trial shipment using ventilated van is not undertaken because of problems with the cargo ship that will carry produce to Manila. Moreover, this alternative has been already been used by one of the exporter-cooperators but because of inability to maximize the capacity of the van, the shipments were stopped.

f. Improving market efficiency

Presently, the mango marketing system is characterized by adversarial relationship, information asymmetry and redundant activities. In this regard, relational marketing was promoted to the farmer clusters and exporter-cooperators. The present challenge is how to develop trust between these players. Initial attempt at direct marketing (i.e. farm directly selling their fruits to the exporters) was unsuccessful as the farmers tend to “pole-vault” once offered with a higher price by other traders. Such “pole-vaulting” practice erodes whatever trust has been gained initially and undermines the relationship being established. Another challenge is for the farmers to produce quality mangoes since exporters prefer farms with high percentage of exportable mangoes.

g. Enhancing Chain Coordination

A meeting with the supply champions were arranged to present the some issues that were raised during interviews with the exporters’ field personnel; among them is the absence of established/ permanent linkage between the exporter and source farms. The project team suggested farm clustering and the exporters agreed to consider this intervention provided that the team would come up with a feasible agreement/contract between the farmers and exporters. Another issue was miscommunication during shipment resulting to delayed arrival for which the exporter-cooperator agreed to issue a Memorandum addressed to the warehouse supervisor & procurement staff. The memo shall contain the duties & responsibilities of the employees during procurement operations to clearly establish the responsibility center in transit.

Among the organizational issues that were raised were inadequate incentive and uncertain employment status for which the exporter clarified that all supervisors are regular employees and are receiving due benefits like 13th month pay. Furthermore, the issue of additional incentive for procurement staff is under consideration. Other issues will also be discussed accordingly during the company’s regular employee meeting.

4.7.6 Australian Results and Discussion

Four consignments of mangoes, 1 223 cartons in total, were exported to China. More consignments were planned but a prolonged delay in the issuing of import permits by the Chinese quarantine authority resulted in fruit being diverted to other export markets.

All 5 collaborators gained experience in preparing export consignments.

Eight meetings of collaborators, stakeholders and the project team were held during the project duration to plan and review activities. All activities were completed as planned, except the training of a Shanghai based Produce Surveyor to do outturn inspections was not done because the number of consignments exported was low due to the delay in issuing of import permits. A summary of each project activity is presented below.

- Provide advice on orchard management
- Advice was provided to orchard managers to ensure compliance with the China Mango Export Plan and to maximise fruit quality.
- Support collaborators to achieve compliance with the China Mango Work Plan

- Six orchards applied for registration for export to China. Five orchards were certified as free from quarantine pests and one orchard in Qld was found to be infested with mango seed weevil.
- The registered orchards were located in Katherine NT, Kununurra WA and Mutchilba Qld. Two VHT facilities were registered to treat and pack mangoes for China.
- The orchard inspections for freedom from quarantines pests were conducted in NT and WA by a registered crop monitor with support from the NT DPIF&W and WA DOA&F, and in Qld by DPI&F extension officers.
- AQIS officers helped clarify the protocol requirements to ensure that compliance was achieved, and together with the Agricultural Counsellor in Beijing they facilitated the issuing of import permits by the Chinese quarantine authority
- Provide advice and training on managing quality from harvest to the retail shelf
- Advice was provided to the collaborators and their supply chain partners on managing quality through personal contact, training sessions, and information products.
- In Shanghai, training and information products were provided to 9 importers and 5 retailers.
- Information products prepared included guides for mango handling systems in both English and Chinese language and training presentations on mango handling. Three existing guides (mango skin colour guide, mango handling guide and mango ripening guide) were translated into Chinese language.
- Handling guides for Australian Mangoes were translated into Chinese and used in training with product handlers to improve handling practices.

Design of export packaging

The project team worked with AMCOR Fibre Packaging and the collaborators to design a package to meet the requirements of customers and the China Mango Export Work Plan and for handling through the supply chain.

The package consisted of an outer with common graphics on the side walls to link the collaborator brands and an inner to pack the fruit (glued or unglued).

Two carton depths were manufactured to suit the different varieties – 110mm for Kensington Pride (KP) and CalypsoTM and 125mm for R2E2.

Bubble plastic was placed under and over the top of fruit. Individual fruit socks were used on the larger fruit sizes for the first consignment of CalypsoTM mangoes.

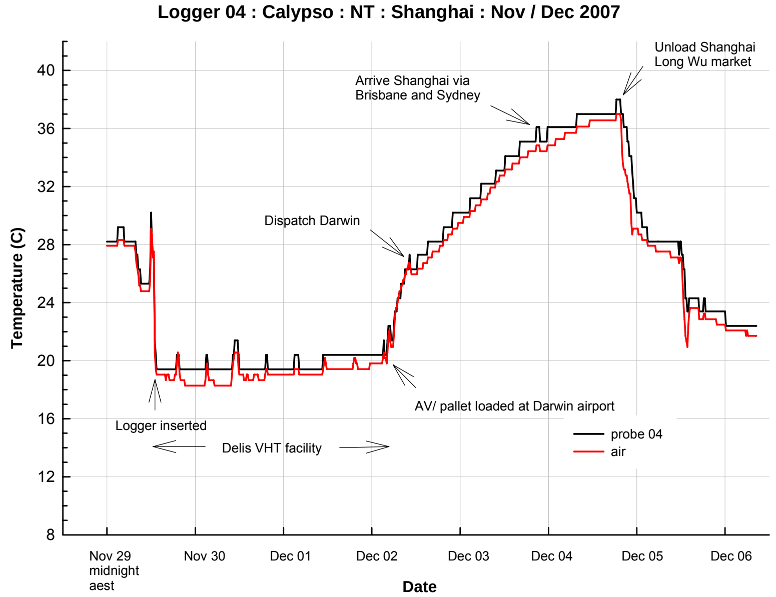
Monitor practices, conditions and quality from harvest to retail shelf

All consignments exported to Shanghai were monitored for handling conditions and fruit quality from pre-sorting and packing at the orchard to receival by the importer in Shanghai.

Reports on the monitoring of each consignment were provided to the collaborators and the results and key findings discussed. The reports included information on the consignment details, key findings, supply chain process flow, temperature profiles through the supply chain, and quality assessments at different points in the supply chain.

Significant quality loss occurred during handling in the supply chain for each consignment. The causes of quality loss were:

- physical damage, sapburn and skin browning during harvesting
- poor temperature management from the packhouse to the VHT facility and to the importer in Shanghai, resulting in fruit being too ripe
- delays due to incorrect documentation resulting in fruit being too ripe
- blush level below the 30% specification.
- Temperature monitoring of initial shipments showed that in transit ripening was a cause of poor product ripening. High transport temperatures are caused by fruit respiration and the quarantine carton design. These temperatures result in overripe fruit and increased disease.



Independent inspections and reports on outturn quality of each consignment

A project team member based in Shanghai completed outturn inspections of fruit quality for the first consignments of CalypsoTM and R2E2 mangoes. Fruit were held in an air conditioned room for 1 week after arrival and assessed for quality.

Outturn inspections were completed by the importers for the 2nd consignments of CalypsoTM and R2E2 mangoes.

Training of a Shanghai based Produce Surveyor to do outturn inspections was not completed because the number of consignments exported was low due to the delay in issuing of import permits.

Market research into the requirements and preferences of importers and retailers and the consumer purchasing habits and preferences for mangoes.

Three market research activities were undertaken – desktop market research, consumer research using focus groups in Brisbane and Shanghai, and in-depth interviews with Chinese importers, retailers and distributors.

Launch of Australian mangoes to the government and private sector in China.

A successful product launch was held in Shanghai.

Sample cartons of the 3 varieties were displayed and each person was given a gift pack of Australian mangoes.

Economic analysis of the cost and returns for direct market access.

An economic export model was developed to enable the collaborators to analyse the costs and returns associated with direct access to China.

Using the model, an economic analysis of the first commercial shipment exported to China was undertaken. Two scenarios were compared – the first was based on supplying mangoes from Katherine to the VHT plant in Mareeba and the second on supplying mangoes from local orchards at Mareeba. The sale price to the importer in China was assumed to be AUD65 per carton. The producer would receive a farm gate return of AUD2.44 per carton for scenario 1 and AUD8.06 per tray for scenario 2.

The economic analysis suggests that for exports to be commercially viable there must be some substantial cost savings, particularly in vapour heat treatment and freight charges. However, care should be taken when extrapolating the results to large commercial consignments. It is expected that future consignments will be able to negotiate better rates and customs and quarantine procedures will be easier to follow.

A summary of the economic analysis is contained in the report, “The Chinese mango market: consumer and supply chain market research”.

Communication of information

Eight meetings were held to plan and review project activities. People either participated in person or by telephone. Each meeting involved the 5 collaborators, 2 VHT facility operators, and representatives from the funders, AQIS, and project team. Representatives from AMCOR Fibre Packaging attended the relevant meetings when carton design was discussed. Meeting notes and agreed actions were distributed after each meeting.

Regular updates on project activities were sent by email to all collaborators and stakeholders.

Summary reports on the monitoring of each consignment were communicated verbally and by email. Detailed monitoring reports on each consignment were provided to the collaborators.

Information products prepared and distributed to collaborators and supply chain partners and publicly available on DPI&F website:

- Guide to mango handling systems for domestic and export supply chains

- Guide to handling of Australian mangoes at export destinations – available in English and Chinese
- Mango skin colour guide poster – Chinese version prepared
- Mango handling guide poster – Chinese version prepared
- Mango ripening guide leaflet – Chinese version prepared
- Training presentations and notes for handling and ripening mangoes – 4 modules

The following market research reports were published and copies provided to the collaborators.

- The Chinese mango market: Desktop research
- The Chinese mango market: Consumer and supply chain market research

4.8 Impacts

4.8.1 Scientific Impacts – now and in 5 years

Philippines

Problems were identified in the supply chain of mangoes in the Philippines from the farm up to the retail market, both local and export.

Six key questions (who are the key customers and what are their product requirements; how do product, information and money flow through the supply chain; what are the activities and services provided at each step in the supply chains; what are the critical logistic issues; who are the major decision makers or drivers in the supply chain, and; what external influences affect the performance of the supply chain) were formulated to answer the basic issues in a supply chain. These key questions can be used in other supply chains of any commodity.

Gaps in R and D were identified which can help in future studies and refocus research directions.

Farmers and sprayers were acquainted on ICM and improvement in quality of mangoes.

Australia.

Problems were identified in the supply chain of mangoes in Australia from the farm up to the retail market in China. These outcomes will guide Research and Development particularly with the development of sea freight after VHT treatment into the Chinese markets.

A new way of working with collaborators in developing a new market was developed and evaluated.

4.8.2 Capacity Impacts – now and in 5 years

Cooperation between farmers was initiated through cluster formation. This paved the way for exchange of knowledge and information among farmers. P & A

Supply chain champions became aware of issues in the supply chain. Awareness of other supply chain players was also increased. P&A

Strengthened capability of Local Government Unit (LGU) and they became acquainted with supply chain, thus awareness on problems of the mango industry was improved.

Research team gained understanding on what supply chain really entails. Knowledge obtained will be of great help for future related researches. P&A

4.8.3 Community Impacts (Social, Economic, Environmental) – now and in 5 years

- Farmers became aware of ICM and were able to experience hands-on application of the concept. [P]
- Demonstration of ICM to the community created a sense of cooperation between research team and in turn initiated cooperation among farm cluster members and the community. [P]
- Increased profitability for the farmers which means sustained job for the sprayers and contractors. [P]
- Changes in mango practices such as efficient use of pesticides and proper cultural management practices contributed to proper management of the environment and lowers down pollution. [P&A]
- Lowered health risks and food safety by using proper use of pesticides and HWT as postharvest disease control measures.
- Increased market access and profitability for the mango industry which means sustained market development. [A]

4.8.4 Communication and dissemination activities

Philippines

- Project meetings where project's activities and developments on the research are discussed.
- Surveys and interviews with supply chain players to map the chain.
- Meeting with supply chain champions to discuss trial improvements and issues that were raised during interviews with the exporters' field personnel.
- Meeting with importers to discuss quality issues and gathered suggestions for improvements of mango supply chain.
- On-site demonstration of cultural practices to the farm cluster and discussions on improving/correcting the farmers' spray program.
- Field visits to the farm cluster to discuss recent developments and answer questions raised regarding production.
- Project leaders attended the 'International Symposium on Fresh Produce Supply Chain Management' in Chiang Mai, Thailand last December 2006. The final paper entitled 'Supply Chain Improvement for Mangoes in the Philippines' was submitted to Agricultural and Food Marketing Association for Asia and the Pacific (AFMA) and the Food and Agriculture Organization (FAO).

Australia

- Eight meetings were held to plan and review project activities. People either participated in person or by telephone. Each meeting involved the 5 collaborators, 2 VHT facility operators, and representatives from the funders, AQIS, and project team. Representatives from AMCOR Fibre Packaging attended the relevant meetings when carton design was discussed. Meeting notes and agreed actions were distributed after each meeting.
- Regular updates on project activities were sent by email to all collaborators and stakeholders.
- Summary reports on the monitoring of each consignment were communicated verbally and by email. Detailed monitoring reports on each consignment were provided to the collaborators.

- Information products prepared and distributed to collaborators and supply chain partners and publicly available on DPI&F website:
- Guide to mango handling systems for domestic and export supply chains
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- Mango skin colour guide poster – Chinese version prepared
- Mango handling guide poster – Chinese version prepared
- Mango ripening guide leaflet – Chinese version prepared
- Training presentations and notes for handling and ripening mangoes – 4 modules
- The following market research reports were published and copies provided to the collaborators.
- The Chinese mango market: Desktop research
- The Chinese mango market: Consumer and supply chain market research
- An article titled “1st mangoes exported direct to China” was published in the Summer 2008 edition of the Mango Matters Newsletter.
- The following press releases were issued to the general media:
- First consignments of mangoes exported direct to China
- Beating mango seed weevil to please the China market
- Three interviews with ABC radio in Qld and NT were broadcast.

4.8.5 Project evaluation

Australia

Interviews were conducted with the four collaborators to evaluate the project objectives and activities, the benefits gained and their future needs for assistance to expand exports to China. The fifth collaborator was not interviewed as the representatives involved in the project have now left the company.

Two collaborators were fully satisfied that their objectives were achieved while the other two collaborators were partially satisfied. The collaborators were disappointed with the responsiveness of their supply chain partners and the quarantine authorities in China. They also wanted more information on the economics of the unofficial trade compared to the direct trade.

Three collaborators felt that the project objectives were mostly achieved and one collaborator thought they were partially achieved. Identifying areas for cost savings was the main area where more could have been achieved.

All of the project activities were regarded as useful to some extent. The following activities were the most useful:

- Support for orchard inspection for freedom from quarantine pests
- Provide advice and training on managing quality from harvest to retail shelf
- Monitoring practices, conditions and fruit quality from harvest to retail shelf
- Consumer focus group research
- Communication of information

The best features of the project were:

- Commercial companies working together and with the DPI team

- The energy of the DPI team to drive the project through to the end

The least effective features of the project were:

- Lack of collaboration and support from Chinese importers and quarantine authorities
- Not enough commercial assessment in the early planning stages

The main benefits that the collaborators gained from the project were:

- A clear understanding of the market requirements and processes for direct access into China
- Some exports were achieved and the protocol was tested

The collaborative effort has broaden the understanding of the effort required to turn a protocol into reality and make it actually work, and the interrelationship between DPI/AQIS

Future needs for developing direct exports to China include:

- Identify suitable partners in China
- Modify the China Mango Export Work Plan to reduce costs of compliance, particularly freedom from mango seed weevil
- Reduce supply chain costs such as VHT and freight
- More staff training and empowering of the supply chain
- Better cooperation from MAF Japan to allow more flexibility for the VHT process

The responses from the collaborator interviews and feedback from AMIA Board meeting in February demonstrate that the project objectives and the desired outcomes were achieved to a satisfactory level.

4.9 Conclusions and Recommendations

Philippines

Mango production, nowadays, appears to be more complex requiring accurate understanding of the phenology and the different factors (e.g. environment, management practices, monoculture) affecting productivity. Basic management skills seem to be inadequate, for instance, ability to access to weather forecast information becomes an advantage. Any changes in weather condition may necessitate modification in the spray program to deter any adverse effect.

The prevailing extension approach, wherein farms are visited only for surveys and information dissemination, is no longer applicable to mango. What is needed is a close technical supervision especially during the critical stages in the production cycle. Accuracy in dosage application is imperative to achieve higher productivity. Any delays or misapplications may result to adverse impacts as chances or probability of overcoming the critical stages becomes very slim.

It has been observed that majority of the trees lacks vigor and overexploited. Trees were forcedly induced twice a year, when supposed to be mangoes are biennial bearing trees. Fertilization is hardly practiced. The contract growing scheme promotes overexploitation. Contract-growers do not show genuine concern because they do not own the trees. There is a need to promote tree-owner producer scheme of certain modifications on the contract to ensure long-term vitality/productivity of trees.

The existing 'all-in' buying scheme does not encourage farmers to improve harvest quality. Future development programs should promote graded buying scheme to better compensate efforts in achieving better quality of produced. Farmers are benefitted as they capture the premium price of quality produced fruits.

The high incidence of anthracnose and stem-end rot necessitates the application of hot water treatment (HWT). However, the demand for the technology is volatile considering the following constraints: the time needed for the treatment causing delays in disposal, the added cost and lack of incentive or premium for HWT-treated fruits.

The challenge is to apply preferably at the farm or at least within 24 hours after harvest. There is a need for an intense 'Info Campaign' to promote the technology (HWT) as the most effective treatment to maintain fruit quality and minimize postharvest losses. Application of HWT directly benefits the retailers and consumers by the reduction of losses and increase in quality. In the long run, growers will benefit through preferential treatment and repeat orders.

The nature of mango distribution/trading system characterized by large volume which has to be moved within short-time period (fast-paced) often results to rough handling. The current 'trucking fee' system where transport fee are charged on per container basis encourages overpacking. Disparity in quality standards within the chain causes repeated product handling. Re-sorting and re-packing were prevalent as quality is not ensured from one distribution point to the next.

More extensive promotion/dissemination of the implication on losses due to poor handling is recommended. Classifiers sent to supply areas must have the proper training on quality control to minimize disparity in quality standards. Exporters may consider implementing measures to encourage classifiers in the field to religiously observe the company's quality standards.

Policy interventions are necessary to address logistics-related issues such as limited capacity of airfreight carrier, increasing costs of inputs and poor farm-to-market road condition. Policy brief regarding inadequate plane cargo carrying export grade mangoes from Davao City to Manila should be pursued. The government may device measures to make these inputs affordable for end-users. The cost of inputs must be reduced by addressing the inefficiencies in the input system and low-cost alternative inputs must be explored. The government should continue improving farm-to-market roads and other transport infrastructure to lessen the costs of transportation and physical damages not only to mangoes but other agricultural products as well.

Marketing is characterized by adversarial relationship, information asymmetry and redundant activities. Relational marketing is being promoted through the creation of farm clusters and linking the clusters directly with exporters. Clustering can really serve as an informal farmer organization through which assistance can be channeled. Access to information on the cultural practices of co-farmers as well as to the technical assistance being provided by the project appears to be the primary motivation of farmers in joining and sustaining the cluster. They have also realized that controlling insect pests requires concerted effort and this can only be made possible if they work as a cluster. Private sector participation can be secured provided they are made to fully understand the project and confidentiality of information is observed.

Building trust between the cluster and exporter is proving to be more challenging than expected. The problem on "pole-vaulting" is a key concern and farmers are averse to marketing contract. Building trust requires a longer process. Closer and more frequent interactions between the farmers and exporters may facilitate the process.

Establishing relational marketing can only be achieved in the long-term. There is a need to pursue long-term sustained government program to improve and optimize the mango supply chain.

Australia

The following critical issues for developing exports to China were identified by the collaborators.

For export to be commercially viable there must be substantial cost savings, particularly in vapour heat treatment and freight charges.

Need to reduce the amount of handling in the supply chain – farm to VHT facility to export dispatch.

Must improve temperature management through the supply chain.

Need to invest in promotion and merchandising to gain market penetration.

Have to educate consumers and supply chain partners in China about Australian mangoes and handling practices.

Need a well planned export strategy – can't stop the unofficial trade so a collaborative effort is needed to target the Chinese market.

Need further improvements to packaging.

Have to improve the import permit process and get the documentation right.

Continuing support is needed to help develop and monitor practices/ systems to manage product quality all the way through the supply chain.

Review the China Mango Export Work Plan to improve the ease and cost of compliance.

The consumer and supply chain market research recommended the following actions for the industry:

Prepare an export marketing plan and identify market segments to be developed.

Adopt niche marketing and target appropriate market segments.

Find a distributor with strong businesses relationships along the supply chain.

Create a product image and position Australian mangoes as an exclusive, fresh and natural tropical fruit.

Consider the Zespri marketing model, particularly their promotional campaigns.

Explore alternative freight methods to reduce landing costs.

Improve logistics to maintain product quality and differentiate from competitors.

Be aware of the unofficial trade and its likely effect on prices.

5 Field evaluation of plant host defence activators

Objective 4: To further develop and evaluate treatments that enhance host resistance and delay or inhibit disease development on mangoes, under natural field

Co-authors/ contributors/ collaborators

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5.1 Acknowledgement

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5.2 Executive Summary

Mango is attacked by a number of destructive pests and diseases causing enormous pre- and postharvest losses. Anthracnose and stem-end rot caused by Colletotrichum gloeosporoides and Lasiodiplodia theobromae, respectively, are the most serious and destructive diseases of mango which limit fruit quality and market access. Under wet and favorable condition, anthracnose can cause total crop failure. Both diseases can infect the fruit leading to the reduction in quantity and quality of marketable fruits and rapid postharvest deterioration. Currently, pre-harvest disease control measures rely heavily on the use of fungicides while hot water and fungicide dip for postharvest disease control. However, the use of fungicides is anticipated to be restricted because of the growing food safety and environment concerns. Thus, it is important that alternative strategies are sought.

Recognizing the importance of the mango industry to smallholders, ACIAR has undertaken a collaborative project between Australia and Sri Lanka to evaluate the prospect of utilizing inherent plant defense mechanisms in the management of postharvest diseases of mango. The compounds such as acibenzolar-S-methyl (Bion®), silicon and kaolin clay compounds show promise for controlling disease with fewer applications required compared to traditional fungicide treatments. Initial trials indicate some treatments have the potential to reduce losses to levels that are better than or comparable to current recommended fungicides. Such project collaborations were later extended to the Philippines with primary aims of assessing novel treatments that enhance host resistance and reduce disease losses in mango and enhancing the capacity of project participants to conduct plant disease research.

In the Philippines, the study was conducted in Davao del Norte and Davao del Sur, representing a wet and a drier mango production system, respectively, with active participations of local government units (LGUs) to assess the field efficacy of resistance-enhancing treatments in reducing the pre- and post-harvest losses due to mango diseases. The three resistance-enhancing treatments were Bion (Boost 500 SC or acibenzolar-S-methyl), Kasil, (silicon-based formulation) and carbonized rice hull ash (RHA) and these were applied as foliar spray, soil

drench and mulch, respectively. The efficacy of these treatments against pre- and postharvest diseases of mango was evaluated under high and minimized (with fungicide spray) disease pressures on the basis of disease incidence and severity, fruit ripening and saleable life index, visual quality and physico-chemical changes.

The overall results of the 3-season field trials suggest that the resistance activators, acibenzolar-S-methyl (Bion) and silicon-based materials (Kasil and rice hull ash) failed to sufficiently stimulate the defense mechanisms of 'Carabao' mango to confer consistent reduction in the severity and incidence of preharvest (blossom blight and scab) and postharvest (anthracnose and stem-end rot) diseases. There was, however, indications that Bion, Kasil and Rice hull ash significantly suppress these diseases but this was not consistent

in another trial season or site. In all trials, the fungicide spray regimes consistently suppressed the incidence and severity of mango diseases. The significant reduction of preharvest diseases (blossom blight and scab) afforded variably by the resistance elicitors (Bion, Kasil and Rice hull ash) and consistently by fungicide application was translated into better fruit yield and quality. The resistance enhancing treatments did not influence any significant change in the silicon content of the fruit peel or the pH level of fruit peel and pulp. The resistance elicitors did not affect the normal ripening behavior of 'Carabao' mango. However, failure to sufficiently suppress postharvest diseases has resulted in relatively short saleable period and very low visual quality. In similar manner there was no clear cut evidence to show that the resistance enhancing treatments exerted positive or negative changes on the physical and chemical attributes of 'Carabao' mango fruits.

5.3 Background

Mango is one of the important fruit crops in the Philippines. It is considered as the 3rd top dollar-earning fruit next to banana and pineapple based on total volume and value of production. In 2004, the country is the 6th largest world producer with a total production of 890,000 mt (FAO Database, 2004). Of this production, only 5% is exported as fresh mangoes and the rest is consumed locally or processed (BAS Data, 2004).

The availability of improved technologies (e.g., flower induction, etc.) coupled with increasing demand of this fruit in the domestic and world markets has encouraged the growers to expand and intensify production. At present, mango fruits can be produced any time of the year (off-season) and in areas with high rainfall conditions (Mindanao). The changes in the production system have enhanced the occurrence and aggressiveness of mango diseases. Among the diseases, anthracnose, caused by Colletotrichum gloeosporioides and stem-end rot caused primarily by Lasiodiplodia theobromae constitute the major pre and postharvest problem. Together, they can cause substantial postharvest fruit deterioration which limit market access and losses can be even greater when further shelf life extension is required for distant market. Scab, caused by Elsinoe mangiferae has now become a serious problem during off-season production causing substantial rejection of fruit for export.

Disease management strategy is mainly focused on pre and postharvest control of anthracnose which rely heavily on the use of fungicides. It is estimated that 60% to 80% of the cost of production is spent on chemical pest control. About 40 % of which is due to high level of fungicide usage. Postharvest hot water treatment at 52-55oC for 5-10 minutes (Quimio and Quimio, 1974; Lizada et al., 1986) or a rapid heat treatment at 59-60oC for 30-60 seconds (Esguerra et al., 2002) has shown to provide adequate control of anthracnose. However, in some cases, postharvest hot water treatment can not achieve a considerable degree of control particularly when disease pressure in the field is high or when preharvest disease management is inadequate. Despite the high preharvest usage of fungicides and postharvest treatment, the loss of fruit quality continues to be a major problem. It is envisaged that the use of fungicides will remain as the backbone of disease management in the foreseeable future. Recently, excessive use of insecticides on mango has resulted in high chemical residues in the fruit restricting market access to Japan. The growing concern about food safety and strict regulatory control programs which are evident in major importing countries necessitate a change in pest control strategies.

Many efforts are underway to develop alternative strategies for the control of mango diseases such as use of biofungicide and other biological means. One of the promising alternatives being pursued is to stimulate or induce natural host resistance by the application of resistance elicitors. A number of chemicals have been shown to enhance preformed defenses and elicit induced defenses in plant tissues. These include acibenzolar-S-methyl (Lawton et al., 1996), salicylic acid (Ram and Vir, 1986; Zainuri et al., 2001), and silicon (Dann and Muir, 2002). Promising results were obtained with foliar application of the synthetic analogue of acibenzolar-S-methyl (Bion ®) for the control of Rhizopus rot of hami melons (Huang et al., 2000), grey mold of strawberry (Terry and Joyce, 2000), passion fruit scab (Willingham et al., 2002) and anthracnose on cashew (Lopez and Lucas, 2002). Collaborative research between Australia and Sri Lanka has shown that immature mangoes have evolved a formidable constitutive antifungal system comprising gallotannins, resorcinols and chitinases. Gallotannins are strongly antifungal compounds located in the peel tissue while resorcinols are antifungal present in the latex and the peel tissue. Mango latex contains at least two chitinases and is antifungal. Salicylic acid and Bion ® applied as postharvest sprays significantly reduced anthracnose development. In preharvest treatments, salicylic acid applied at mid-fruit fill reduced anthracnose developed by 65-90%. Chitinase and phenolics were induced when salicylic acid-treated fruit was challenged-inoculated with C. gloeosporoides. Soil enrichment with silicon (Kasil) resulted in some reduction in anthracnose and stem-end rot but not consistently. The abovementioned compounds show promise for controlling mango diseases with fewer fungicide applications. Thus, these activators could prove valuable in the commercial management of mango diseases.

This current Philippines-Australian collaborative project is an offshoot of the Sri Lanka-Australia research collaboration and focused on practical field evaluation of host defense activators in delaying postharvest disease development and assesses their efficacy in controlling other field diseases such as scab. Of particular interest is the effect of new treatments on the quality and shelf-life of harvested fruits. The farmer-participatory approach is employed during the project implementation in Mindanao where disease is a major problem since production is timed during the rainy season (off-season).

5.4 Objectives

The overall objective of the project (Philippine extension) is to reduce reliance on synthetic fungicides, which are increasingly considered undesirable because of growing food safety and environmental concerns and more strict regulatory control programs. This was partly achieved through the following specific objectives:

Specific Objectives	Outputs
Objective 1 To assess the efficacy of selected chemical treatments which enhance host resistance and reduce disease losses in mango	Evaluation of the efficacy of plant defense activators for the control of field and postharvest diseases of 'Carabao' mango Recommendations for treatment combinations which may elicit field defense responses, affect yield disease level and reduce anthracnose and stem-end rot in 'Carabao' mango fruits
Objective 2 To foster improvements to field and postharvest disease management and enhance the capacity of project participants in conducting plant disease research	Baseline information about current farmer disease management practices Farm and operators of packing houses using improved disease management practices Project team trained to carry out integrated field disease management trials Collaborative experience of project team and others in the region with similar problem and interests

5.5 General Methodology

The Philippine project activities were primarily conducted in the Southern Mindanao, Philippines. The general methodology is presented on the basis of project objective as follows:

Objective 1. To assess the efficacy of selected chemical treatments which enhance host resistance and reduce disease losses in mango

Field-based Experiments

Experimental Sites. Field experiments were conducted in two separate areas with distinct climatic conditions namely: (a) Linga Mango Farm, in Mamacao, Kapalong, Davao del Norte representing a pronounced wet condition, and (b) Belcris Mango Farm, in Matti, Digos, Davao del Sur with distinct wet and dry condition. Mango trees of uniform age (about 8-12 years old) and canopy were selected in each area. The trees were labeled and tagged with colored plastic ribbons to represent corresponding treatments.

Experimental Design and Treatments. The field experiments followed a factorial experiment arranged in Randomized Complete Block Design (RCBD) with three replications. A single mango tree served as an experimental unit where each treatment combination was applied. Based on the results of the first year trial, non-application of fungicide for both experimental sites resulted in severe blossom blight and scab infections and very poor mango fruit appearance regardless of the resistance enhancing treatment applied. As such, treatments which involved non-application of fungicide were eliminated from the experiment. The resistance-enhancing treatments were applied in combination with the optimized fungicide spray program. Following were the treatments applied:

T1 - Bion (Boost 500 SC or Acibenzolar-S-methyl)

T2 - Kasil (silicon)

T3 - rice hull ash (RHA)

T4 - combination of RHA + Kasil

T5 – combination of Bion + RHA (Davao del Sur only)

T6 – optimum fungicide only

Optimum Fungicide and Treatment Application. Fungicide combined with Bion was sprayed using a high-volume power sprayer (Kawasaki brand KJ-AS25) with 800-1400 rpm rate capacity of 14 L/minute, pressure of 25-50 kg/cm2, and powered by 5 HP Honda engine. The volume of spray applied per tree was 20 liters. Mancozeb (Fungizeb 80 WP) at 500 g/200 L was applied at 8-12, 15-18, 21-25, 30-35 and 55-65 days after flower induction (DAFI). Azoxystrobin (Amistar 25 SC) was sprayed at 70 ml/200 L at 21-25, 25-30 (if frequent rain), 40-50 and 55-65 DAFI (Figure 1). A sticker (Hoestick) at 100ml/200 L was used to ensure the tenacity of fungicides. For the enhancing treatments, Bion was applied as foliar spray at 2 ml/10 L; while Kasil (Silicon) at 26.7 ml/10 L of water was applied as a soil drench. The RHA (100 kg/tree) was applied as mulch with basal fertilizer during flushing. The schedule of resistance enhancing treatment applications in the two mango farms were as follows:

Treatments	Application schedule
1 - Bion	1st spray - panicle elongation (15-18 DAFI)
	2nd spray - fruit set (30-35 DAFI)
	3rd spray - prior to bagging (50-60 DAFI)
	4th soil drench (80 DAFI)
	5th soil drench (100 DAFI)
2 – Kasil	1st soil drench at 15-18 DAFI
	2nd soil drench at 50-60 DAFI
	3rd soil drench at 80 DAFI
	4th soil drench at 100 DAFI
3 - Rice hull ash	mulch (4 months before flowering)

Cultural Care and Management. Formative and center-canopy pruning was done prior to flushing so that the mango trees shall have the desired canopy shape. Dead and diseased branches were removed. Three kilograms (3 kg) of fertilizer at a ratio of 1:4:2 parts urea (46-0-0), complete (14-14-14 NPK), and muriate of potash (0-0-60 NPK) were applied per tree. This was done 3-4 months before flower induction (MBFI) to induce vigorous tree development. Glyphosate (Round-up) at 4.2.L/ha per hectare was applied at least 2 m around the tree to control weed growth. Weeds that grow between the mango trees were trimmed by grass cutter. Paclobutrazol (Cultar 25SC) was applied at the rate of one gram (1g) active ingredient per linear meter of canopy diameter to enhance floral initiation and to ensure high flowering intensity. The experimental trees were induced to flower by spraying 2.5% of potassium nitrate (KNO3). A follow-up spray of 1.5% KNO3 was done to ensure high density flowering for all the trees. Major insect pests of mango such as leaf hopper, tip borer, mango midge (cecid fly) and others were controlled by recommended insecticides. Bagging was done at about 65 DAFI using local newsprint to protect fruits from insect damage and to improve fruit quality. Fruits were harvested at 111 DAFI in Linga Farm and at 112 DAFI in Belcris Farm.

Data Gathered and Analysis. Disease severity was measured following the standard diagrams for blossom blight and scab (see Appendices). Blossom blight severity was determined at 29-30 DAFI using 50 randomly tagged panicles per tree while scab severity was evaluated at 50-56 DAFI. Fruit set and fruit yield was determined on 50 randomly tagged panicles per tree. The data was statistically analyzed using Analysis of Variance (ANOVA). The treatment means were compared using Duncans' Multiple Range Test under the Irristat Procedures.

Laboratory-based Experiments

Experimental Design and Treatments. Seventy five (75) randomly selected fruits harvested from each treatment were utilized for the evaluation of postharvest diseases. These were set in a Completely Randomized Design (CRD) with three replicates per treatment.

Data Gathered and Analysis. Incidence of anthracnose was measured based on the number of fruits infected over the total number of fruits harvested per treatment. This was determined at seven (7) days after harvest stored under ambient condition (25-27oC). The disease severity was measured using a standard diagram or index. Incidence of stem-end rot was also determined at seven (7) days after harvest. This parameter was measured based on the number of fruits infected over the total number of fruits harvested per treatment. The number of days from 60 % yellow (PCI=4) to 10% disease severity was counted to determine until when the fruits can be marketed or are acceptable to the consumer. Rate of ripening was monitored based on change in peel color using peel color index (PCI). Visual quality rating (VQR) was determined at table ripe stage (7 days after harvest). At the table ripe stage, fruits were:

Peel Color Index Visual Quality Rating

- completely green	9 – 8 Excellent, field fresh
2 - breaker, trace of yellow at the stem end	7 - 6 Good, slight defects
3 - more green than yellow	5 - 4 Fair, moderate defect
4 - more yellow than green	3 Limit of marketability
5 - trace of green	2 Limit of edibility
6 - completely yellow	

analyzed for their firmness, total soluble solid (TSS), titratable acidity (TA) and pH. Firmness of both sides of the fruit was determined using stationary penetrometer where the numerical equivalent (in kg) was recorded. Total soluble solid (TSS) of the fruit extract was measured using hand held refractometer and the value was expressed in 0Brix. For titratable acidity (TA), fruit extract was titrated with standard NaOH and this was expressed as % maleic acid (predominant acid in mango). The pH of the fruit was determined using the pH meter. The data was statistically analyzed using Analysis of Variance (ANOVA). The treatment means were compared using Duncans' Multiple Range Test under the Irristat Procedures.

Objective 2. To foster improvement to farm and postharvest management of disease and enhance the capacity of project participants to conduct plant disease research.

Postgraduate Student Training

The project activities contributed to the postgraduate studies and thesis of Ms. Marry Joy Porras of Deparment of Agriculture in Zamboanga City (Mindanao) who was awarded an MS degree in Plant Pathology by the Graduate School, University of the Philippines Los Baños.

Project Visit

The project leader from PCARRD, Dr. Jocelyn Eusebio accompanied by two project scientists, Drs. Oscar Opina and Elda Esguerra of UPLB visited Australia from August 13-17, 2004. The main objective of the visit was to hold discussions with the Australian counterparts on project extension focus and work plans and to participate in international congress of entomology in Brisbane. During the stay, the team visited the DPI & F research facilities at Indooroopilly and Nambour research centers, where they were briefed on the activities of the Sri Lankan component of the project to which the extension is linked; participated in an undergraduate student session lead by Dr. Donald Irving, University of Queensland Gatton Campus; held discussions with their Australian counterparts on project direction and focus and jointly developed a tentative work plan for the 2004-2005 cropping season in the Philippines.

Drs. Oscar Opina and Elda Esguerra visited Australia in December 2005. While in Brisbane, they visited Brisbane fruit and vegetable market and held discussion with the project teams. Dr. Chrys Akem and Mr. Tony Cooke accompanied them to the Bundaberg production district, DPI & F's Ayr Research Station, DPI&F Mareeba and mango breeding research program at Southedge Research Station. It was a very fruitful visit and the two project scientists expressed their sincere appreciation for having the opportunity to see the Queensland mango industry and interact with DPI & F Colleagues.

Drs. Oscar Opina and Elda Esguerra visited Australia in September and October, 2006. The main purpose of the visit was to participate in the October 1 workshop on Activation of Plant Defenses in Horticultural Crops at DPI & F Indooroopilly. While in Australia, they joined Dr. Chrys Akem to participate in the Australiasian Plant Pathology Conference in Adelaide.

Drs. Oscar S. Opina and Elda Esguerra frequently visited the project sites in Southern Mindanao to supervise and demonstrate to project participants the conduct of field experiments such as treatment applications, data gathering and analysis and other experimental activities.

Project Workshops and Field Day

Workshops were held in the two project sites before the project was implemented. During the workshops, discussions were done with the project collaborators (LGUs and Farmer Cooperators) regarding the project objectives, focus, work plans and responsibilities of project participants. The basic research techniques and procedures employed in the field experiment were also explained. Field days were held in the project sites during the course of the project to demonstrate the integrated crop management in mango focused on pest and disease management. The field days were well attended by mango growers, municipal agricultural officers and technicians and other mango stakeholders.

5.6 Achievements, Objectives and Outputs/Milestones

Objective 1: To assess the efficacy of selected chemical treatments which enhance host resistance and reduce disease losses in mango.

What has been achieved?	What has not been achieved?
The disease control efficacy of the defense activating compounds acibenzolar-S-methyl (Bion), potassium silicate (Kasil) and rice hull ash when applied as preharvest treatments to mango cv ‘Carabao’ was evaluated in a series of field trials over three seasons. Trial results suggest that Bion, Kasil and rice hull ash enhanced a certain degree of resistance on ‘Carabao’ mango against pre- and postharvest diseases but their effects were not consistent in all trial seasons or site. In most cases, the fungicide spray regime applied gave significant control of field and postharvest diseases.	Due to inconsistent efficacy of the defense activators, it has been difficult to formulate firm recommendation on the use of activators to reduce disease in mango. We recommend that further field studies focus on the use of rice hull ash as part of the integrated crop management of mango to improve crop nutrition and disease resistance. This will also enhance waste utilization in rice production.

5.6.1 Objective 2: To foster improvements to field and postharvest disease management and enhance the capacity of project participants in conducting plant disease research.

What has been achieved?	What has not been achieved?
Two grower cooperators involved in trials at Davao del Norte and Davao del Sur have benefited from ACIAR research program in terms of improved field and postharvest disease management in mango on their farms. Improved yield of higher quality fruits has resulted from their involvement with this project. Two demonstration field plots (“Techno-Demo”) were established at the Davao del Norte property where the research trials were conducted. The first plot was based on improved crop management practices incorporating optimal disease and pest control strategies (including need-based spray application), fruit bagging, cultural practices (pruning, orchard hygiene, nutrition), postharvest treatments, etc. The second plot was based on current farmer’s practice (ie. calendar-based spray applications and minimal or no cultural management). Effective collaborative links were established between Australian and Filipino project teams. Key project team member from the Philippines travelled to Australia in August 2004 to participate in a project discussion with Australian team members at DPI&F. This workshop provided an opportunity for planning of field experiments as well as standardization of techniques. Dr. Opina and Dr. Esguerra also visited Australia in December 2005 and October, 2007 providing an opportunity for further information exchange, project planning, training and familiarization with the Queensland mango industry during the peak harvesting period. Reciprocal visits by Australian team members (Dr. Akem and Mr. Cooke) to the Philippines have also been undertaken which strengthened collaborative links. Project participants from the offices of provincial agriculturist of Davao del Norte and Davao del Sur have benefited from the project in terms of enhancing their research capability to conduct disease management field trials. A MS candidate in plant pathology has graduated as a result of this project.	

5.7 Key Results and Discussion

Objective 1. To assess the efficacy of selected chemical treatments which enhance host resistance and reduce disease losses in mango

Field-based Experiments

Field trials on ‘Carabao’ mango have been conducted in three and two fruiting seasons in Davao del Sur and Davao del Norte, respectively. Results from the first and second trials in both trial sites have been presented in 2005 and 2006 annual reports. The overall results of the field trials indicated that application of resistance activators on ‘Carabao’ mango exerted variable efficacy in reducing the incidence and severity of preharvest and postharvest diseases of mango.

Preharvest diseases. In Davao del Norte, the 2005 trial showed discernible reduction in the severity of blossom blight and scab (Figure 7.1). However, only Bion provided significant reduction of blossom blight severity. When the application of resistance elicitors was super-imposed on fungicide spray (minimized disease pressure), Kasil and rice hull ash significantly reduced severity of blossom blight.

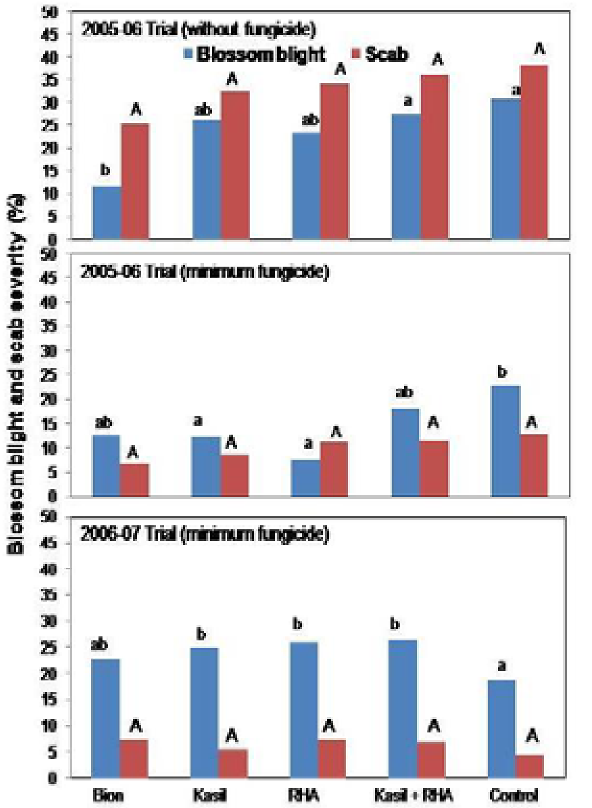

Figure 7.1 Mango blossom blight (anthracnose) and scab severity of ‘Carabao’ mango fruit as affected by resistance elicitors under without and minimum fungicide protection in Davao del Norte field trials.

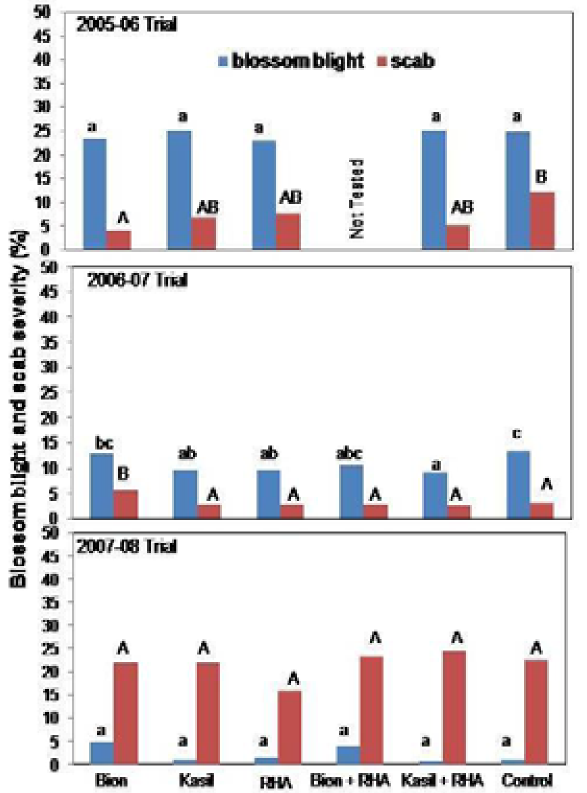

Figure 7.2 Mango blossom blight (anthracnose) and scab severity of ‘Carabao’ mango fruit as affected by resistance elicitors under minimum fungicide protection in Davao del Sur field trials.

In another trial (2006) on the same site, the resistance elicitors failed to suppress the severity of blossom blight and scab. In both trials, the fungicide spray regime consistently reduced the severity of preharvest diseases.

In Davao del Sur 2005 trial, Bion significantly suppressed scab but failed to exert effect on blossom blight. The other resistance activators did not reduce the severity of blossom blight and scab. In the second trial (2006), Kasil, Rice hull ash and their combination significantly reduced blossom blight severity while Bion appeared to enhance scab severity. In the 2007 trial on the same site, the resistance activators failed to elicit resistant reaction of ‘Carabao’ mango against blossom blight and scab.

Postharvest Diseases. The effect of the resistance activators on the incidence of postharvest diseases (anthracnose and stem-end rot) is shown in Figure 7.3, 7.4 and 7.5. Results of field trials in two sites indicated variable efficacy of the resistance activators. In Davao del Norte 2005 trial, Bion consistently reduced the incidence and severity of anthracnose under high and minimized disease pressure while Kasil reduced the incidence of anthracnose only when the disease pressure was minimized. In the second trial (2006) in the same site, the resistance-activators failed to elicit enough level of resistance in the fruits which manifested similar degree of anthracnose incidence and severity. In Davao del Sur, the three successive trials consistently showed that the resistance activators did not influence the incidence and severity of anthracnose.

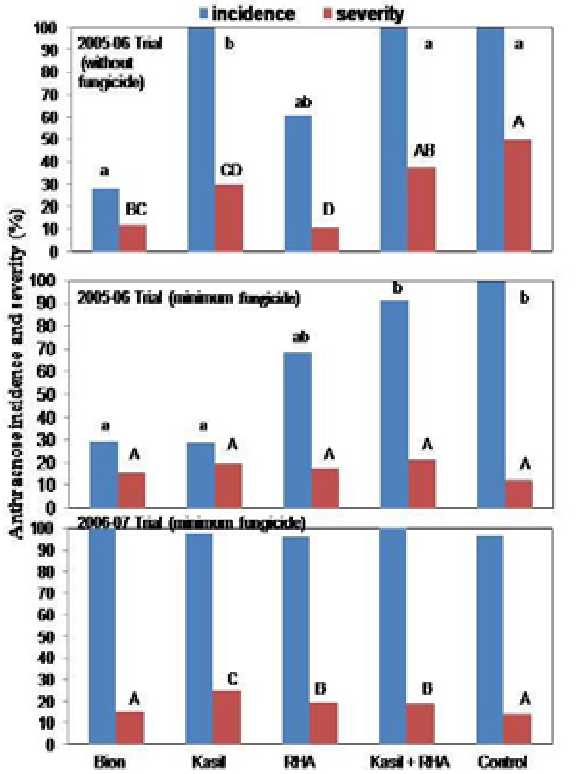

Figure 7.3 Anthracnose incidence and severity of 'Carabao' mango at seven days after harvest as affected by the different resistance elicitors under without and minimum fungicide protection in Davao del Norte field trials.

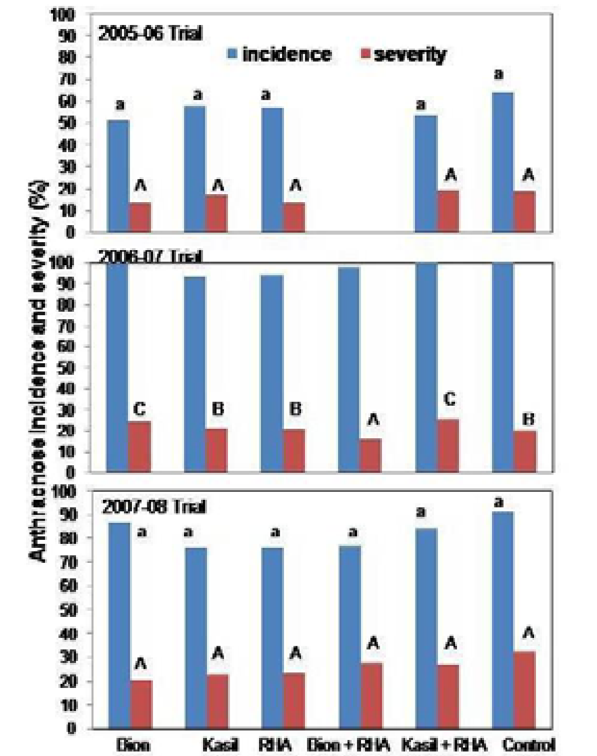

Figure 7.4 Anthracnose incidence and severity of 'Carabao' mango at seven days after harvest as affected by the different resistance elicitors under minimum fungicide protection in Davao del Sur field trials

During the first and second trials in both sites, assessment of stem-end rot incidence on fruits taken from trees treated with resistance activators showed low level of infection. The low level of stem-end rot is primarily due to high incidence of anthracnose which obscures the development of stem-end rot. Thus, the effect of activators can not be reliably demonstrated. During the 2007 trial where incidence of stem-end rot was relatively high, there was an observed reduction of stem-end rot incidence on fruits treated with activators, however, such reduction was not statistically significant.

In all trials, the application of resistance enhancing treatments provided variable effects while the application of fungicide spray regime consistently reduces the severity and incidence of pre- and postharvest diseases of 'Carabao' mango.

The failure of the activators to exert significant effect in the reduction of disease level can be attributed to inability of the activators to elicit enough level of field resistance in 'Carabao' mango. It is also possible that the high level of disease pressure and variable conditions that exist in the trial sites abscure or mask the expression of the induce resistance

Fruit yield components. Field trials in Davao del Norte and Davao del Sur indicated that the application of resistance activators failed to improve the fruit yield of 'Carabao' mango (Figure 7.6). However, in one trial where Bion and Kasil significantly reduced the severity of blossom blight, such reduction was translated into significantly higher yield. The application of fungicides consistently afforded higher fruit set and retention and finally higher fruit yield.

Silicon and pH level. The silicon content of the peel of fruits taken from both Davao del Sur and Davao del Norte farms significantly increased during the period 60 DAFI – 100 DAFI and significantly declined at harvest time or during 120 DAFI (Figure 7.7).

A lower level of silicon was detected in fruits from Davao del Norte but an increase in its concentration towards fruit maturity (100 DAFI) was also recorded. With the exception of Kasil in Davao del Sur, the resistance enhancing treatments did not produce significantly different silicon level in the peel of fruits. Rice hull ash, a rich source of silicon, consistently failed to increase the silicon content of fruit peel.

In both experimental sites, the resistance-enhancing treatment failed to influence a significant change in the acidity of fruit pulp. Although less acidic, peel pH was not affected by resistance-enhancing treatments at any of the fruit stages (Figure 7.7).

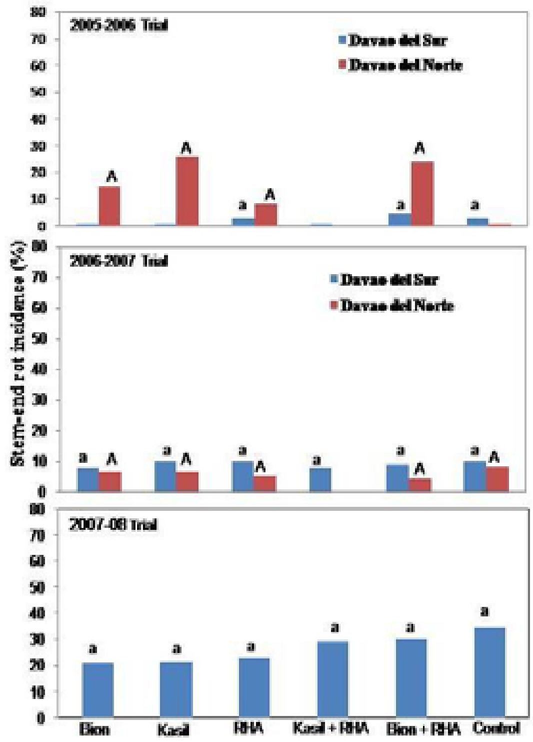

Figure 7.5 Stem-end rot incidence of 'Carabao' mango at seven days after harvest as affected by the different resistance elicitors under minimum fungicide protection in Davao del Sur and Davao del Norte field trials.

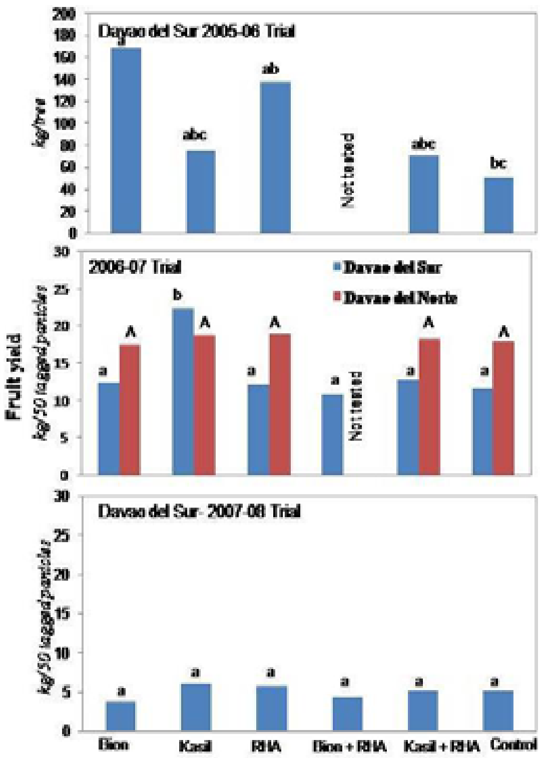

Figure 7.6 Fruit yield of 'Carabao' mango as affected by resistance elicitors under minimum fungicide protection in Davao del Norte and Davao del Sur field trials.

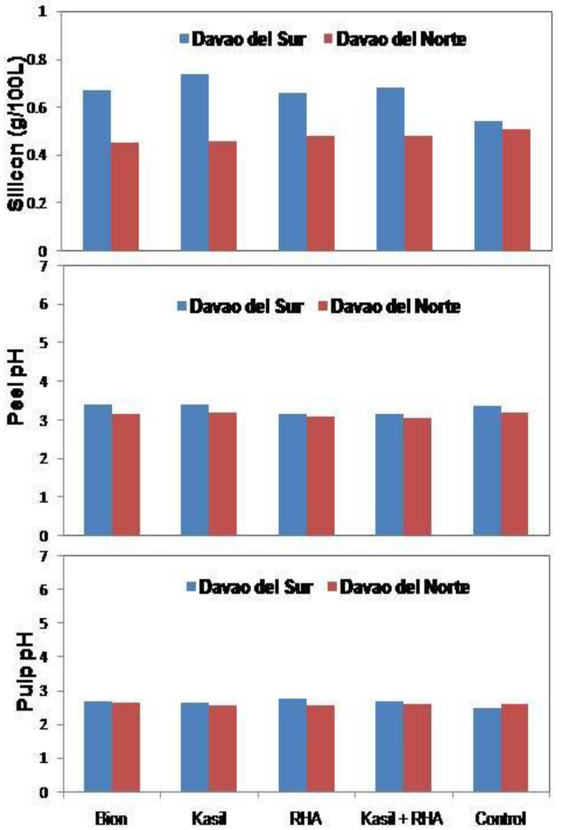

Figure 7.7 pH and silicon levels of composite peel and pulp samples of 'Carabao' mango fruits taken at 100 days after flower induction from trees subjected to different resistance elicitors during the 2005 trials.

Laboratory-based Experiments

Table 7.1 and 7.2 presented the effect of the resistance-enhancing treatments on the fruit quality of 'Carabao' mango. Results of the field trials in both experimental sites suggested that the activators essentially did not influence the ripening pattern or the peel color changes of fruits. Fruits attained the table ripe stage within 7 days after harvest. The saleable life index, a measure of saleable period of fruits was not prolonged by the application of activators. The saleable life index of fruits from trees with activators ranged from 1 to 3 days which was too short under market standard. The failure to control postharvest diseases has resulted to low visual quality of fruits and very short saleable life index.

In similar manner, the application of resistance-enhancing treatments did not significantly influence any physico-chemical change in 'Carabao' mango fruits (Table 7.2). General observation suggested that no clear-cut evidence that improved physical or chemical changes can be solely attributed to the application of resistance activators.

Table 7.1 Peel color index (PCI), saleable life index (SLI) and visual rating (VQR) of mango fruits seven days after harvest from trees treated with different resistance-enhancing treatments under minimum fungicide and no fungicide protection in Davao del Sur and Davao del Norte during 2005-2006 and 2006-2007 fruiting season.

TREATMENT	DAVAO DEL SUR			DAVAO DEL NORTE		
	PCI	SLI	VQR	PCI	SLI	VQR
Minimum fungicide						
2005-2006 Trial						

Bion	5.07	1.50 a	2.88	5.43	2.33 a	3.17
Kasil	4.7	1.50 a	2.5	5.5	3.00 a	2.5
Rice hull ash (RHA)	4.65	1.25 a	2.88	5	3.00 a	2.35
Kasil + RHA	5.27	1.75 a	2.38	4.93	2.67 a	2.43
Control	5.07	1.50 a	2.63	4.85	2.50 a	2.6
2006-2007 Trial						
Bion	6	2.3	3.3 a	6	3.1 b	3.9 bc
Kasil	6	2.8	3.9 ab	5.9	2.6 b	3.7 b
Rice Hull Ash (RHA)	6	2.8	3.8 ab	5.7	3.0 b	4.0 bc
Bion + RHA	6	3.2	4.3 b	----	----	----
Kasil + RHA	6	2.2	3.3 a	5.9	3.1 b	3.8 b
Control	6	2.9	3.7 ab	5.7	2.9 b	4.2 bc
2007-2008 Trial				Trial not conducted		
Bion	4.6	----	3a			
Kasil	5.2	----	3.2a			
Rice Hull Ash (RHA)	4.8	----	3.1a			
Bion + RHA	4.9	----	2.8a			
Kasil + RHA	4.7	----	2.9a			
Control	4.7	----	2a			

Table 7.2 Physico-chemical changes in mango fruits seven days after harvest from trees treated with different resistance-enhancing treatments under optimum fungicide protection in Davao del Sur and Davao del Norte during 2005-2006 and 2006-2007 fruiting season.

	Firmness (kg)		TSS (0Brix)		TA (%)		pH	
Under minimum fungicide2	DDS	DDN	DDS	DDN	DDS	DDN	DDS	DDN
2005-2006 Trial								
Bion	3.73 ab	2.67 a	16.27 ab	16.27 a	0.57 a	0.27 a	4.03 d	4.57 bcde
Kasil	3.03 abc	3.07 a	17.6 a	16 a	0.43 ab	0.19 bc	4.07 dc	4.37 e
Rice hull ash (RHA)	3.03 abc	1.83 b	15.73 b	16.4 a	0.3 bc	0.18 bc	4.33 a	4.83 a
Kasil + RHA	2.93 bc	2.13 b	17.2 a	15.73 a	0.3 bc	0.17 c	4.33 a	4.5 cde
Control	3.33 abc	1.73 b	17.47 a	16.53 a	0.33 bc	0.2 bc	4.37 a	4.7 abcd
2006-2007 Trial								
Bion	2.46 ab	2.42 ab	16.4	16.3 bc	0.31	0.40 a	4.3	4.27 ab
Kasil	2.96 b	2.71 bc	16.4	15.2 b	0.37	0.58 b	4.08	3.92 ab
Rice Hull Ash (RHA)	2.92 b	3.0 c	15.7	14.9 ab	0.22	0.51 ab	4.3	3.67 a
Bion + RHA	3.0 b	----	16.8	----	0.39	----	4.28	----
Kasil + RHA	2.34 ab	1.96 a	16.5	16.8 c	0.27	0.28 a	4.15	4.50 b
Control (OF)	2.21 a	2.92 bc	16.4	15.7 b	0.24	0.49 ab	4.22	4.12 ab

5.8 Impacts

5.8.1 Scientific impacts – Now and in 5 years

It is clearly demonstrated and confirmed that immature mangoes have evolved a formidable constitutive antifungal system (resorsinols gallotannins and chitinases) which could be utilized to suppress mango diseases. It is also shown by the limited experiments that activators such as salicylic acid, Bion® (acibenzolar-S-methyl) and silicon (Kasil) can enhance this antifungal system resulting in some reduction in anthracnose and stem-end rot. However, this project (Philippine Extension) proved that the activators failed to enhance these antifungal systems sufficient enough to confer resistance in 'Carabao' mango under normal mango production system. This suggests that there are some field factors that limit the expression of induced resistance in mango. It is expected that in the next 5 years, these factors can be identified and manipulated so that these activators can be profitably integrated in the overall crop management of mango and reduce disease losses.

This project has contributed to the graduation of one MS Student in Plant Pathology and Training of research staff of LGUs of Davao del Sur and Davao del Norte to conduct field research. The former MS student is now with the Department of Agriculture in the Southern Philippines and highly involved in the national mango research program. This capacity enhancement will strengthen the generation of more scientific information.

The project collaboration also fostered mutual and active research partnership within the project team in the Philippines and enhanced strong collaboration between Philippine and Australian research team.

5.8.2 Capacity impacts – Now and in 5 years

This project has significantly strengthened the research capacity of the Philippine team. Most benefited are the project collaborators (LGU staff and farmer cooperators) in the project sites, whose skills in the field experimentation and mango disease management implementation are enhanced. Equally benefited are the two Philippine collaborating scientists gaining additional expertise in induce resistance research and enhancing the perspective in the global mango industry. This project also contributed to the training and one MS Student in Plant Pathology who is now actively involved in mango research.

5.8.3 Community impacts – Now and in 5 years

While the project failed to recommend the use of activators due to their inconsistent efficacy, the project has a direct impact to the community by the virtue of the following:

- The project showcased a truly integrated crop management of mango focused on integrated pest and disease management. The project demonstrated to the community that good quality mangoes can be sustainably produced through proper crop nutrition, cultural management and judicious application of pesticides. It is anticipated that there will be a change in the traditional mango growing practices of mango growers in the community as a result of the farm demonstration.
- The project conducted field days to showcase the success of the improved system of mango production. The field days were well attended by mango growers, municipal agricultural officers and technicians and other stakeholders.

5.8.4 Economic impacts

In the Philippines, the heavy reliance of pesticides to control pests and diseases of mango has substantially reduced the margin of profit of mango production. The present escalation of the cost of farm inputs renders mango production economically unsustainable. There are two key areas in this project which can have direct economic impact. The project which enhanced the adoption of integrated pest and disease management focused on the reduction of pesticide usage thereby reducing the cost of production and improving economic sustainability of mango production. The utilization of activators, as a result of the preliminary field trials will also reduce the reliance to fungicides which could also substantially reduce the cost of production. In addition, the use of silicon-based products such as rice hull ash to enhance resistance in mango could also enhance waste utilization of rice production which could bring economic benefit to both mango and rice farmers.

5.8.5 Social impacts

Mango is an important component of Filipino diet. The availability of this fruit is seriously hampered by pre- and postharvest diseases. The reduction of losses due to these diseases entails heavy use of fungicide which results in higher price and fungicide residues of fruits. As a result of the adoption of new disease management practices, the society will be benefited by way of the following:

- Affordable price and improved fruit quality
- Improved confidence and food safety of consumers
- Lower health risk of farm workers

5.8.6 Environmental impacts

The environmental impact of the project is connected with the reduced application of fungicides as a direct result of the adoption of new disease management practices. The environmental benefits are:

- Reduced environmental pollution (water, soil and atmosphere)
- Improved diversity of natural microflora in mango orchards
- Enhanced natural biological control mechanisms of the mango orchards

5.8.7 Communication and dissemination activities

The Philippine project team utilized project meetings, workshops, field days and farm demonstration as a means of communication among project participants as well as dissemination of field trial findings. Activities during the course of the project are as follows:

- Series of high level meetings and participatory workshops were conducted before the actual implementation of the field trials. During these meetings and workshops, project objectives, methodologies, work plans and anticipated problems were discussed.
- Two field days where held at the farm of the project cooperators which were well attended by growers, mango spray contractors, municipal agricultural officers and technicians.
- Two field plots, superimposed in the project cooperator's farm were established during the course of the project to demonstrate the integrated crop management of mango with focus on IPM, nutrient and cultural management. The demo plots were frequently visited by mango growers.

5.9 Conclusions and Recommendation

5.9.1 Conclusions

On the basis of the results of field trials, it is concluded that under the prevailing conditions in the field trials the resistance elicitors (Bion and silicon-based materials) failed to elicit sufficient level of resistance in 'Carabao' mango to confer consistent reduction in the severity and incidence of pre- and postharvest diseases. It is further concluded that there is no enough convincing reason to recommend the resistance elicitors as part of the integrated disease management of 'Carabao' mango.

5.9.2 Recommendations

Based on the findings of the project, we recommend the following:

- While the potential of resistance elicitors was not successfully demonstrated under field condition by this project, it is important to look into the reasons or identify the factors (e.g., environment or biological) that limit the enhancement of defense mechanisms by the elicitors.
- Defense activators that are cost-effective should be evaluated for pre- and postharvest diseases of ‘Carabao’ mango. Should Bion be registered by Syngenta for mango, it will come at a high cost that is not affordable to small mango growers. Further study on silicon-based materials such as rice hull ash to stimulate defense mechanism should be pursued. It is not only cost effective but also can enhance waste utilization
- Information on integrated crop management focused on mango nutrition and pest/disease management should be made widely available to mango growers.

5.10 References

5.10.1 References cited in report

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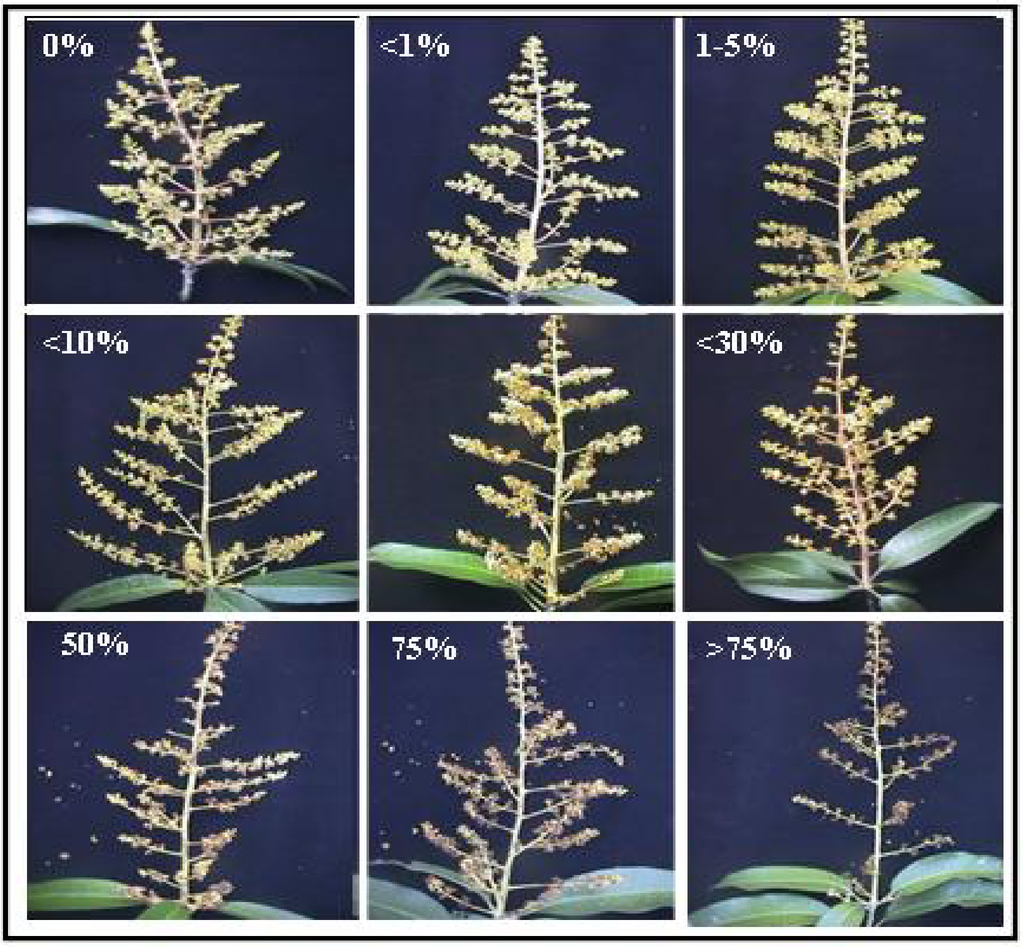
5.10.2 List of publications produced by the project

ACIAR YEAR 1 REPORT 2005. Management of postharvest diseases of sub-tropical and tropical fruit using their natural resistance mechanisms.

ACIAR YEAR 2 REPORT 2006. Management of postharvest diseases of sub-tropical and tropical fruit using their natural resistance mechanisms.

5.11 Appendixes

Appendix 5.11.1. Arbitrary severity rating for mango blossom blight used in Belcris and Linga farm



0% – inflorescence apparently healthy with no discernable anthracnose infection; browning of flowers is mainly due to natural senescence or withering.

<1% – very few flowers appear black due to anthracnose infection; infection is estimated as less than 1%.

1-5% – about one to five percent of the flowers on the primary peduncles, mainly located at the basal part of the inflorescence are infected with anthracnose.

<10% – floral infection is estimated as less than 10%; many fruit sets are apparent.

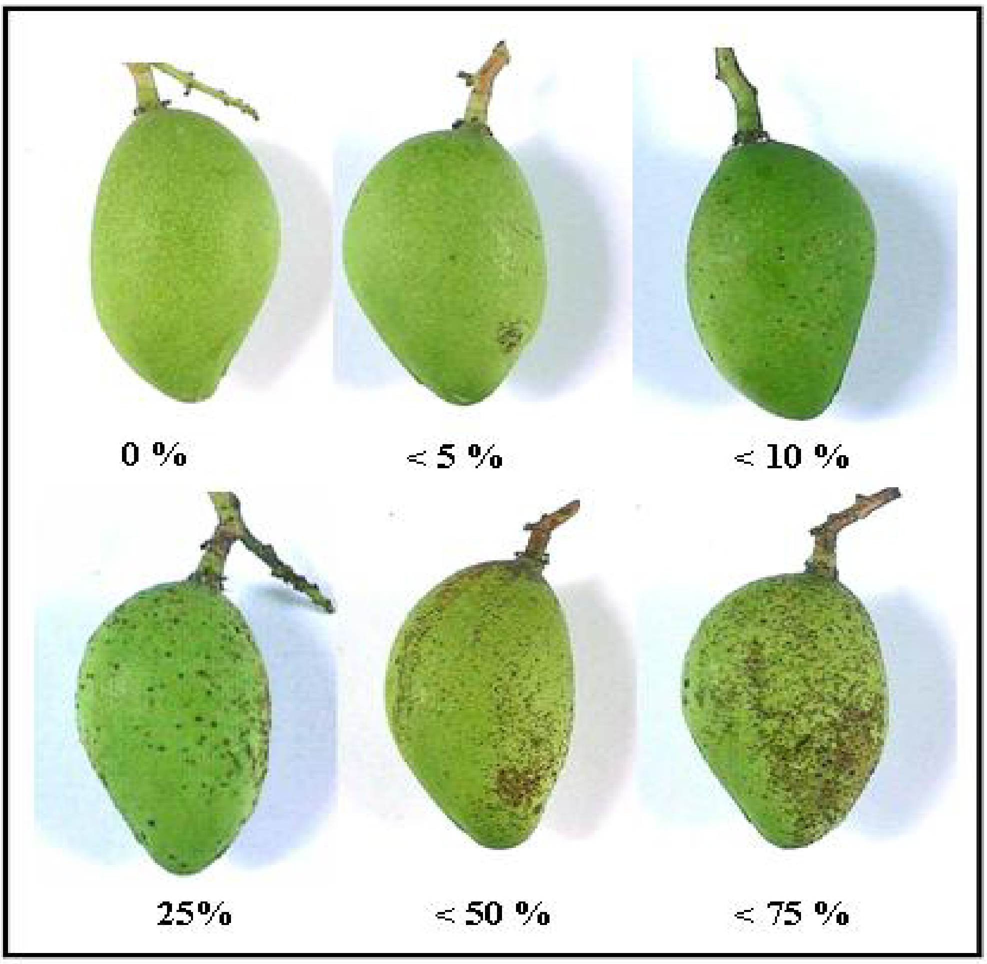
10-20% – 10 to 20% of the flowers are blighted but numerous fruit sets are apparent at the basal portion of the peduncle.

<30% – blight severity is estimated as less than 30 percent.

50% – 50% of the flowers are blighted.

75% – 75% of the flowers in the primary peduncle are blighted; very few fruit sets are apparent.

>75% – more than 75% of flowers in the primary peduncle are blighted.


0 %
< 5 %
< 10 %
25%
< 50 %
< 75 %