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Smallholder HOPES—horticulture, people and soil

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Smallholder HOPES—horticulture, people and soil

Proceedings of the ACIAR–PCAARRD Southern Philippines Fruits and Vegetables Program meeting, 3 July 2012, Cebu, Philippines

Editors: John Oakeshott and David Hall

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Cover: Jackfruit (*Artocarpus heterophyllus*) is marketed as the 'flagship fruit' in the Eastern Visayas region of the Philippines. Job Abuyabor (centre of image) is a leading jackfruit grower in central Leyte. (Photo: Mara Faylon)

Foreword

Smallholder fruit and vegetable farmers in the southern Philippines face many barriers to maximising profits and being competitive in the marketplace.

The production barriers that prevent many smallholder crops achieving maximum yields and quality include soil and nutrition issues, damaging weather conditions, pests and diseases, and postharvest losses. There are also constraints such as agricultural policies, local infrastructure, access to markets and market information, and access to finance and extension services. These challenges disrupt supply chains and threaten Filipino farmers' livelihoods, making the fruit and vegetable industry less competitive and sustainable.

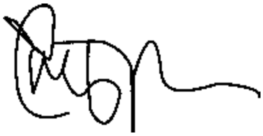
The southern Philippines fruits and vegetables program, which ran from May 2008 until December 2012, was a collaborative research model jointly managed by the Australian Centre for International Agricultural Research (ACIAR) and the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD). It comprised nine projects covering a range of commodities and research areas that were identified through consultation.

The program's primary goal was to contribute to economic growth in the southern Philippines, and to improve the livelihoods of Filipino farmers and their families. Building capacity of local researchers and equipping policymakers with enhanced tools and knowledge for decision-making are among the research program's many achievements. Australian researchers have also benefited with enhanced capacity to understand tropical pests, diseases, soil factors and nutrition. This will flow on to Australian farmers, who will have access to methods for better pest and disease management, protected cropping, improved nutrition and reduced postharvest losses for crops such as papaya and mango.

Based on an independent review, ACIAR and PCAARRD have agreed to continue funding research in fruits and vegetables in the southern Philippines to build on this program's achievements.

The papers presented in these proceedings show the diversity and quality of the research undertaken over the 4 years of the ACIAR–PCAARRD southern Philippines fruits and vegetables program and are an important contribution to the science community, bilateral relationships, and the ultimate beneficiaries—the farmers in the Philippines and Australia.

Dr Nick Austin
Chief Executive Officer
ACIAR



Dr Patricio Faylon
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Introduction

Les Baxter[1] and Jocelyn Eusebio[2]

Commencing in May 2008 and finishing in December 2012, the Australian and Philippine governments collaborated in a 4-year initiative to find long-term solutions to the issues that impinge on fruit and vegetable value chains in the southern Philippines.

The southern Philippines fruits and vegetables program was a collaborative research model jointly managed by the Australian Centre for International Agricultural Research (ACIAR) and the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD). Both organisations jointly undertook a comprehensive consultation and then managed the program, which embraced nine projects covering a range of the identified priority disciplines and research areas.

The two key aims of the program were to contribute to the economic growth of the region through improving smallholder and industry profitability, and by increasing market competitiveness of selected high-value fruit and vegetable crops.

The crops identified through industry consultation as high priority for development included potato, tomato, brassicas, leafy vegetables, mango, papaya, durian and jackfruit. Within each of these priority crops, the program contracted 55 key researchers from 27 research organisations across the Philippines and Australia to focus on a particular research question across nine project components: four fruit components, four vegetable components and one combined economics and policy component

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Southern Philippines fruits program

The southern Philippines fruits program was managed through the Queensland Department of Fisheries and Forestry in Australia. Research focused on five areas:

1. papaya supply chains—developing a supply chain that can improve competitiveness by reducing losses associated with rapid fruit ripening and disease
2. *Phytophthora* diseases—seeking strategies to reduce losses to durian and jackfruit yields due to disease
3. papaya crop management—creating integrated crop management strategies for sustainable production and improved profitability of this important and expanding crop
4. mango crop management—focusing on improvements in crop residues, nutrition, pest and disease control, and extension, and developing an integrated pest management (IPM) approach.
5. economics and policy (both programs)—measuring technologies, informing research processes, enhancing adoption, and identifying policy constraints and solutions.

Southern Philippines vegetables program

The southern Philippines vegetables program was managed through the New South Wales Department of Primary Industries in Australia. It aimed to assist the estimated 4.5 million Filipino households involved in vegetable production who earn less than A$1 per day. Research focused on four areas:

1. soils—overcoming the obstacles of declining soil fertility and soil-borne diseases, and developing sustainable fertiliser management (organic and inorganic)

2. protected cropping—developing low-cost protective cropping systems for the central Philippines (Visayas) that allow farmers to produce crops in harsh weather conditions and be competitive in the markets offering higher economic returns that have been 'out-of-season' under traditional growing systems
3. bacterial wilt disease—investigating this devastating soil-borne disease of potato, tomato and eggplant in Mindanao, in order to disseminate management strategies and improve access to clean potato seed planting material
4. value chains—creating collaborative marketing groups linked to buyers to achieve sustainable premium returns.

The papers in this publication were initially presented at the ACIAR–PCAARRD End-of-Program Horticulture Conference on 3 July 2012, at the Cebu Parklane International Hotel, Cebu, Philippines. Following the structure of the program, papers have been grouped into three sections: fruits, vegetables and economics.

The farther fruit and vegetable production occurs from the domestic and export markets, the more difficult it becomes to maintain the quantity and quality of these perishable crops. The unifying theme for all the papers in this publication is the investigation and implementation of technologies that provide livelihood benefits to smallholder farmers, by creating a more efficient and effective production and delivery system to the consumer. The papers presented in this volume have a focus on priority crops and the key issues of reducing production losses, increasing production quantity, improving the quality of delivery to the consumer, and understanding the operations of the markets and consumer values.

The fruit papers are based upon specific commodity crops and begin appropriately with a consumer-defined assessment of fresh papaya. Understanding the intrinsic value that a consumer is 'willing' to pay for in a papaya provides other participants in the supply chain with information on where they should focus efforts and investment. The handling guides from this project resulted in a large reduction in postharvest losses and an improved economic outcome for all the supply chain members. The extension process of the research focused on participatory action research (PAR). This involves farmers being mentored to explore strategies through their own on-farm trials. This approach was successfully used in combination with research into specific pests and diseases in projects for jackfruit, durian and mango to design best-practice strategies for integrated crop management. Another aspect of the program was the testing of new biological controls for pests and diseases. Particularly in the papaya and durian projects, the teams uncovered and tested some exciting biological alternatives that can be incorporated into crop management programs.

The vegetable papers are based around specific themes of soils, production, clusters and markets for a range of vegetables. Clustering of smallholder vegetable farmers and incorporating an across-discipline approach to meeting the farmers' needs were shown to increase incomes significantly by up to 50% and also instil a sense of empowerment. The clustering papers look at the interaction with markets, quality impediments and a step-by-step guide towards developing a sustainable cluster. The obstacles to developing a potato industry and improving production of solanaceous crops in Mindanao are mainly centred around soil-borne diseases, and four of the papers examine management tools for improving production—aeroponics, soil amendments, tolerant potato species, and understanding the phenotypic and genotypic relationships of the soil bacteria.

Seven of the papers presented provide an insight into economics and policy implications facing smallholder horticulture farmers, and the expected benefits from the research undertaken by the other projects within this program. Two ex-ante impact assessment papers and one gross-margin impact analysis suggest that smallholders will benefit greatly from adoption of the IPM strategies proposed. The results from these papers fed into an economic surplus model used to evaluate the worthiness of a project for research and development (R&D) investment. The model showed a high social return for investments in horticulture R&D. Two papers analysing the performance of cabbage and mango farmers show statistical evidence suggesting farmers who can finance their own operations and are participating in production training will enjoy increased profitability. While these results should be obvious, it does provide more evidence for changes regarding smallholder farmers' inability to access finance in the Philippines. Similarly, a paper on the importance of road and port networks to the horticultural industries in Mindanao makes a strong case for increasing government investment into infrastructure. Again, while this is not a surprising conclusion, the paper does detail the complex transport system and provide empirical evidence that investing in infrastructure will bring benefits to smallholder horticulture farmers.

There were 190 individuals who contributed to the success of this program and, in various degrees, to the writing of these papers. Notably, there has been a strong contingent of young researchers beginning their careers, which bodes well for the future of horticultural research and an ongoing friendship and bilateral program between the Philippines and Australia. The relationships and collaborative approach expressed across this program has truly set a benchmark for future large programs to emulate.

Acknowledgments

The papers presented in this publication were developed under two ACIAR-funded programs:

- HORT/2007/066—Enhanced profitability of selected vegetable value chains in the southern Philippines and Australia
- HORT/2007/067—Improved domestic profitability and export competitiveness of selected fruit value chains in the southern Philippines and Australia

We are grateful to all our partner organisations who participated in this program; in particular the collaboration and strong partnership with PCAARRD, led by Executive Director Dr Patricio Faylon and his staff in the Crops Research Division. We are also grateful to the two Australian commissioned organisations—the Queensland Department of Fisheries and Forestry and the New South Wales Department of Primary Industries.

Thank go to the panel of reviewers who commented on all the papers and, in particular, Dr Ponciano Batugal, who led the review process. Finally, to all the 190 program participants, thank you for your participation towards increasing agricultural knowledge and improving the livelihoods of many smallholder farmers in the Philippines.

Fruits

Study tours were an important training component of the horticulture program. Allan Siano participated in a 14-day mango study tour of Australia by the Samal Island Mango Growers Association in November 2010. (Photo: John Oakeshott)

Consumer-orientated quality systems improvement through value-chain analysis of 'Solo' papaya fruit

Elda B. Esguerra[1], Matilde V. Maunahan[1], Dormita R. del Carmen[1], Wella L. Absulio[1], Gloria D. Masilungan[1], Ray Collins[2] and Tim Sun[2]

Abstract

The southern part of the Philippines is currently the major source of 'Solo' papaya fruit for export and the domestic markets. As in other perishable crops, when supply areas move further away from the consumption centres, quantity and quality losses occur. This study aimed to identify and implement quality improvement opportunities to reduce losses and deliver consumer-defined value in papaya through value-chain analysis.

Mapping the information and relational flows within the Supplier Company (the project collaborator whose name was withheld for confidentiality reasons), and among the other chain members (grower–suppliers, customers such as retail outlets and the consumers) showed that information flows were partial at best and that relationships were basic or transactional. Apparently, there is lack of consumer insight by chain members. Consumer-defined value assessed through focus group discussions followed by formal consumer survey and conjoint analysis indicated that consumers valued papaya that are free from blemish and decay, are sweet and have good colour (yellow–orange). Mapping the product flow from the farm to the distribution centre in Metro Manila revealed major quality and quantity losses from disease, non-uniform ripening, fruit immaturity and mechanical damage. Moreover, product performance was highly variable.

Consumer surveys combined with chain mapping enabled activities along the chain to be characterised as value-adding, necessary but non-value adding, or wasteful. Collectively, these performance measures enabled the identification and implementation of improvement opportunities to reduce losses, maintain product quality, build more effective relationships and deliver consumer-defined value. These include capacity building of stakeholders in the chain; handling trials on maturity, which determines fruit sweetness; regulation of ripening; and disease control with hot water treatment. Development of harvesting and postharvest handling guides through adaptive and participatory action research, together with capacity building, resulted in a 37–73% reduction in papaya rejection at the company packinghouse. A notable impact of the project was the enhanced export market access of the growers' association brought about by the application of postharvest technologies aimed at meeting customer requirements.

Introduction

Papaya is among the top 10 economically important fruits in the Philippines. It ranks ninth in terms of production volume and area planted (BAS 2010). The production of papaya is concentrated in Mindanao, particularly in the regions of SOCCSKSARGEN,

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Northern Mindanao and Davao, which account for 65% of national output. In 2009, of the total 176,656 tonnes produced, around 93% was consumed domestically and only 1.3% exported. The growing awareness of consumers of the fruit's superior nutritional value and rich content of active components that protect the human body from diseases[1] provides opportunity for market expansion, both in the local and export arenas. Data from BAS (2010) indicated that there is an increasing trend in per-capita consumption of papaya from 1.59 kg in 2000 to 1.78 kg in 2009. In the domestic market, however, the common feedback of dissatisfied consumers is the lack of sweetness of fresh papaya fruit, which needs to be addressed by the project. On the other hand, customers or buyers in export markets such as the Middle East and Singapore have different quality specifications, such as preferred stage of ripeness upon arrival, which the supplier needs to satisfy. These require application of postharvest technologies that will maintain the quality of the fruit from the farm until it reaches the final consumer.

The bulk of the papaya marketed in Metro Manila and outlying provinces come from South Cotabato in Mindanao. As in other crops, when supply areas move further away from the consumption centres, quality and quantity losses occur due to the inherently high perishability of papaya, aggravated by rough and multiple handling as the fruit moves along the chain. In this current project, where the cooperation of a company supplying papaya to different supermarkets was engaged, initial supply-chain mapping of 'Solo' papaya grown in Tupi, South Cotabato, in Mindanao, and distributed in various supermarkets in Metro Manila and outlying provinces, revealed that losses in the range 14–30% occur. The papaya growers who supply the company bear the losses which translate to reduced income. A walk through the chain to map the product flow will identify the points where losses both in quantity and quality and, in turn, consumer value occur. This will then enable identification of improvement opportunities to reduce losses and maintain product quality valued by the consumer.

This study was conducted to identify and implement improvement opportunities to reduce losses and maintain produce quality through value-chain analysis, particularly on 'Solo' papaya. Specifically, the study aims to (1) analyse the information flow and relationship strength of different players in the value chain that affect the chain performance, (2) understand consumer preferences for papaya, (3) map the product flow and identify activities that will create consumer value, and (4) reduce fruit rejection through the application of postharvest technologies.

1 Papaya fruit nutrition facts at <www.nutrition-and-you.com/papaya-fruit.html>, accessed 23 February 2013.

Review of literature

Value-chain analysis

A value chain refers to a sequence whose systems and behaviours are focused on delivering value to its customers and, most importantly, to the end consumer (Collins 2010). Moreover, Bonney et al. (2007) indicated that sustainable competitive advantage has two fundamental requirements: a strategic orientation that is focused on consumer value, and value chains that are coordinated and responsive to the dynamic needs and wants of the final consumer. In contrast to the traditional supply chain which focuses upstream, a value chain focuses downstream, understanding what consumers value in a commodity and delivering it as effectively and efficiently as possible (Clark et al. 2010). Zimmerman and Van der Lans (2009) indicated that industry innovation should consider foremost the trends in consumer demand and preferences to insure that the products that reach the market are the ones that consumers want to buy. Among the current trends that are expected to continue in the future is consolidation or formation of alliances among producers and marketers from different production areas (Kader 2010).

Losses in the papaya handling chain

The southern part of the Philippines (Mindanao) is the major source of papaya marketed in Metro Manila and outlying provinces in Luzon. A multilayered and disaggregate sector characterises the papaya supply chain. From the farm until papaya reaches the retail market, it undergoes 10–12 handling steps (Esguerra et al. 2009). Due to the inherently high perishability of the fruit, losses occur.

In papaya, Coursey (1983) reported losses in a 40–100% range in developing countries, due to physiological disorders, mechanical injury and decay. Grierson and Wardowski (1988) in their study of the magnitude of losses in tropical fruits such as papaya reported that losses ranging between 15 and 35% were incurred due to decay, weight loss and mechanical injury. A local study conducted by Serrano and Lizada (1996) showed, that in a commercial shipment of papaya from Northern Mindanao to a wholesaler's packinghouse in Manila, losses ranging between 27 and 42% were sustained owing to pre- and postharvest handling factors. The causes of losses were as follows: misshapen fruit (26%), insect damage (2–16%), 'evergreen' or immature fruit (3–20%), bruised, compressed and cut fruit (17–20%), and diseased and prematurely ripened fruit (20–47%).

Postharvest technologies to reduce losses and maintain fruit quality

Collins (2010) stated that postharvest science and technology can also be defined as focused on consumer value. Accordingly, activities such as solving handling and transport problems, extending shelf life or working on fruit maturity and the like are aimed at meeting consumer value. Technologies to maintain the quality and, in effect, reduce postharvest losses have been developed as follows:

Optimised harvest maturity

One of the important factors to consider in supplying consumers with fruit of acceptable eating quality is maturity. Harvest maturity determines the fruit's propensity for long-term storage and/or transport, ex-store or ex-transport quality and, eventually, flavour and aroma formation during subsequent ripening (Fellman et al. 2003). Optimal harvest must take place during the optimal maturity stage of the fruit, considering the intended use, such as direct marketing or long-term storage (Streif et al. 2010).

Unlike mango and banana, papaya fruit has very little starch reserve for the production of soluble sugars after harvest (Chan et al. 1979, as cited by Zhang and Paull 1990). Akamine and Goo (1971) reported that starch content in papaya during fruit development is 0.1% of dry weight, hence fruit are not harvested until the skin shows some yellowing. When the fruit seeds and pulp begin to change colour and mature, which is about 100 to 140 days after flower opening, there is a dramatic increase in the sugar content (Selvaraj et al. 1982). However, this sugar is derived from the movement to the fruit from the leaves and not from the breakdown of starch (Chen et al. 2007). As the fruit changes colour, total soluble solids (TSS) change is only 1.5 to 2% (Akamine and Goo 1971).

Regulation of fruit ripening

Regulation of ripening involves either enhancement or retardation of the ripening process. Fruit ripening is a sequence of biochemical events that transforms a physiologically mature but inedible fruit into one possessing all the desirable qualities of a ripe fruit (Rimando et al. 2007). In papaya, ripening-associated changes include softening, colour change from green to yellow–orange due to chlorophyll degradation and/or synthesis of carotenoids, and formation of flavour and aroma (Aziz-Abou et al. 1975; Lazan and Ali 1993). Ethylene has been generally accepted as the hormone that plays a key role in inducing ripening, particularly in climacteric fruits such as papaya. There are several methods of inducing or enhancing fruit ripening, such as exposure of the fruit to ethylene gas, dipping or spraying with ethylene-releasing chemicals such as ethephon (2-chloroethyl phosphonic acid) or exposing the fruit to calcium carbide, which generates acetylene, an ethylene analogue. In papaya, wholesalers and retailers commonly use ethephon and calcium carbide (personal communication). Ethylene gas treatment (100 ppm, 24 hours exposure) of papaya requires a temperature of 18–25°C (Ann and Paull 1990). Under these conditions, papaya ripened in 3–4 days

Retardation of ripening, on the other hand, is desired when fruit is intended for long-distance transport either during domestic inter-island transport or long-distance sea shipment for export. Moreover, delaying the ripening controls the release of the fruit to the market. Temperature management is the most important factor governing the ripening and quality of fruit after harvest. At 10–13°C, ripening of papaya is slow (Chen and Paull 1986). At colour-break stage, papaya can be stored at 7°C for 14 days without affecting the normal ripening when transferred to ambient temperature. 'Sinta' papaya fruit harvested at colour-break stage can be stored at 13–15°C for 2 weeks (Mercadero and Esguerra 2000).

Modified atmosphere packaging/storage

Modified atmosphere storage, along with controlled atmosphere (CA) storage, is considered to be the second-most effective method, after low-temperature storage, for prolonging the shelf life of fresh produce (Wiley 1994). Modified atmosphere refers to the reduced oxygen and elevated carbon dioxide levels in a carefully sealed unit, for example, within polymeric films such as low-density polyethylene, but the gas levels are not controlled. This is the most preferred method for storing produce in small packages. Gas exchange is regulated through the provision of macro- or micro-perforations or films with diffusion windows where gas exchange occurs (Emond et al. 1998). For export requiring long-distance sea shipment, maintenance of the cold chain and the modified atmosphere chain are important to globalisation of produce marketing (Kader 2010). 'Solo' papaya at the 20% yellow stage kept in sealed polyethylene bags for 5 days at 22°C remained firm and exhibited slow colour development (Manenoi et al. 2007).

1-methylcyclopropene treatment

The development of the gas 1-methylcyclopropene (1-MCP) provides a new approach in manipulating the ripening and senescence of climacteric fruits (Sisler and Serek 1997). 1-MCP prevents the action of ethylene in plants by bonding permanently to ethylene receptors such that ethylene cannot exert its action, which eventually leads to delayed ripening (Blankenship and Dole 2003). It is available commercially as a complexed formulation (powder) that releases 1-MCP gas when dissolved in water. It has been registered in several countries for specific applications in a wide variety of crops (Watkins 2008). One advantage of using 1-MCP in fruit commerce is the long-lasting ripening inhibition, which prevents quality losses during marketing and shelf life (Streif et al. 2010).

Treatment of papaya fruit with 0.3 ppm 1-MCP for 16 hours at 20°C inhibited the ripening (Balbontin et al. 2007) but reduced the production of esters responsible for fruit aroma. Manenoi et al. (2007) reported that treatment of papaya fruit with 100 nL/L 1-MCP at colour-break stage resulted in ripe fruit with rubbery texture, while fruit treated at 25% skin yellow ripened normally. This study pointed to the importance of fruit maturity to the timing of 1-MCP application.

Postharvest disease control

Anthracnose caused by *Colletotrichum gloeosporioides* is an important postharvest disease of papaya fruit (Quimio and Quimio 1974). Symptoms of infection are apparent only as the fruit ripens. They appear as sunken, water-soaked brown-to black-spots that, in severe cases, have orange masses of spores and mycelia. Another important disease is stem end rot (SER) caused by *Botryodiplodia theobromae* wherein symptoms occur as a broad, water-soaked margin at the stem end, with the lesion turning gray to black (Ilag et al. 1994). Symptoms of infection in the case of SER are also apparent even when the fruit is still unripe. For both diseases, control measures include field sanitation, carefully timed preharvest fungicide spraying (Paull et al. 1997), hot water treatment in combination with fungicide (Paull 1990), or hot water treatment alone for 10 minutes at 49–51°C, or a 20-minute dip in 0.1% thiabendazole (Serrano 2004). Sepiah (1993) reported that these diseases can be controlled by prochloraz or propiconazole fungicides during storage and transport. Hot water treatment in combination with fungicides improves the efficiency of controlling anthracnose (Teixeira da Silva et al. 2007).

Naturally occurring compounds as sources of antimicrobials led to the synthesis of broad-spectrum 'natural fungicides' such as azoxystrobin, which are classified as reduced-risk fungicides by the US Environmental Protection Agency (Adaskaveg and Fonster 2010). The effectiveness of azoxystrobin was tested during long-term, CA storage of mangoes. Dipping mangoes in 125 ppm azoxystrobin after hot water treatment for 10 minutes at 55°C effectively reduced anthracnose and SER after 28 days under CA and 5 days in air at 23°C (Esguerra and Opina 2008).

Value-chain analysis

Information and relational flows

Value-chain analysis looked at the competitiveness of the chain in terms of both its effectiveness and efficiency (Collins 2010). It is a form of diagnosis that identifies opportunities for improvement to meet what consumers value in a product. The major stakeholders in the domestic papaya supply chain were engaged in mapping the material, information and relational flows to determine what drives the system.

Table 1 shows the different players and their roles in the value chain. The results of two rounds of interviews, followed by ground-truthing, pointed to strong, two-way information flows between the junior managers, supervisors and even merchandisers. These are the personnel of the company who are in the supermarket outlets and who are in contact with consumers. Information is freely and timely shared among them. Moreover, all the chain members are aware of the company's goal of a 15% increase in sales and a reduction in 'bad orders' (rejects) to 5%. That the company personnel have been with the firm for several years, rising through the ranks and starting as merchandisers themselves, is indicative of the loyalty, trust, strong motivation and commitment of the chain members. There is also generally good rapport, partnership, and an open relationship among staff, perhaps one factor that keeps staff members in the company.

Table 1. Key stakeholders and their roles in the papaya value chain

Level	Stakeholder	Role
Farm (Tupi)	Grower cum shipper	Grows, sources, harvests, packs and ships papaya fruit from Tupi to Manila
Broker (Manila)	Broker	Gives orders to the grower cum shipper, picks up fruit from the pier and delivers to the company warehouse
Company (Manila)	Quality control officer	Receives delivery at the warehouse, supervises sorting
	Auditor	Programs forecasting, sets minimum volume for display, checks/monitors display in stores, prepares reports
	Junior manager	Directs the supervisor and merchandisers, oversees fresh produce operations, coordinates with store managers
	Supervisor	Monitors stocks and quality of produce, checks display areas (stock and cleanliness); acts also as merchandiser
	Merchandiser	Receives papaya delivered to the store, arranges fruit, in contact with consumers
Store/retailer (supermarket)	Supervisor	Checks volume and quality supplied by the company, checks display shelves
	Consumers	Buyers of papaya fruit

Between the company and the supermarkets (customers), a good relationship and open communication with the company staff is maintained. However, despite this open communication, the inconsistent quality and supply of papaya remains the major concern of the store supervisor.

With regard the broker of papaya to the company and the grower cum shipper, trust is apparent, with the broker responsible only for marketing or delivering the papaya to the company warehouse in Paranaque, while the grower cum shipper takes charge of harvesting, packing and shipping to Manila. The role of the broker is valued by the company since they eliminate risks such as sourcing of fruit. There is apparently poor consumer insight at the grower cum shipper's level since they are concerned only with the blemish-free and colour-break stage maturity requirements of the company. They do not consider sweetness as a quality attribute since, according to them, consumers are attracted to only good-looking fruit.

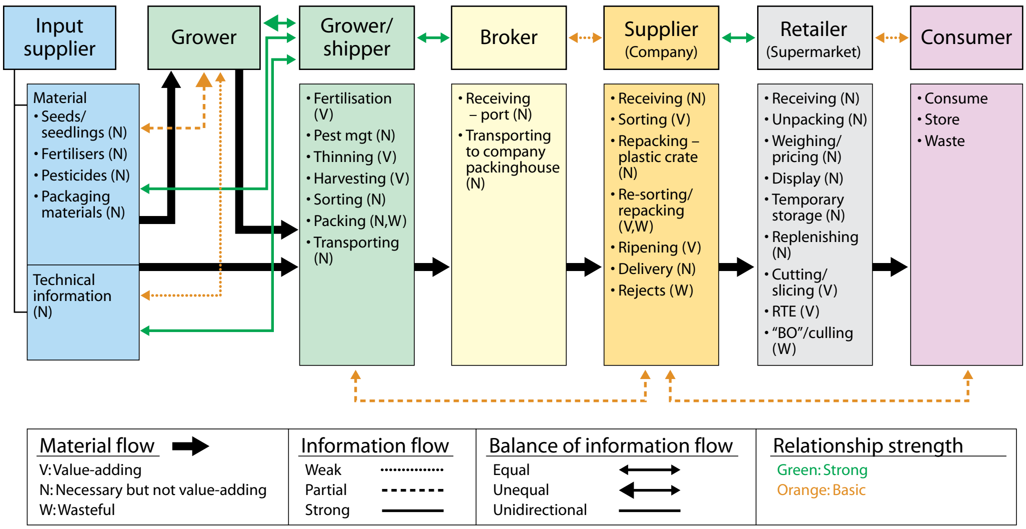

Figure 1. Current state of the papaya value chain indicating the information flow, strength of relationships among the stakeholders and the categories of material flow

In the interviews with all the stakeholders except the grower cum shipper, problems reported with regard to papaya were as follows: inconsistent quality; immaturity; poor ripening or failure to ripen; inadequate sweetness; bitterness; and decay. Growers on the other hand, indicated pest and disease problems.

From this series of interviews and mapping, the current state of the value chain is shown in Figure 1. The flow of information is characterised as partial between the grower/shipper and the company, and the relationship strength is only basic or transactional. On the other hand, a strong relationship and two-way information flow exist between input supplier and the grower and grower/shipper. Between the company and the consumer, the relationship is also basic and information flow is only partial.

Understanding consumer preferences

Having mapped the information flows and strength of relationships among the stakeholders in the chain, the next step is identifying the quality attributes consumers value in a papaya fruit. This was achieved through focus group discussion and formal consumer survey.

Focus group discussions

Focus group discussion (FGD) is a qualitative way of getting a quick and easily accessible initial appreciation of what consumers value in a commodity. The results of two FGDs revealed that papaya is purchased and consumed mainly for its health benefits and rarely as gift, which is unlike banana and mango. Respondents buy papaya from public markets, supermarkets and fruit stands, the first being the most common. The frequency of purchase is once or twice a month. In fruit selection, consumers are very particular about appearance, followed by ripeness and, lastly, size. Based on appearance, they prefer fruit that are smooth, with good colour (yellow–orange) and bruise/defect-free. They usually buy papaya at the ready-to-eat stage of ripeness. Lack of sweetness, which they attribute to immaturity, is what usually disappoints this group of papaya consumers. Accordingly, they are willing to pay for better quality papaya, but only to an upper limit of 35.00 pesos/kg.

Consumer survey and conjoint analysis

This study made use of a two-stage survey questionnaire. The first stage was designed on the basis of the results of FGDs, while the design of the second stage, for the conjoint analysis, drew on the results of the first formal survey.

Based on the results of the first-stage survey of 232 consumers, the topmost attributes looked for in a papaya were sweetness (27%), overall quality (15%) and colour (13%) (Figure 2). Based on external attributes, consumers preferred medium-size fruit, with full yellow peel colour and free from blemishes and decay. For the internal attributes, pulp with yellow–orange colour, average sweetness and 'just right' firmness/texture were desired.

While the first-stage survey provided information on the product attributes looked for by consumers, it could not, however, quantify how much more important an attribute is relative to the others. The joint effects of product attributes on final purchase decision of consumers was thus determined using conjoint analysis (North and de Vos 2002; Dagupen et al. 2009). A full-profile approach to conjoint analysis, as suggested by Hair et al. (1998), was followed, using the fractional factorial or orthogonal design generated through SPSS software. Four product attributes, namely absence of decay or damage, degree of sweetness, peel colour and price, each classified into three levels, were identified and used in the product profile card. Results showed that consumers gave highest importance to absence of decay or damage (36.75%). Sweetness was second in importance (29.6%), followed by peel colour (degree of ripeness). Price is the least important to papaya consumers. Utility estimates which indicate

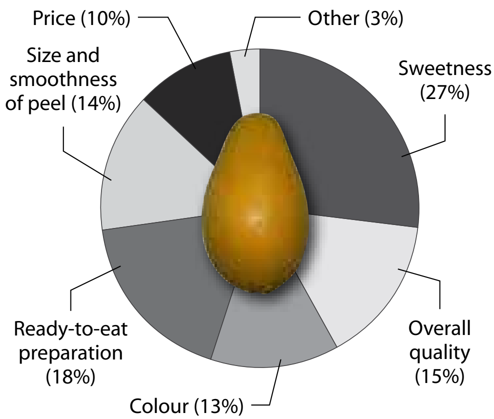

Figure 2. Attributes of papaya fruit sought by consumers and (inset) a quality papaya fruit as perceived by consumers

how each level of attribute relates to preference; i.e. positive values for strong preference and negative values for non-preference, showed that consumers preferred papaya that is free from decay or damage, very sweet, has full yellow peel colour and has a price within the range of 20.00–30.00 pesos/kg.

Cluster analysis was performed to classify consumers into homogenous groups based on their relative factor importance scores. Two market segments or clusters were identified for papaya. The first cluster is the aesthetic-conscious group (53% of respondents), which gives premium to blemish-free peel; the second cluster is the taste-sensitive group which desires sweet-tasting papaya (Table 2). This latter group indicated willingness to pay a higher price. Hence, the cost–benefit of any improvement plan or technology application/adoption must be taken into consideration.

Sweetness as a quality attribute, especially as perceived by consumers, is very subjective. Thus, an objective value of sweetness was established to serve as a basis in interventions during production and harvesting. A total of 88 fruit at the table-ripe stage were sampled. Sliced fruit were presented to the panelists for sensory evaluation, and the corresponding Brix level of the pulp extracts was determined. Based on the outcome of sensory evaluation, fruit with TSS content of 10°Brix and above are sweet, those with 9°Brix and below are less sweet, and are not sweet if TSS is 7°Brix and lower. At present, no fruit with greater than 12°Brix was evaluated to provide data for the very sweet rating.

The aforementioned quality attributes that consumers value in a papaya are indicative of the improvement opportunities that can be taken in three ways, either separately or in combination with each other, as has been suggested earlier by Thomas (2005) for other fruits and vegetables. These are: (1) by improving the inherent sweetness potential of the variety used in production through cultivar selection and/or breeding; (2) by optimising the conditions under which the plants are grown, such as adopting appropriate fertilisation; and (3) by optimising the handling and storage of the produce. The quality improvement plans of Collins (2009) suggested a focus on the important question of: 'Where is the consumer value in what we are proposing to do?'.

Table 2. Comparison of the averaged importance and utility estimates for the attributes and their factor levels that influence consumer (n = 185) preference for 'Solo' papaya

Attributes/ factor levels	Overall[a]		Cluster 1[b]: 'Aesthetic-conscious group'		Cluster 2[c]: 'Taste-sensitive group''	
	Averaged importance (%)	Utility	Averaged importance	Utility	Averaged importance (%)	Utility
Decay/damage	36.75		44.29		28.26	
None		1.1356		1.5944		0.6188
Slight		–0.0556		–0.2844		0.2021
Moderate		–1.0800		–1.3099		–0.8209
Sweetness	29.60		23.00		37.03	
Very sweet		0.8905		0.6454		1.1667
Just right		–0.0155		–0.0651		0.0402
Not sweet		–0.8750		–0.5804		–1.2069
Peel colour	19.44		19.43		19.45	
Full yellow		0.5212		0.4685		0.5805
Three-quarters yellow		–0.1755		–0.1858		–0.1638
Half yellow		–0.3457		–0.2827		–0.4167
Price (pesos)/kg	14.21		13.28		15.26	
20–30		–0.0351		0.2934		0.0632
31–40		–0.0351		–0.1378		0.0805
41–50		–0.1500		–0.1556		–0.1437

[a] Pearson's r = 0.992; [b]Pearson's r = 0.992; [c]Pearson's r = 0.990.

Mapping the product/material flow

Mapping the flow of papaya from Tupi, South Cotabato, to the company packinghouse revealed losses along the supply chain. The grower cum shipper has regular labourers who harvest, sort and pack fruit at the farm. The maturity index that they follow is the appearance of a trace of yellow at the apical portion of the fruit (termed *silay* or S1) although, in most instances, fruit that are fully green are included. Quality is lost even at harvest, as shown by the 10–15% field rejects attributed to immaturity, off-shape or deformation, insect damage due to scale insects and white flies, old bruises, decay and 'choco spots'. Fruit is individually wrapped with newspaper, placed in 65–70 kg capacity wooden crates lined by a layer of used carton, then delivered to General Santos City port and loaded in 10-foot container vans. Sea shipment to Manila takes about 3 days. The broker in Manila delivers the papaya from Manila port to the company packinghouse where they are unpacked and sorted. The fruit is again wrapped with the same newspaper and packed in 18–20 kg capacity black plastic crates. Only fruit with a peel colour of at least 60% yellow are acceptable for supermarket distribution. Green papaya are left in the packinghouse to ripen naturally or artificially using ethephon (brand name 'Ethrel'). Those with slight damage are minimally processed; i.e., peeled, sliced and packed in polystyrene trays with plastic film overwrap (cling wrap).

In the company warehouse, rejection during the 3-day holding period totalled 14.4%. Rejection was due to mechanical damage (bruising and compression), latex stain and diseases, most notably stem end rot (Table 3). Wide variation in the maturity of the fruit was also identified as a major problem resulting in papaya fruit that do not ripen or, if they do, have a flat taste or are not sweet, a common complaint of the consumers in supermarkets supplied by the company. Diseases such as anthracnose and stem end rot are latent infections, and symptoms become apparent only as the fruit ripens. This is the stage when fruit are on the third day of holding in the company warehouse or on the supermarket shelves.

Table 3. Causes of papaya rejection at the company warehouse

Defect	Proportion (%)
Anthracnose	21.2
Stem end rot	18.2
Surface mould	18.2
Choco spots	15.2
Old bruises	12.1
Latex stains	9.1
Immaturity	3.0
Shrivelling	3.0

To identify improvement plans, the activities in the chain from the input supplier to the consumer were then categorised as value adding (V), necessary but non-value adding (N) or wasteful (W). In the case of the grower/shipper, fertilisation and harvesting (in terms of maturity) are considered as value-adding activities (Figure 1) as these determine the quality of the fruit, particularly the level of sweetness. For the broker, receiving papaya at the port and transporting it to the packinghouse/warehouse of the company are necessary but non-value adding. At the company packinghouse, the value-adding activities are sorting and ripening with ethephon. Re-sorting and repacking are value-adding but can be considered also as wasteful due to repeated handling that damages the fruit. Rejects are considered as waste, which the project aims to reduce. At the supermarket, the value-adding activities are cutting the fruit into halves and packing it in polystyrene trays with plastic film overwrap or having it minimally processed (peeled, sliced and packed) or served as fresh cuts. Most of the activities in the supermarket, such as replacing old stocks and replenishing the display, are necessary but not value-adding.

Quality improvement opportunities in the value chain

Based on the analysis of the current state of the value chain, the desired state of the chain is presented in Figure 3. Values related to sweetness can start at the input supplier through the use of varieties that are inherently sweet. Value can also be added during production through appropriate fertilisation, and harvesting at the recommended stage of maturity. Freedom from decay can be addressed also during production through integrated disease management.

Improving product quality through fruit maturity

Skin colour is used commercially to describe papaya maturity (Lazan et al. 1989; Paull and Chen 1997). The fruit is harvested when there is already prominent yellow colouration on the skin to ensure normal ripening. However, for most papaya growers

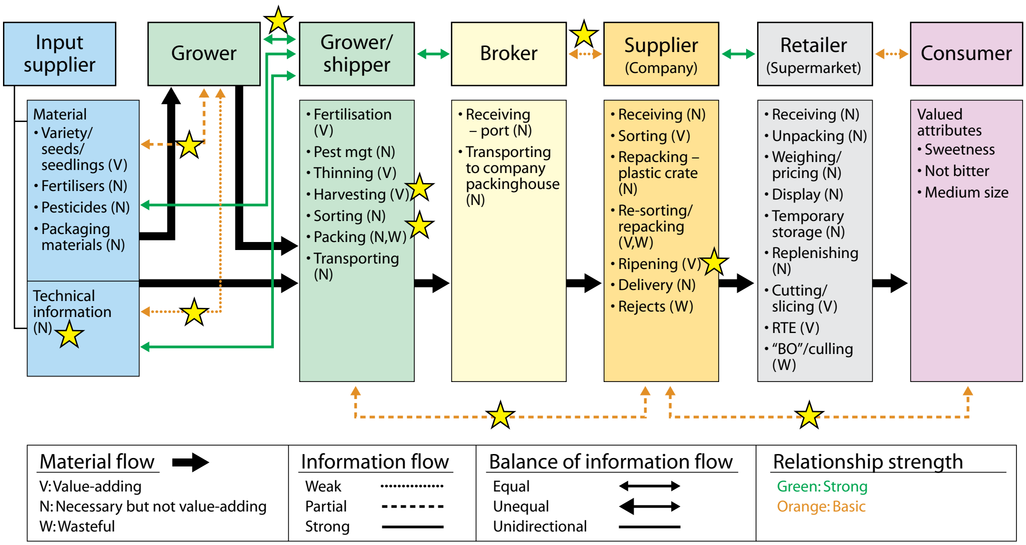

Figure 3. Future state of the papaya value chain. The stars (☆) indicate the improvement opportunities to meet the quality attributes desired by papaya consumers.

cum shippers in Tupi, papaya are already mature when they are light green with a very slight streak of yellow known locally as *silay* (designated as M1) and the two fruit just above (designated as M2 and M3) are also mature.

When we got fruit samples from 100 trees simulating the M1, M2 and M3 stages, we found that there is a wide variation in the maturity of the fruit at harvest. In fruit classified as M1, which is more mature (although a yellow streak on the skin is not prominent), the yellow–orange pulp colouration is not yet apparent in some fruit. The M2 and M3 fruit, which the growers consider mature, were apparently still immature based on pulp colour and the low TSS, with M1 having 7.92°Brix, 6.48°Brix for M2 and 6.24°Brix for the M3. These TSS values were way below the standard of 12°Brix at harvest set by exporters.

That the M2 and M3 fruit were still immature was validated at the ripeness stages, at which TSS content was very low (Table 4). Our parallel study on establishing the Brix level perceived by consumers as sweet or not sweet showed that papaya with 10–12°Brix is sweet, and is not sweet when Brix is below 10. Thus, the maturity index currently used by the growers is not appropriate. This is probably the reason for the common complaint of customers that fruit lacks sweetness. Papaya has a low starch content at harvest (about 0.1%), hence the sugars responsible for sweetness in the ripe fruit will not come from the conversion of starch into sugars (Gomez et al. 2002). The dramatic increase in sugar content of papaya occurs when the seeds and the pulp show colour change (Chen et al. 2007). These are the reasons for the recommendation to harvest when yellow colour becomes prominent.

For fruit harvested at the green stage, induction of ripening using ethephon is often done since ripe fruit are more appealing to the consumers and command a higher price. However, in immature fruit, ethephon enhanced only the ripening regardless of the stage of maturity and did not affect the physico-chemical properties of the fruit (Table 4). A 6–7% weight loss of the fruit at the ripe stage did not result in shrivelling. When not ripened with ethephon, the rate of ripening was slow and not uniform within the lot. Most of the M3 fruit were still green even on the seventh day after ethephon treatment, indicating immaturity.

Regulation of ripening

Growers cum shippers realise that colour break is the appropriate stage to harvest papaya fruit. However, the 3-day shipment under abusive temperatures from General Santos City to Manila and the need to harvest the fruit 1 day before shipment forces them to harvest at the green stage. If fruit are harvested at a more advanced stage of maturity to meet the desired sweetness, problems such as

Table 4. Physico-chemical properties and weight loss of table ripe ethephon-treated papaya fruit harvested at three maturity stages and ripened at 25°C

Fruit maturity	Ethephon (2,000 ppm)	Physico-chemical properties			Weight loss (%)
		Firmness (kg force)	Total soluble solids content (˚Brix)	Titratable acidity (%)	
M1 (*silay)*		2.05 a	8.42 a	0.078 a	7.33 a
M2 (First fruit above *silay)*	–	2.47 a	8.00 ab	0.080 a	6.79 a
M3 (Second fruit above *silay)*		2.79 a	7.66 abc	0.079 a	7.28 a
M1 (*silay)*		1.55 a	7.47 abc	0.079 a	7.75 a
M2 (First fruit above *silay)*	+	1.52 a	7.18 bc	0.078 a	7.31 a
M3 (Second fruit above *silay)*		1.70 a	6.79 c	0.083 a	7.45 a
CV		*23.45*	*4.97*	*9.20*	*6.78*

Means followed by the same letter within columns are not statistically significant, HSD at 0.05%.

premature ripening, over ripening or short shelf life will be encountered. Two techniques of retarding ripening during sea shipment were tested.

1-methylcyclopropene treatment to retard ripening

1-methylcyclopropene (1-MCP) is the latest addition to the postharvest techniques aimed at retarding ripening of climacteric fruits such as papaya. 1-MCP regulates ripening-associated changes through its action of irreversibly binding with the ethylene receptors such that ethylene cannot exert its action (Blankenship 2003). Earlier studies have shown that treatment of 1-MCP in papaya fruit delayed the onset of respiration and ethylene production, thus retarding the rate of ripening (Manenoi and Paul 2007; Ali and Mamat 2009). The effect of 1-MCP treatment in 'Sunrise' papaya fruit in retarding ripening fruit harvested at two stages of maturity was therefore tested.

Treatment of papaya fruit with 1-MCP at peel colour index (PCI)1 and 2 retarded ripening during the 3-day sea shipment from general Santos City to Manila. This was in contrast to the advanced stage of ripeness (more than 60% yellow) of control fruit. Treatment with ethephon (2,000 ppm) 5 days after 1-MCP treatment hastened the peel colour change, particularly of colour-break fruit, attaining the full yellow colour on the eighth day (Figure 4). In the case of fruit treated with 1-MCP at PCI 1 and induced to ripen, although peel colour change was slow, the rate of colour change was comparable with the control. Fruit treated with only 1-MCP and not induced to ripen with ethephon failed to attain full-yellow peel colouration.

Softening is one of the prominent changes during fruit ripening. Textural changes occur due to the action of ethylene-dependent enzymes such as polygalacturonase (PG), β-galactosidase (β-gal), pectin methyl esterase (PME), endoxylanase and endoglucanase (Manenoi and Paull 2007; Sañudo-Barajas et al. 2009). In this study, regardless of the papaya maturity, 1-MCP treatment of fruit dramatically retarded fruit softening. Firmness values of the fruit range from 6.1 to 6.9 kg/cm force, compared with only about 2 kg force in the control fruit (Figure 5). Even with application of ethephon, the fruit did not soften, even though peel and pulp colour were already yellow–orange. The same results were observed in 'Gold' and 'Rainbow' papaya in which the negative effect of 1-MCP in softening could not be reversed (Manenoi and Paull 2007).

From the results of this study, it can be concluded that, unless a method that will ensure normal ripening and softening of 1-MCP-treated fruit can be developed, the use of 1-MCP cannot be recommended.

Modified atmosphere packaging during sea shipment

Ripening of fruit can also be regulated through modification of the storage atmosphere typified by enclosing fruit in polyethylene bags of suitable thickness. Earlier studies on papaya indicated that the fruit is responsive to modified atmosphere packaging (MAP) and that normal ripening ensued after removal of fruit from MAP. The potential therefore of MAP during sea shipment from General Santos City to Manila was evaluated. Low-density 0.05 mm polyethylene (PE) bags were used to line wooden crates prior to packing of papaya fruit. Ethylene

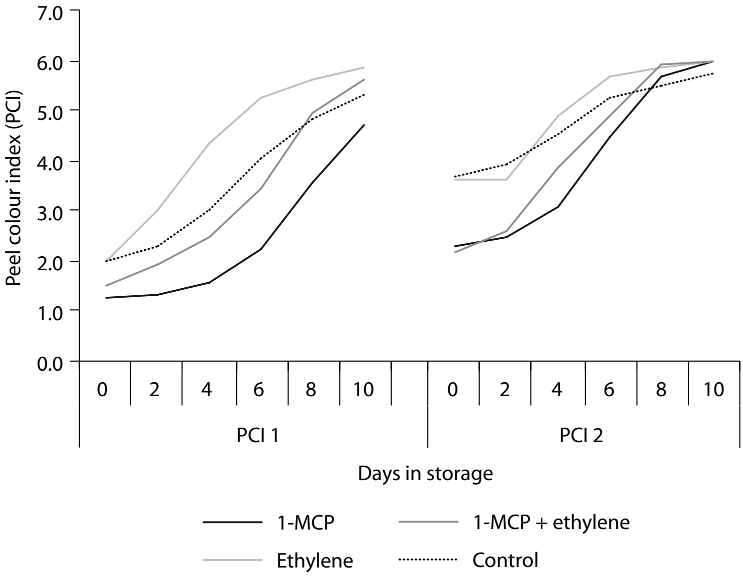

Figure 4. Peel colour change of 'Sunrise' papaya fruit treated with 1-methylcyclopropene (1-MCP) at two stages of maturity: peel colour index (PCI) 1 = green; PCI 2 = colour break

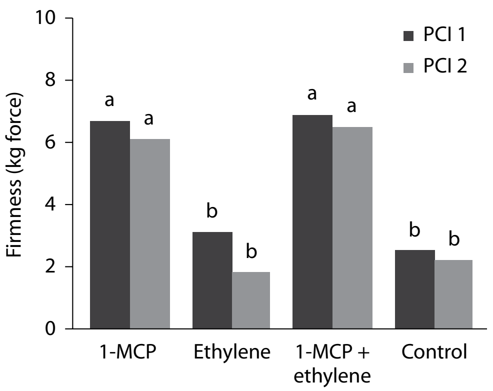

Figure 5. Firmness of 'Sunrise' papaya fruit at the ripe stage. Fruit were treated with 1-methylcyclopropene at peel colour index (PCI) 1 and PCI 2

adsorbents (EA) were also included in the pack of papaya.

Table 5 shows the peel colour index of papaya fruit after 5 days of exposure to MAP. The control crates (no EA) with fruit harvested at S1 (green stage) from both suppliers A and B were of mixed ripeness stage although most were still at colour-break stage. When harvested at a more advanced stage, which is S2 (colour break), fruit from supplier A were already nearing ripeness (PCI 4.4) upon arrival in Manila, validating the claim of the shippers that more mature fruit are not fit for long-distance shipment. In the case of S2 fruit from another grower–shipper (supplier B), ripening seemed to be retarded with the use of EA, even though the crates were lined with only carton material. When PE bags were used as liners and 30 sachets (2 g per sachet) of ethylene adsorbent were used, ripening was completely retarded in both S1 and S2 fruit. This was attributed to the modification of the atmosphere inside the PE bag resulting in the retardation of ripening. However, the use of PE bags led to a high incidence of decay due to high relative humidity inside the bags.

When the fruit from PE bags were ripened at ambient temperature (28–30°C) conditions, simulating the holding conditions at the company's warehouse in Manila, S1 and S2 fruit did not attain full-yellow peel colour, even with the application of ethephon. On the other hand, fruit packed in crates with and without EA ripened normally, although S1 fruit exhibited a slower rate of ripening compared with S2 fruit in the case of those sourced from Supplier B.

Table 5. Peel colour index of papaya fruit 5 days after exposure to modified atmosphere packaging (MAP)

Method of ripening inhibition	Peel colour index			
	Supplier A		Supplier B	
	S1	S2	S1	S2
Ethylene adsorbent + carton	2.6	4.6	1.7	2.5
Ethylene adsorbent + MAP	1.2	2.0	1.2	2.0
control	2.3	4.4	1.7	3.0

From the results of these trials, it appeared that S2 fruit would meet the requirement of the consumer with regard to sweetness and desired stage of ripeness upon arrival. However, the 3-day shipment duration at high temperatures led to premature ripening and, in some fruit, over-ripening upon arrival in Manila. While the use of EA appeared to retard ripening even though not used in a closed system (i.e. as inserts in crates with only carton lining), this was obtained only in S2 fruit coming from only one of the suppliers. On the other hand, when PE bags were used as liners, ripening was inhibited but moisture condensation inside the PE bag enhanced decay. Follow-up handling trials will therefore be conducted on the method of EA application and modification in the use of PE bags. This trial will be combined with field application of hot water treatment for disease control.

Hot water treatment for disease control

Delayed hot water treatment

Marketability and shelf life of papaya fruit are limited by diseases, particularly anthracnose caused by *Colletotrichum gloeosporioides* and stem end rot caused by *Phomacaricae papayae* (Martins et al. 2010). These diseases become a problem when fruit have more than 40% skin yellowing. Heat treatments have been used in papaya to control decay (Couey et al. 1984). Previous Australian-funded projects of the Postharvest Horticulture Training and Research Centre (PHTRC) of the University of the Philippines Los Baños (UPLB) had optimised the temperature–time combination for hot water treatment (HWT) of Philippine-grown 'Solo' papaya and this served the as the basis of this experiment.

Table 6 shows the effectiveness of HWT (50°C, 10-minute dip) in reducing or controlling the incidence of decay in different varieties of papaya even with delays in its application. For 'PPY' and 'Sunrise' varieties, stem end rot (SER) rather than anthracnose is apparently the problem. On the other hand, 'Red Bonita' is susceptible to anthracnose, and HWT only reduced the incidence even though severity of anthracnose infection was only slight (data not shown). Anthracnose is initiated in developing fruit in the field and symptoms show up later, after harvest (Alvarez and Nishijima 1987), hence the need for timely preharvest fungicide spraying. HWT can only reduce but rarely eliminate infection once established (Couey et al. 1984). Even with delayed application of HWT, reduction in disease incidence ranged from 33 to 100% depending on variety and source of fruit.

Comparison of on-farm and delayed hot water treatment

Figure 6 shows the results of the preliminary trial of on-farm versus delayed application of HWT. The incidence of both stem end rot and anthracnose was

Table 6. Incidence of anthracnose and stem end rot of different papaya varieties 10 days after hot water treatment (HWT)

Variety	Anthracnose (%)		Stem end rot (%)	
	HWT	Control	HWT	Control
PPY	0	0	20	30
Red Bonita	20	30	0	0
Red Solo	0	40	10	40
Sunrise (supplier A)	0	0	10	60
Sunrise (supplier B)	0	0	10	40

reduced by HWT. Unexpectedly, delayed application of HWT (4 days after harvest when peel colour was still at colour-break stage) resulted in better disease control than on-farm HWT, which was applied on the day of harvest. The difference in response of papaya fruit to on-farm and delayed HWT can be attributed to the effect on the onset of decay of curing, which involves holding fruit at high temperature (30–35°C) before the application of any postharvest treatment. In citrus fruit, curing at 35°C for 24 to 48 hours significantly reduced the incidence of green mould (Zhang and Swingle 2005), which they attributed to healing of fruit injuries and/or production of phytoalexins during curing. This needs to be validated in the case of papaya. Incidence of 'choco' spot was also somewhat reduced by HWT. Another trial needs to be conducted to validate the results obtained. In this batch of fruit, stem end rot was more of a problem than anthracnose since the onset of the latter disease was observed only when fruit were already at advanced stages of ripeness, that is, at PCI 4 to 5, while that of stem end rot occurred when fruit were still at PCI 3 (more green than yellow). Moreover, the severity of stem end rot infection was higher than that of anthracnose.

Reducing heat treatment time with different temperature–time combinations

One of the reasons cited for the non-adoption of HWT for disease control is the long treatment time involved, which can be a bottleneck, especially if large volumes of fruit are to be treated. In mango, it was shown that the conventional method of HWT, that is, a 10-minute dip at 52–55°C, can be modified such that temperature of the water can be raised to 59°C and dipping time is thereby reduced to only 30 to 60 seconds (Esguerra et al. 2006). In response to the concerns raised by potential users of HWT for papaya, an experiment was conducted using different temperature–time combinations of HWT.

High HWT temperature (57°C) and long dipping time (5 minutes) resulted in poor colour development with fruit not attaining full-yellow peel colour after 9 days at ambient conditions (data not shown). However, the lowest incidence and severity of anthracnose among the different treatments applied immediately after harvest was observed in fruit treated at 57°C for 5 minutes. However, this treatment combination was not recommended due to abnormal peel colour development brought about by high temperature. The results of treating fruit at 53°C for 5 minutes are also notable, with better peel colour development and good disease control (data not shown). In these treatments, anthracnose incidence and severity were very low and almost comparable with the usual 50°C, 10-minute dip treatment. Moreover, the incidence of stem end rot was also lower compared with the usual treatment. The other temperature–time combinations, particularly those at higher temperatures, did not result in an adequate degree of disease control. The results of the present study are not yet conclusive and further trials are recommended.

The absence of HWT facilities in the production areas in Tupi, South Cotabato, as well as in the packinghouse of the company in Metro Manila,

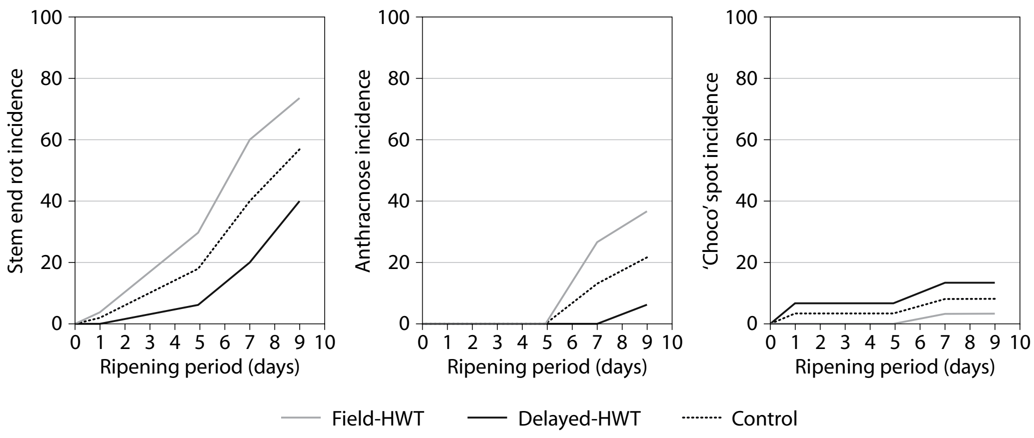

Figure 6. Incidence of stem end rot, anthracnose and 'choco' spot in papaya fruit subjected to on-farm and delayed hot water treatment (HWT) at 50°C for 10 minutes

hinders the adoption of HWT. However, as a result of the training conducted and the export shipment trials in which the benefits of HWT were shown, the local government unit of Tupi, South Cotabato, has indicated funding support for the fabrication of hot water tank that can be used by interested groups.

Capability building

Enhancing awareness on improved production and postharvest handling techniques can be made possible through training activities. Since a total systems approach is envisioned in project implementation, our project on 'Analysis of the constraints to selected tropical fruit (papaya) supply chains and implementation of improved quality systems for the southern Philippines and Australia', the C1 component of the ACIAR Fruit Program, was linked with the ACIAR C3 component project titled 'Integrated crop management strategies for productive, profitable and sustainable production of high quality papaya fruit in the southern Philippines and Australia' during the conduct of the training.

Training on papaya production and postharvest handling

A 2-day training on papaya production and postharvest handling was held on 24–25 May 2011 at the training hall of the Municipal Agricultural Office of Tupi, South Cotabato. It was participated in by 52 growers, growers–shippers and traders of papaya whose markets are mainly Metro Manila, Iloilo and Cagayan de Oro City. There were also three representatives of an exporting firm, Diamond Star AgroProducts, Inc. Five modular PowerPoint presentations were developed and used during the training. In all the topics, the results of the consumer survey, the value-chain analysis conducted in the papaya chain, and the improvement opportunities aimed at delivering those attributes of a papaya valued by consumers were discussed with the participants. The project staff of the ACIAR-funded project on 'Improving productivity of papaya fruit' were also invited as resource persons for the presentations on integrated pest management and nutrient management.

Training of company personnel

Training of company personnel (26 participants) involved in papaya procurement, receiving, quality control, sorting and merchandising was conducted on 29 July 2011 at the conference room of the company packinghouse cum warehouse in Parañaque City. The training was held for only half a day since all the participants needed to be back at their work in the afternoon. The training was aimed at familiarising the staff on different postharvest handling techniques to maintain quality and minimise damage and losses during sorting, packaging, distribution and retail display.

From export to export

The original intent of the project was to engage the cooperation of papaya exporters but this did not eventuate. The project thus focused on the domestic supply chain. However, recent developments indicated that we can rejoin the original intent, but this time in collaboration with the papaya growers' association of Tupi, South Cotabato. The markets identified are the Middle East and Singapore. In collaboration with the members of the growers' association, the Municipal Agricultural Office of Tupi, South Cotabato, the Growth with Equity in Mindanao (GEM) Program of USAID, and the buyer, several experiments were conducted to meet the desired quality requirements of the customer (importer) in terms of stage of ripeness and freedom from defects, particularly decay upon arrival in the importing country.

Briefly, the methodology involved the following: harvesting papaya fruit at commercial maturity, sorting them as to freedom from defects, trimming the pedicel and subjecting the fruit to HWT at 50°C for 10 minutes. Since sea shipment to the Middle East takes 14–18 days, several treatment combinations were tested after HWT; such as fungicide treatment after hydro-cooling and packing fruit in cartons lined with polyethylene film to create a modified atmosphere inside the pack. The use of fungicide such as azoxystrobin was based on an earlier study on mango, in which for long-term storage, HWT needed to be supplemented with fungicide (Esguerra and Opina 2008). The use of 13°C as a storage/shipping temperature was based on the earlier studies of Serrano (2004b).

Middle East shipment

Using the papaya growers' harvest maturity index, which is mature green to colour break, 'Sunrise' papaya fruit free from mechanical damage and insect infestation can be shipped to the Middle East using a reefer van set at 13°C. Based on the results of initial studies, the postharvest handling guide for long-distance refrigerated sea-shipment of papaya is as follows:

1. harvest 'Sunrise' papaya fruit at the green mature to colour-break stage (ensure that fruit are free from mechanical damage and insect infestation)
2. apply HWT at 50°C for 10 minutes
3. hydrocool fruit in 125 ppm azoxystrobin after HWT
4. dry, cool and wrap fruit individually in polystyrene cups and pack in carton boxes (5 kg net)
5. ensure a transit temperature of 13°C for 14 to 21 days
6. ripen at 25°C; fruit can be allowed to ripen naturally or, if rapid ripening is desired, fruit can be treated with 2,000 ppm ethephon

This handling guide was adopted by the growers' association of Tupi, South Cotabato, during the two successful shipments of 'Sunrise' papaya to Dubai and Abu Dhabi in August 2011.

Singapore sea shipment

Sunrise papaya fruit used in the experiment were obtained from a member of the Matutum Tropical Fruit Association (MATROFA) who apparently follows good cultural management in his papaya production since fruit were of good quality. Since the importer wanted the fruit to arrive at Singapore at near ripe stage and ready for distribution, two colour stages were tested. Moreover, the shipping temperatures that we tested were, at 15°C and 18°C, higher than the recommended 13°C, to allow ripening to take place during the 7-day sea shipment from Davao to Singapore. If 13°C were used, papaya would still be unripe upon arrival.

Results showed that papaya at colour 4 (more than 30% yellow peel) will meet the desired stage of ripeness after the 7-day sea-shipment to Singapore (near ripe stage) and will still allow distribution to supermarkets/retail outlets and shelf life of 3–5 days. Moreover, fruit at this stage were sweeter than fruit at colour 2 (10% yellow peel colour).

Papaya at colour 2 were not yet ready for distribution after the 7-day sea shipment regardless of shipping temperature and whether or not they were treated with ethephon. Only upon transfer to a higher temperature was ripening accelerated, and it took about 3 days at 23°C for fruit to attain the desired ripeness stage for retail.

Ethephon treatment is necessary before transport if the shipping temperature is 15°C; at 18°C, ethephon treatment may be omitted, although there will still be some fruit that were not yet at near ripe stage after 7 days. Upon display of fruit in retail shelves, and if the temperature is high (23°C), papaya will ripen rapidly.

Baseline performance analysis

Following the benchmark data gathering in April 2009 in the company packinghouse with regard to the extent of papaya rejection, a follow-up collection of baseline data was conducted. The quality of 'Solo' papaya delivered by three papaya suppliers to the Paranaque packinghouse was monitored to determine changes or improvements in quality over time. The period under study included both peak and lean months of production and supply; that is, October 2011 and March 2012 (5 months later), respectively. Key informants in the area reported that there is excess supply of fruit in October and November, while a production gap occurs during the summer months of February until May.

Table 7 shows the volume and extent of rejects or 'bad order (BO)' of papaya received at the company packinghouse in Metro Manila in April 2009 (benchmark data) and in specific shipments in October 2011 and March 2012 (average of two shipments). The original and the major suppliers (A and B) both had shipments during the period. Supplier A is the company's original and main supplier for 6 years, while supplier B is currently the biggest source who had been forwarding fruit from South Cotabato twice weekly for over a year. On the other hand, the third and newest source (supplier C) of barely 8 months had had deliveries monitored in only March 2012.

Based on the benchmark data of 14.4% rejection or BO in April 2009, rejection was reduced considerably over the evaluation period of October 2011 to March 2012. Reduction in rejection ranged from 37% to 73%, which can be translated as reduction in losses of the suppliers since rejected fruit are returned to them and are not paid for by the company. Since supplier 1 does not have local outlets in Metro Manila to which rejects that are still marketable could be forwarded and sold at a lower price, he shoulders all the rejects reported at the company packinghouse. The reduction in rejects therefore translates to an increase in revenue of the supplier, which should be shared by him with the growers, in terms of a higher farm-gate price. Information on this aspect has not been gathered or validated with the grower–shipper. This still needs to be examined.

Table 7. Rejection of papaya fruit during the 3-day holding period in the company packinghouse[a]

Day	Evaluation date/supplier/rejects (%)					
	(April 2009) (benchmark)	October 2011		March 2012		
		A	B	A	B	C
1	5.5	0.9	2.4	0.4	2.7	0.7
2	1.2	8.2	0.6	2.2	3.2	1.8
3	7.7	0	3.7	1.3	1.3	4.1
Total	14.4	9.1	6.7	3.9	7.2	6.6
Percentage reduction in rejection		36.8	53.5	72.3	50.0	54.2

[a] Data were obtained from the company; A, B and C are the suppliers

For all suppliers, mechanical damage and disease were the primary reasons for rejection. While these observations have been fed back to the suppliers and possible solutions to these problems have been discussed with them, such as reducing the size of the wooden crate (to reduce mechanical damage) as well as HWT for disease control, these have not been adopted. The size of wooden crate (60 kg capacity) cannot be reduced since the transport fee is on a container rather than a weight basis. In the case of HWT, there are no facilities in the area and, except for supplier C since he is also targeting the export market, suppliers are not keen on investing in such a facility. However, the local government of Tupi has expressed interest in funding the fabrication of a hot water tank for use by papaya growers and traders. It is worth noting that, in the causes of rejection, immaturity was not recorded during the 3-day evaluation. It cannot be concluded yet whether this was a result of the training conducted in July 2011, which highlighted the importance of maturity in relation to sweetness valued by the consumer.

The company has three papaya suppliers from Tupi. To determine if there are improvements in the quality of fruit they supply, sensory evaluation scores of 'Solo' papaya, comparing the different papaya growers from South Cotabato, are presented in a spider web or radar chart (Figure 7). Such charts show the gaps among the different treatments tested, display the important categories and reveal concentrations of strengths and weaknesses. The different sensory parameters evaluated for comparison of fruit from the different growers were the following: peel colour, pulp colour, sweetness, flavour, firmness and Hedonic rating.

Viewing the differences among the growers, sensory profile of papaya from Concepcion (supplier A) and Nimes (supplier B) were similar (Figure 7). Manansala received the highest ratings for pulp colour, sweetness, flavour and Hedonic rating, which did not overlap with the other suppliers. This indicates that among the growers–suppliers of the company, Manansala produces better fruit than Concepcion and Nimes. Figure 7 also shows that increased ratings for pulp colour, sweetness and papaya flavour corresponds to an increased Hedonic rating. This implies that these sensory attributes of papaya need to be maintained to ensure that the fruit will be consistently liked or preferred.

Conclusion

The performance measures (information flow, relationships, product mapping) together with consumer surveys collectively enabled the identification and implementation of improvement opportunities to

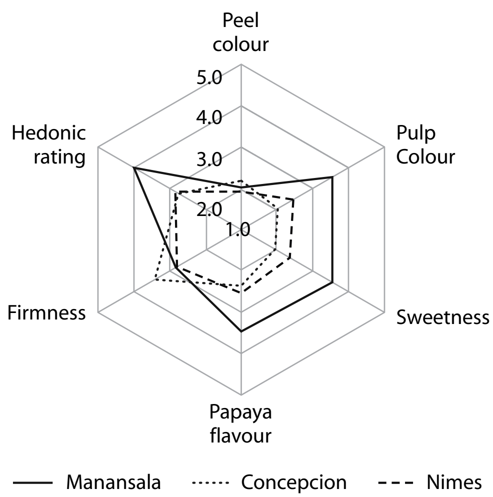

Figure 7. A spider web chart of the sensory profile of papaya fruit supplied to the company by three growers–suppliers in different locations

reduce losses, maintain produce quality and deliver consumer-defined value. Improvement activities that focus on quality attributes valued by the consumers include maturity as a determinant of sweetness, HWT for disease control and regulation of ripening. Technologies on these improvement opportunities have been developed during previous Australian-funded projects. In our current project, these earlier technologies were verified and modified to suit the current situation of the project collaborators in South Cotabato. The project cooperator has adopted HWT as a standard operating procedure of papaya for export to Singapore.

Lack of information on proper postharvest handling as well as consumer insight on attributes valued in a papaya was validated during the two training activities conducted in Tupi (the source/supplier of fruit) and in the company (the customer). Training, coupled with participatory research with growers–suppliers and company staff, and giving the stakeholders feedback on the results of research conducted appeared to have had an impact, measured as a 37–73% reduction in rejection of papaya fruit delivered by grower–suppliers to the company. The reduction in rejection translates to increased recovery of marketable fruit and, in turn, increased returns to the grower cum shipper. The reduction in rejection translates to reduced postharvest losses.

Enhanced market access, both domestic and export, necessitates creating an enabling environment, which was partly demonstrated in this project. This was achieved through the collaborative efforts of the following: (1) the project research team, which provided technical assistance in validating and/or modifying existing technologies, training, information dissemination and constant feedback on the outcome of the research; (2) the local government of Tupi, South Cotabato, through the Municipal Agricultural Office, which has been highly involved in the project, thus ensuring sustainability, and has provided assurance of financial assistance for the establishment of packinghouse facility with a hot water tank as a service facility; and (3) the GEM program of USAID, which facilitated the market linkage and also provided support to the fruit association through training and provision of plastic crates.

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Participatory action research (PAR) on *Phytophthora* management delivers positive outcomes for smallholder jackfruit farmers

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Abstract

Jackfruit production in the Philippines is hampered by the occurrence and high incidence of *Phytophthora* disease causing a decline syndrome affecting farms, particularly in the Eastern Visayas Region. This project aimed to increase the productivity of jackfruit by allowing the smallholder jackfruit farmers to have hands-on experience in improved orchard management, with an emphasis on the management of *Phytophthora* disease. A participatory action research (PAR) approach was used. Four jackfruit farmer stakeholders evaluated disease management strategies of their choice. Improved cultural practices, such as sanitation and cultivation, construction of drainage canals, mounding, mulching and application of chemicals and plant defence activators including mancozeb (Dithane®), phosphonate (Agri-Fos®), benzothiadiazole ('E Boost'), chitosan and acetylsalicylic acid (aspirin) were evaluated by the farmers. Trials were regularly monitored by the component leader and staff. The application of the disease management strategies tested by the PAR collaborators improved the health status of the jackfruit trees, reduced production cost, reduced losses due to the disease, and increased yield and consequently the farmers' incomes. Other jackfruit farmers have also benefited from the results of these trials because they have witnessed the actual improvements in the farms of stakeholders during farmer field days and personal visits to the farms. The extension training of agricultural technicians on disease management, conducted by the project in collaboration with local government units (LGUs), is expected to improve the capabilities of these extension workers in answering farmers' questions about the jackfruit decline problem The involvement of LGUs had caught the awareness of policymakers in the region, highlighting the importance of this disease and its management, and the benefits to jackfruit farmers.

Introduction

Jackfruit *(Artocarpus heterophyllus*), known in the Philippines as 'Langka' or 'Nangka', is one of the most popular and widely grown fruits (Haq 2006; Pinoy Farmer 2008). It is marketed as the 'flagship fruit' in the Eastern Visayas Region because of the outstanding jackfruit variety called 'EVIARC Sweet' developed by the Department of Agriculture–Eastern Visayas Integrated Agricultural Research Center (DA–EVIARC). Through a previous program of the Department of Agriculture (DA) there was massive planting of jackfruit by some farmers in the region (Macapanas 2011). In 2005, the total area planted was 13,319 hectares (ha) with a total jackfruit production of 52,647 tonnes (t). Production has steadily increased and now between 2 and 3 tonnes per week are shipped to other regions and major cities such as

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Cebu and Manila (DA–EVIARC 1997; PCARRD–DOST 2003).

Jackfruit production, however, was hampered by the occurrence and high incidence of an unidentified decline syndrome which causes initial leaf yellowing, defoliation, decline and wilting and, in some cases, death of jackfruit trees. In some farms up to 100% of the trees were affected. The aetiology of this disease was undiagnosed until recently. This project came about due to this threat to jackfruit production in the region. During a previous scoping study in 2007, diseased seedlings were seen in nurseries, indicating that poor nursery practice could be involved in spreading the disease. *Phytophthora* diseases occur in a range of tree crops and successful integrated pest management (IPM) strategies have been developed for many of these crops (Drenth and Guest 2004). It was hypothesised that this decline syndrome is caused by *Phytophthora* species and that improved orchard management could be a way of reducing disease losses, leading to sustainable yield increases, improved fruit quality and, ultimately, an increase in smallholder farmers' incomes.

This project aimed to increase productivity of jackfruit in the Philippines by encouraging smallholder jackfruit farmers, through simple participatory action research trials, to have hands-on experience in testing improved disease management strategies in their orchards, particularly in managing *Phytophthora* disease.

Materials and methods

Stakeholder workshop

A stakeholder workshop was conducted at Del Monte, Camp Phillips, Bukidnon, in Mindanao, on 30 July–1 August 2008 at the beginning of the project. The participants included jackfruit farmer stakeholders identified to engage in the participatory action research (PAR) trials, as well as representatives from the durian and papaya industries. The farmer stakeholders were identified based on the suggestions of DA–EVIARC staff in Abuyog who already had a relationship with these farmers and they were among the recipients of the plant-now-pay-later (PNPL) program. These farmers were also willing to participate in the trials.

To increase the stakeholders' understanding of *Phytophthora* diseases and to overcome poor dissemination of information about disease management, the participants were given theoretical and practical training in the isolation, diagnosis, biology and epidemiology of *Phytophthora*. They were also exposed to the different management options for *Phytophthora* disease of other crops, such as durian and cacao, by the Australian collaborators. To promote more effective dissemination of information about disease management, the concept of PAR was introduced. Workshop participants were able to identify topics for the PAR trials they wanted to undertake in relation to the management of the jackfruit decline problem.

Implementation of farmer trials to test management strategies to disease incidence, yield and income

After the workshop, PAR trials were conducted by four farmer stakeholders in relation to *Phytophthora* management on their respective farms. The trials established were monitored regularly by the component leader and staff. Each participant evaluated the management options discussed during the first training workshop. The different PAR trials, their objectives and general methodology are described below.

PAR trial 1—The effect of drainage and mounding on the incidence of wilt disease on an established jackfruit plantation – Romualdo Marcelino (jackfruit farmer, Ormoc City)

Rationale

This trial was based on the knowledge that *Phytophthora*, a soil-borne pathogen, is favoured by excess water on the ground, especially near the roots, and that mounding trees and construction of drainage canals can help reduce the high incidence of *Phytophthora* disease in the orchard. Furthermore, the type of mounding medium may have an effect on the incidence of the disease and the yield performance of jackfruit.

Objective

To determine the effect of drainage and mounding on the incidence of decline disease in an established jackfruit plantation.

Methodology

This trial was conducted in a 1.5 ha jackfruit farm in Curva, Ormoc City, with 15-year-old trees. The farm was partitioned into one area with drainage and one without drainage. For the area with drainage, a main canal with a depth of 1 m × 1 m wide was constructed through the middle of the plantation.

Lateral sub-canals of 0.5 m depth × 0.5 m wide were constructed parallel to the main canal. The depth and cleanliness of the canals was maintained to minimise obstruction of water flow. One area of the orchard had drainage, while another area was undrained. Trees were mounded using a range of media to raise the soil level by approximately 0.5 m. The composition of mounding media used was soil alone, vermi-compost + mudpress, and dried chicken manure + mudpress. Mounding medium was applied twice a year to maintain its level.

The disease incidence and severity of disease were recorded every month. The disease severity was rated according to the scale below:

- 1 = no premature yellowing of leaves, dieback/canker
- 2 = 25% premature yellowing of leaves/dieback/canker (1–5 lesions)
- 3 = 50% premature yellowing of leaves/dieback/canker (6–10 lesions)
- 4 = 75% premature yellowing of leaves dieback/canker (11–15 lesions)
- 5 = 100% premature yellowing of leaves/dieback/canker (16 or more lesions)

The yield of fruit harvested was recorded annually. Cost of production was determined every fruiting season, to allow profitability analysis. This was done by computing the gross margin of the different interventions made.

PAR trial 2—Effect of sanitation, cultivation and mulching on the incidence of jackfruit decline – Miguel Pedroso (jackfruit farmer, Carayman, Calbayog City)

Rationale

Phytophthora is a notorious pathogen that produces an explosive amount of inoculum when conditions are favourable to it, which is why it is called 'the plant destroyer'. It is a polycyclic pathogen, thrives in a wet tropical environment and attacks many host plants. Because of this knowledge, this trial was conceived to investigate the effect that simple cultural practices have on the incidence of the disease. The farmer stakeholder elected to test sanitation, cultivation and mulching of trees in reducing the incidence of the disease.

Objectives

1. To determine the effect of sanitation, cultivation and mulching on the control of decline disease on jackfruit
2. To determine the costs and returns of the treatments applied.

Methodology

This trial was conducted on a 2 ha farm in Carayman, Calbayog City, in Samar, with 11-year-old trees. There were four treatments: sanitation (once a month ring weeding of the plants), cultivation (cultivating the area below the canopy with a hand hoe), banana mulching (two sacks of chopped banana leaves placed around the tree) and *Gliricidia* mulching (two sacks of *Gliricidia* leaves placed around the tree). The experiment was laid out in a randomised complete block design with three replications per treatment. Monthly monitoring was done to determine disease incidence and severity. The disease-severity rating scale was the same as described above. Fruit yield was recorded every year. Costs and returns of production were determined every cropping year to determine the economic viability of each treatment applied.

PAR trial 3—Integrated approaches for the management of Phytophthora *decline of jackfruit –Julio Munoz (jackfruit farmer, Alibaba, Calbayog City)*

Rationale

This trial was conducted on a 3 ha farm in Alibaba, Calbayog City, in Samar, with 10 year-old trees. Initially, 357 jackfruit trees had been planted on this farm but only 243 trees had survived at the time the trial started. The farm is situated in a lowland area beside a rice field which encountered flooding during heavy rainfall such that 95% of the trees were affected. Integrated approaches that included improved cultural management and chemical control were applied on this farm, since almost all of the trees were infected with the disease. Different chemical treatments that included fungicides and plant defence activators were tested.

Objectives

1. To determine the effect of integrated management approaches on the incidence of jackfruit decline
2. To determine the profitability of the treatments measures applied.

Methodology

A drainage channel 1 m × 1 m was constructed along the rice field and sub-channels were constructed to reduce waterlogging. Trees were mounded with a mixture of soil, dried chicken manure and rice straw. Other improved cultural management practices included sanitation, pruning and bagging of fruits. The insecticide cypermethrin ('Bushwack') was applied to control black ants when needed.

Chemicals were applied to test if they would cure existing infections. The following treatments were applied:

- T_0 – control, no chemical applied
- T_1 – phosphonate (Agri-Fos® 400) applied as a trunk injection every 6 months (15 mL of 30% solution applied per m^2 of tree canopy) using a tree injector
- T_2 – phosphonate (Agri-Fos® 400) mixed with Pentra-Bark® wetting agent (1.5% Pentra-Bark® with 40% phosphonate in water) as bark penetrant sprayed onto the trunk from 2 m application height to run off applied every 3 months
- T_3 – chitosan (100 ppm applied monthly as a spray)
- T_4 – aspirin or acetylsalicylic acid (five powdered tablets per 16 L water applied as monthly spray)
- T_5 – mancozeb (Dithane® M-45) as fungicide check was applied through spraying the leaves of the tree every month at the rate of 4 tablespoonsful/16 L water.

Each treatment was replicated three times with 10 plants per replicate arranged in a randomised complete block design. Disease incidence and severity were assessed monthly. Fruit yield was recorded every year. Costs and returns of production were determined every cropping year to obtain the economic viability of each treatment applied.

PAR trial 4—The effect of chemical application and phosphonate injection in the management of jackfruit decline – Job Abuyabor (jackfruit farmer, Mahaplag, Leyte)

Rationale

Chemicals such as phosphonate had been reported to be effective in the treatment of *Phytophthora* diseases in other crops and fruit trees. Testing phosphonate and other chemicals for the control of jackfruit decline was the purpose of this PAR trial.

Objectives

1. To determine the potential of chemical application and phosphonate injection to control jackfruit decline
2. To determine the economics of the interventions made.

Methodology

The PAR trial was conducted in a 3–5-year-old jackfruit plantation with an area of approximately 1.8 ha in Barangay San Isidro, Mahaplag, Leyte. There were six treatments with three replications per treatment and 10 trees per replicate. The experiment was laid out in a randomised complete block design. Jackfruit trees were subjected to chemical spraying and trunk injection. The chemicals used were: 1. phosphonate (Agrifos 400) applied as trunk injection every 6 months; 2) phosphonate mixed with Pentra-Bark®; 3. Boost 50 SC (benzothiadiazole); 4. chitosan (Poly-N-glucosamine); 5. Dithane® M-45 Neotec (mancozeb); and 6. control (untreated trees). The trees were rated based on the percentage cankers on the trees. Cankers were noted at the start and at the end of the project. Percentage canker reduction per replicate per treatment was then computed.

Other interventions applied and profitability analysis

Aside from the interventions that the above PAR trials applied to the farms, all of the participating farmer–researchers practised other improved cultural management practices in their farms, such as tree pruning, overall farm sanitation and fruit bagging, and two farmers (Job Abuyabor and Miguel Pedroso) practised tree and fruit tagging. Analyses of the farm production costs and gross margin as a result of the treatments were also conducted in all these trials to determine the profitability of the different interventions.

Final workshop and formulation of *Phytophthora* management options

Results of the different PAR trials were presented during a final workshop at which the stakeholders' trials and personal experiences were reported and discussed, and successful disease management strategies were identified.

Results

Participatory action research outcomes

PAR trial 1—The effect of drainage and mounding on the incidence of wilt disease on an established jackfruit plantation

Disease incidence and severity as affected by drainage and mounding

Disease incidence was computed as the ratio of jackfruit trees showing symptoms of disease over the total number of trees in each treatment. Disease incidence of 1 would mean that 100% of the jackfruit trees showed symptoms, while 0 would mean no disease symptoms were evident. Disease incidence was initially high regardless of drainage but fell with time in areas with drainage, compared with trees in the area without drainage, regardless of mounding treatments (Figure 1).

A slight fluctuation in the disease severity was observed with time and this could be due to the different weather conditions in the different months (Figure 2). It can be seen in Figure 2 that the general trend was for a decline in disease severity in the trees growing in the area with drainage compared with those in the area without drainage.

Jackfruit trees mounded with soil showed lower disease incidence than trees without mounding (Figure 3). Trees treated with chicken manure + mudpress or vermi-compost + mudpress were observed to have significantly lower disease incidence compared with unmounded trees and trees mounded with soil only. The effect was more pronounced in the area with drainage. In both areas, a greater decrease in disease incidence was observed in trees mounded with chicken dung + mudpress. The same trend held true with regard to disease severity. Trees mounded with chicken manure + mudpress had the lowest mean disease severity rating and the effect was more pronounced in the area with drainage (Figure 4).

Yield and profitability analysis

The effect of the treatments on yield of jackfruit trees for two consecutive years is shown in Figure 5. The yield was higher in the area with drainage, in all treatments. In both areas, mounding with chicken dung + mudpress produced the highest yield. The yield was generally higher in 2011 than in 2010, especially in trees mounded with chicken manure + mudpress with 6.53 t/ha in 2011 compared with nearly 5 t/ha in 2010. The gross margin was significantly greater from jackfruit trees growing in the area with drainage compared with the area without drainage (Figure 6). The effect of mounding on gross margin was, however, more pronounced during the second year, suggesting it takes time for some treatments to have an effect on disease. Mounding with chicken dung + mudpress or vermi-compost + mudpress still produced a significantly higher gross margin, with chicken manure + mudpress being the most effective with a gross margin per hectare of 55,032 pesos (equivalent to about $US1,3153 at current exchange rate at the time). This could be due to the improved soil health through increased microbial activity and availability of additional nutrients

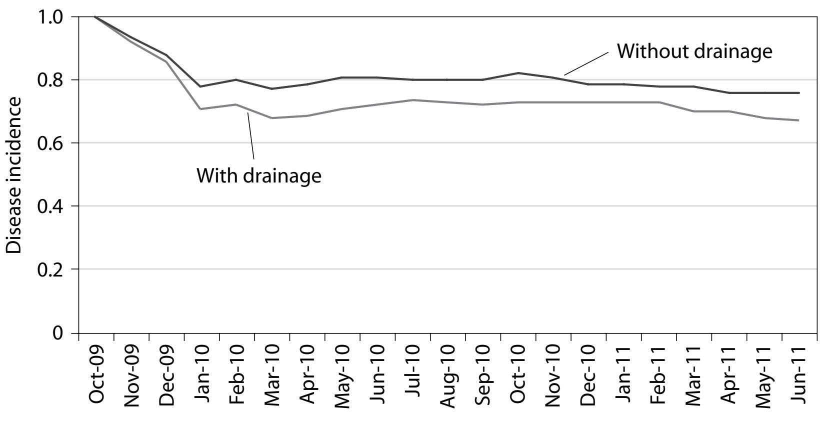

Figure 1. Mean disease incidence in jackfruit trees as affected by drainage conditions

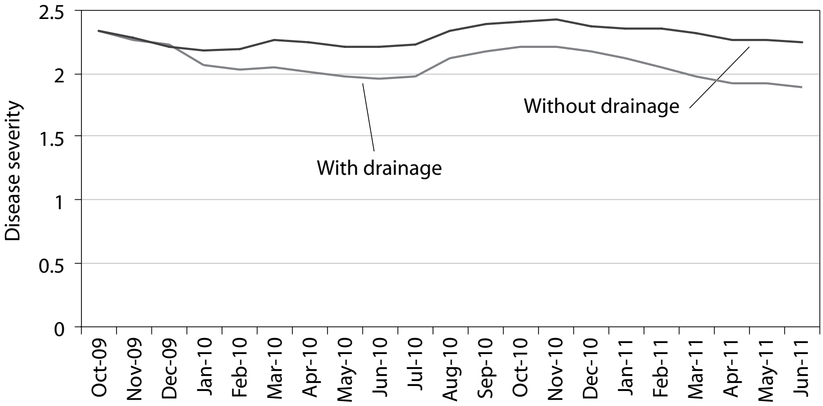

Figure 2. Mean severity (see text for explanation of rating) of disease in jackfruit trees in areas as affected by drainage conditions

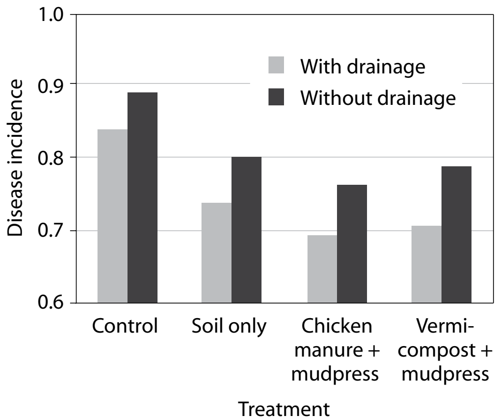

Figure 3. Mean disease incidence as affected by the mounding media in areas with or without drainage

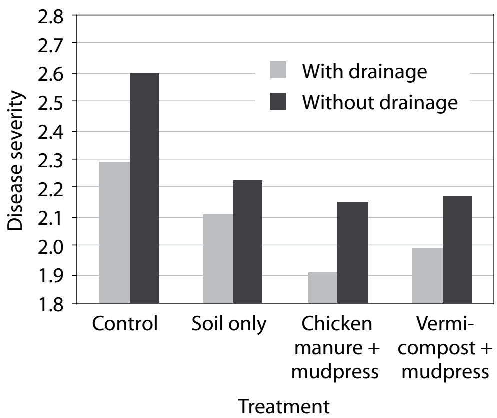

Figure 4. Mean disease severity (see text for explanation of rating) as affected by the mounding media in areas with or without drainage

present in the mounding materials, and indirectly due to the reduced disease incidence caused by the mounding media and improved drainage.

PAR trial 2—Effect of sanitation, cultivation and mulching on the incidence of jackfruit decline

This trial investigated the effect of sanitation (ring weeding), cultivation and mulching on *Phytophthora* incidence and severity. Disease incidence (Figure 7) and disease severity (Figure 8) both decreased with time, regardless of the treatments applied. This could be due to other improved cultural management practices applied to the trees, such as pruning and proper disposal of infected fruits and farm waste. Among the treatments applied, the greatest reduction in disease incidence was observed on the trees mulched with 'kakawate' (*Gliricidia sepium*).

During the first 2 years of implementation, the different treatments had no effect on jackfruit yield but, during the third year, trees mulched with banana leaves and kakawate had significantly higher yields (18.97 and 23.35 t/ha, respectively, compared with trees subjected to only under-brushing (plain sanitation) and cultivation (12.36 and 13.46 t/ha, respectively; Figure 9). This implies that the beneficial effect of the mulching on yield took time to take effect. The same trend was observed in the net income per hectare. The net income was highest in

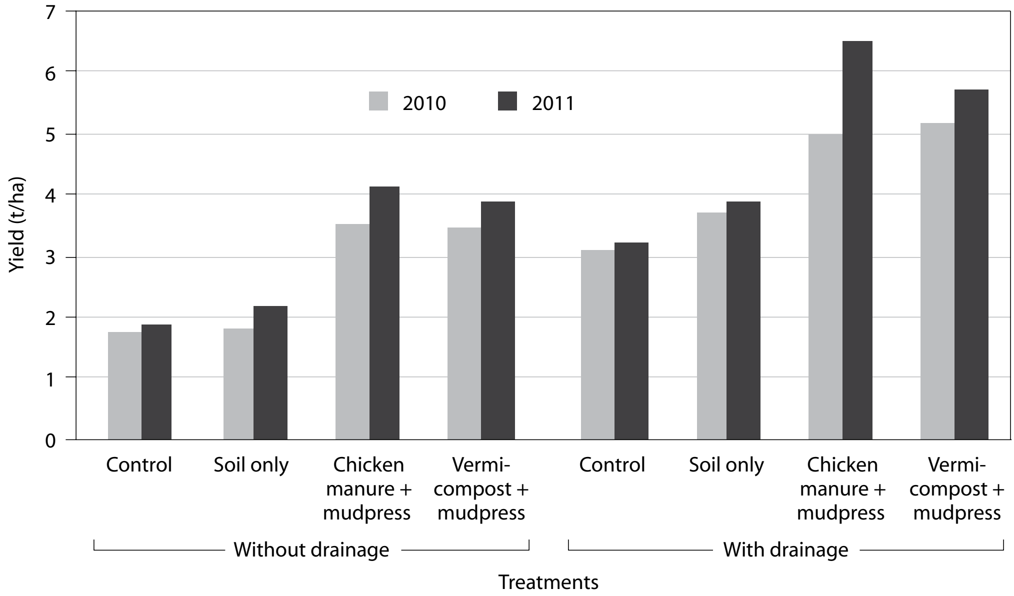

Figure 5. Jackfruit yield as affected by different mounding medium media and drainage

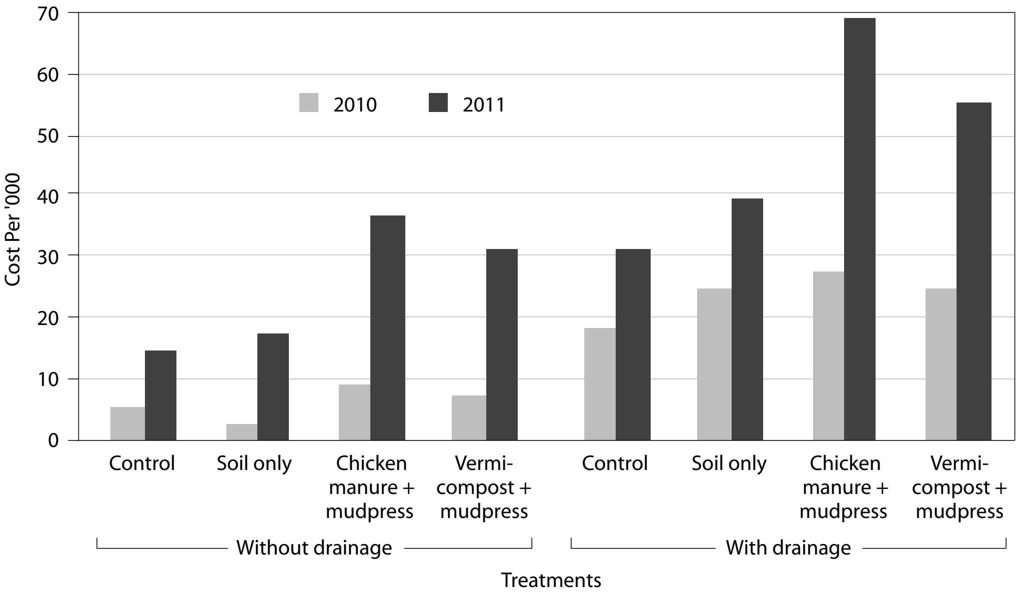

Figure 6. Gross margin as affected by different mounding media and drainage

trees mulched with kakawate but this materialised only during the third year. Kakawate-mulched trees had a net income per hectare of 163,115 pesos (approx. $US3,858), while banana-mulched trees had a net income per hectare of 120,753 pesos (approx. $US2,856) (Figure 10).

PAR trial 3—Integrated approaches for the management of Phytophthora decline of jackfruit

Improved cultural practices

This trial started at a later date than the other PAR trials. This farm was severely affected by jackfruit decline, so integrated approaches, including pruning of dead twigs and branches, mounding trees with a mixture of soil, rice straw and chicken dung, and sanitation were applied across the entire orchard in addition to the chemicals and plant defence activators. The initial cultural treatments significantly improved the condition of the trees before the application of the chemicals. The trees produced new shoots, more leaves and started to bear fruit (Figure 11).

Disease severity and incidence as affected by chemical treatments

All the chemicals applied significantly lowered the disease incidence (Figure 12) in the trees, with chitosan the most effective. The same trend was observed in terms of disease severity (Figure 13). Trees injected with phosphonate produced the highest yield in the second year (2.9 t/ha), followed by chitosan (2.5 t/ha) and aspirin (2.2 t/ha) (Figure 14). The application of phosphonate injection still gave the highest gross margin (55,265 pesos; $US1,307), followed by chitosan (42,051 pesos; $US995) and aspirin (39,926 pesos; $US945) (Figure 15). Phosphonate + Pentra-Bark® spray was unprofitable during the first year, due to the high cost of Pentra-Bark®.

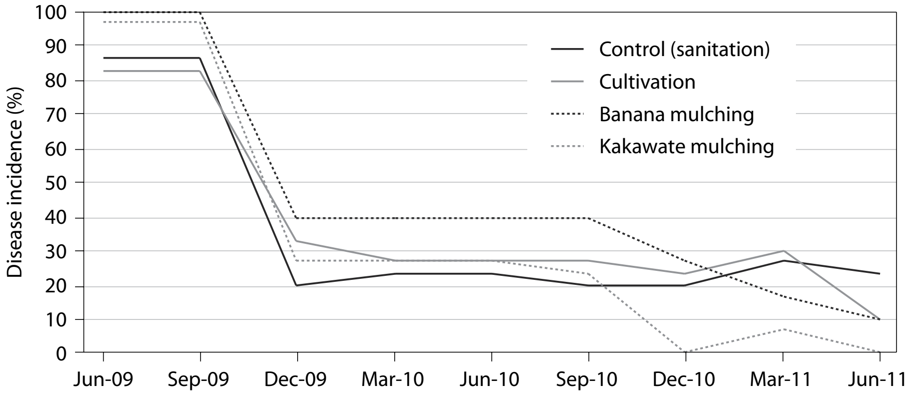

Figure 7. Incidence of *Phytophthora* disease in jackfruit trees as affected by sanitation, cultivation and mulching

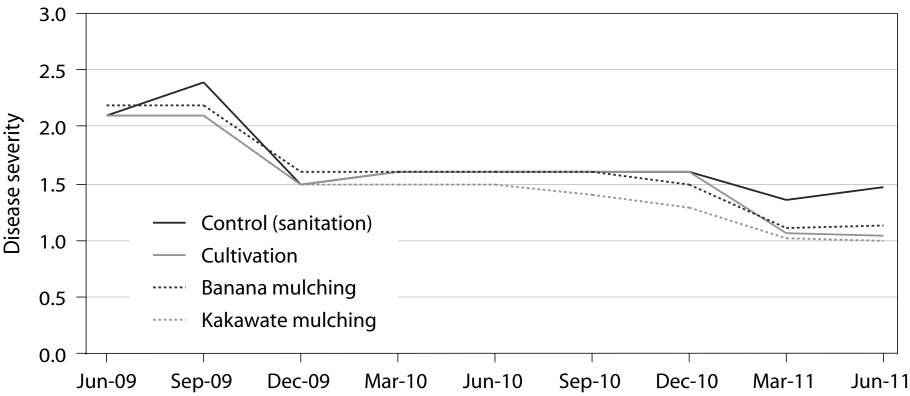

Figure 8. Severity (see text for explanation of rating) of *Phytophthora* disease in jackfruit trees as affected by sanitation, cultivation and mulching

PAR trial 4—The effect of chemical application and phosphonate injection in the management of jackfruit decline

On this farm, the trees that were randomly assigned to the untreated control were healthier than trees assigned to some of the treatments, so benchmark data on the percentage of canker lesions were taken as well as final data (initial count of the number of cankers per replicate treatment and the final count). The percentage canker reduction was calculated and compared between treatments. Based on these data, the greatest percentage of canker damage reduction was observed in trees treated with phosphonate injection (Agri-Fos®), followed by phosphonate + Pentra-Bark®, then mancozeb (Dithane®) (Figure 16). All the treated trees had less canker damage than the control plants ($\alpha = 0.05$). The canker reduction in the untreated plants could be attributed to other improved cultural management practices, such as pruning, sanitation and insect control, applied to all the trees.

The highest yield (7.78 t/ha) was derived from trees treated with benzothiadiazole ('E Boost'), followed by Agri-Fos® + Pentra-Bark® (7.58 t/ha). Similarly, the highest gross margin per ha was derived from trees treated with benzothiadiazole (171,323 pesos; $US4,053) in this trial, followed by phosphonate plus Pentra-Bark® (157,113 pesos; $US3,716) (Table 1). Control plants had a higher gross margin than the rest of the treatments since, at the beginning of the trial, they were healthier than the treated plants.

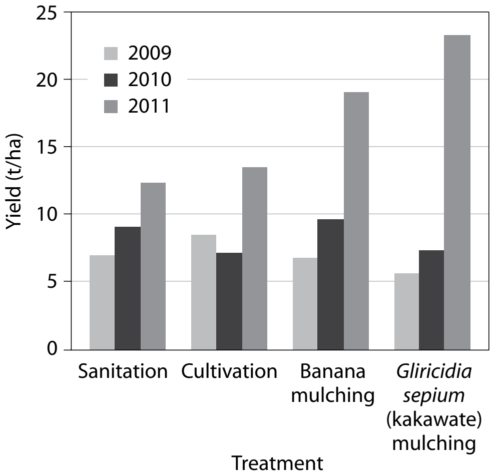

Figure 9. Jackfruit yield as affected by sanitation, cultivation and mulching

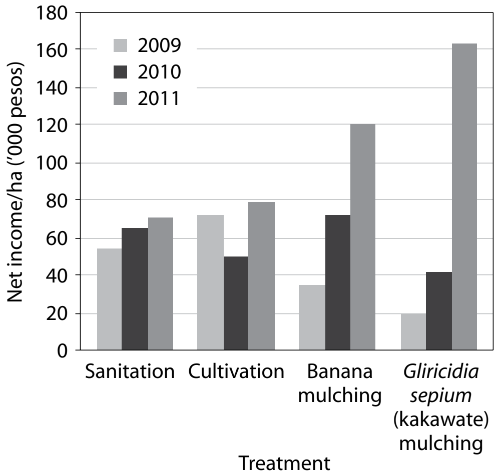

Figure 10. Net income per hectare as affected by sanitation, cultivation and mulching

Figure 11. Trial 3 farm before, in 2009 (left), and after, in 2010 (right), improving the cultural management of the trees.

Discussion

Positive outcomes of the PAR trials

The hands-on experience of the farmer stakeholders in their respective trials, plus the knowledge they gained from farm cross-visits, interaction with other stakeholders and scientists, seminars and farmer field days greatly improved their knowledge and capacity to manage jackfruit disease and the crop in general. Other jackfruit farmers also benefited from these trials because the properly managed PAR trial sites on farms served as showcase and model farms to neighbours and during field days. The involvement of a range of industry stakeholders in the PAR trials served to develop stronger relationships between the scientists, farmers, extension agencies and other industry stakeholders. Participants regularly meet and discuss the progress and outcomes of their trials among themselves and with other growers, promoting easier access to and dissemination of information.

Increased yields and, consequently, increased incomes, have been realised by the participating PAR growers following the implementation of management strategies on their farms. For example, in Samar, Mr Julio Munoz initially had 95% disease

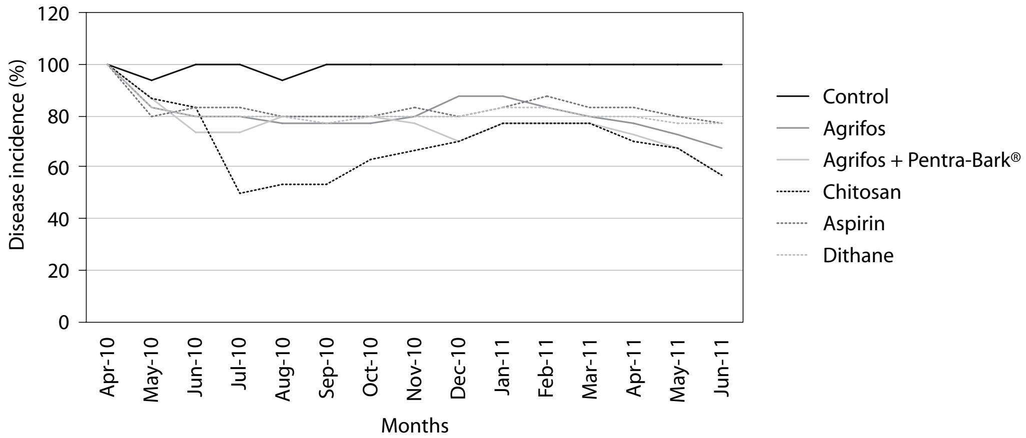

Figure 12. Incidence of *Phytophthora* disease in jackfruit trees as affected by different chemical treatments

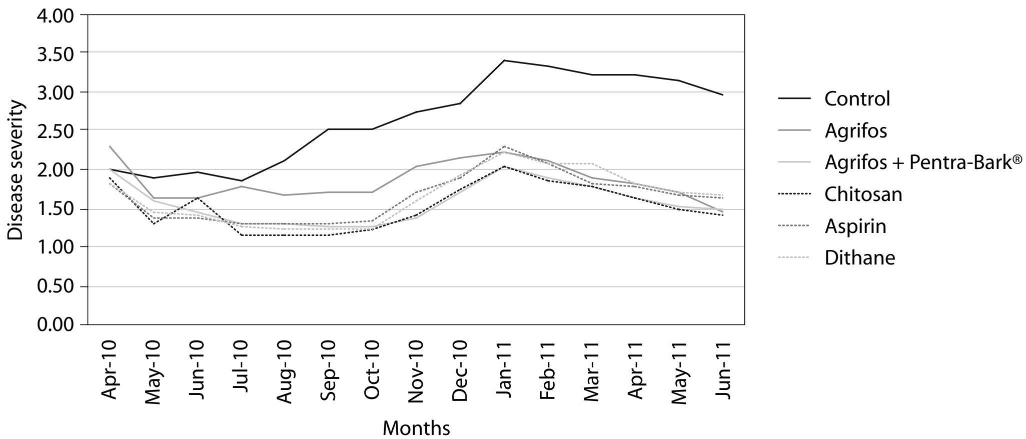

Figure 13. Severity (see text for explanation of rating) of *Phytophthora* disease in jackfruit trees as affected by different chemical treatments.

Table 1. Gross margin (pesos) as affected by chemical applications on the trial 4 farm

Particulars	Control	Agri-Fos® 400	Agri-Fos® 400 Pentra-Bark®	Benzothia-diazol'E Boost'	e Chitosan	Dithane®
Cost of production	18,048.68	23,616.26	32,417.11	23,198.16	23,922.37	22,426.58
No. of productive trees	137.00	121.05	142.11	147.37	136.84	126.32
Av. wt/ fruit (kg)	8.76	8.81	9.23	9.01	8.96	8.30
Av. no. of fruits/ tree	5.00	5.26	5.78	5.86	4.73	5.21
Yield (kg/ha)	5,993.68	5,609.65	7,581.23	7,780.85	5,799.48	5,462.27
Yield (t/ha)	5.99	5.61	7.58	7.78	5.80	5.46
Gross income @ 25 pesos/kg	149,842.11	140,241.29	189,530.76	194,521.16	144,986.95	136,556.84
Gross margin	131,793.42	116,625.03	157,113.66	171,323.00	121,064.58	114,130.26

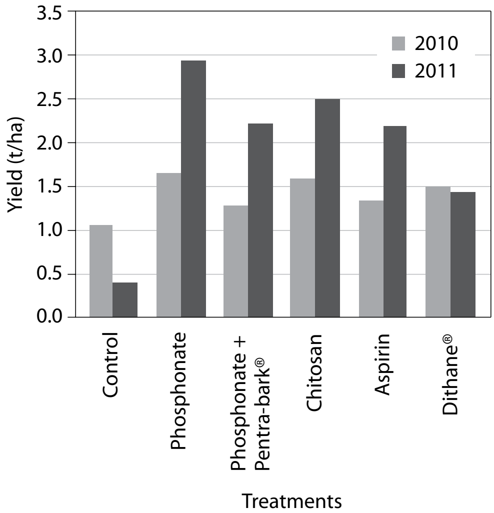

Figure 14. Yield of jackfruit (tonnes/ha) as affected by chemical applications during the two cropping seasons on the trial 3 farm

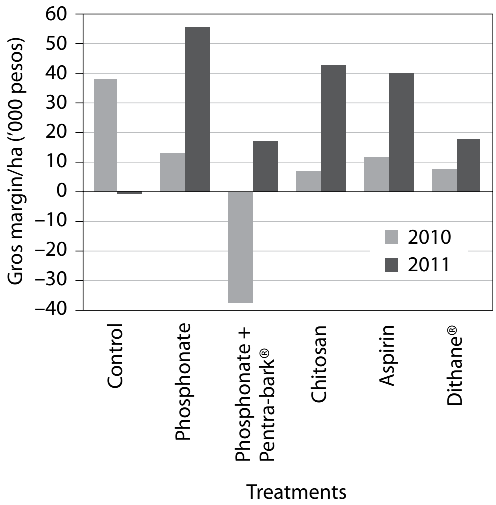

Figure 15. Gross margin as affected by different chemical applications during the two cropping seasons on the trial 3 farm

incidence on his farm. Following the construction of drainage channels, improvement of soil organic matter through the addition of soil, chicken dung and rice straw as mounding medium, and chemical treatments, the incidence of disease has declined to less than 60 % and the health status of his trees has improved, thereby increasing yield ($\alpha = 0.05$) and the gross margin.

The addition of organic soil amendments, including chicken manure, vermi-compost and mudpress, *Gliricidia* and banana mulch and improved soil drainage has improved the health of the soil and may reduce the need for inorganic fertilisers. More-targeted use of effective chemicals will reduce the impact of excess, ineffective chemicals on the environment.

Formulation of disease management options

A final workshop was held at the end of the PAR trials, at which the results of the different PAR trials were presented. Through sharing of observations and knowledge by the scientists and farmer stakeholders,

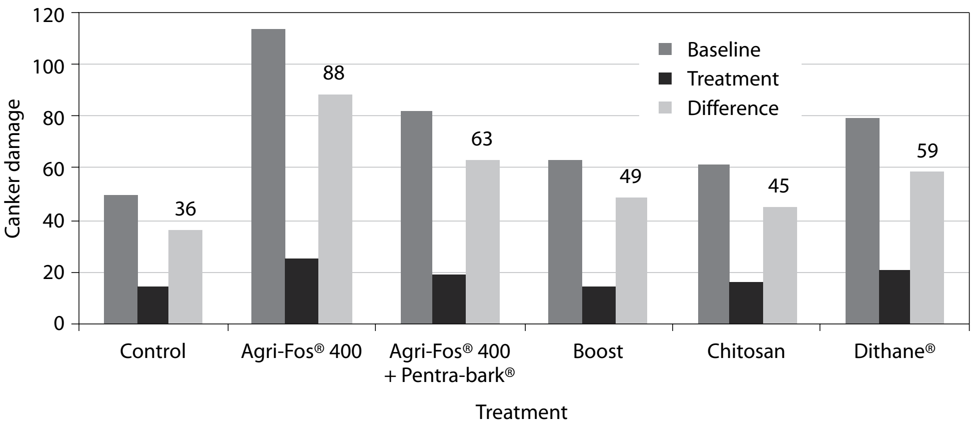

Figure 16. Canker damage reduction in jackfruit trees as affected by different chemical treatments on the trial 4 farm

Phytophthora management options were formulated by the group through development of a series of low-, medium- and high-input options from which farmers can choose. A leaflet for jackfruit *Phytophthora* management was produced and distributed to agricultural extension workers in the different local government units (LGUs) in Eastern Visayas.

Extension training

The successful results of the PAR trials and the *Phytophthora* disease management options have been disseminated to agricultural technicians, extension workers and jackfruit farmers through farmer field days (Figure 17) and through a series of six training workshops for agricultural technicians involved in fruit crops in the different municipalities and provinces of Leyte, Samar and Biliran islands (Figure 18).

Conclusion

The simple PAR trials conducted by selected jackfruit farmers enriched their knowledge and skills in managing *Phytophthora* disease. They also learned other best practices in orchard management from local scientists and from each other through farm cross-visits and interactions during farmer field days (FFDs) and extension training. Their farm income had significantly increased after a short period of actual experimentation in their farms.

The project had increased the health status of the jackfruit trees in their farm, had reduced costs of production, and had lowered losses due to the disease and increased yield and the farmers' incomes. Strategies such as the addition of organic soil amendments including chicken manure, vermicompost and organic mulches helped improved the health of the soil and may reduce the need for inorganic fertilisers. Furthermore, more-targeted use of effective chemicals will reduce the impact of excess, unneeded chemicals on the environment.

Other jackfruit farmers have also benefited from the results of these trials because they have witnessed the actual improvements on the farms of stakeholders during the FFDs and personal visits to the farms. Also through the FFDs and an extension leaflet produced from the research, they gained knowledge about the disease and how to apply the new technologies and manage them on their farms.

This project had contributed to ACIAR and PCAARRD's mandate in advancing scientific knowledge, not only to local scientists but also to jackfruit farmers themselves who were trained not only on the practicalities but also on the science of what they were doing on their farms. This project has developed technologies for verification and use of other jackfruit farmers in the region. The extension work conducted by the project in collaboration with LGUs in training of agricultural technicians in disease management is expected to improve the capabilities of these extension workers in answering farmers questions about jackfruit decline and its management. The involvement of LGUs raised the awareness some policymakers in the region about the importance of this disease and its management.

Figure 17. Farmer field days conducted by the project in Leyte and Samar

Acknowledgments

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Figure 18. Photo documentation of training conducted in Catarman, Northern Samar, Salcedo, Eastern Samar, and at Visayas State University, Visca, Baybay City (Leyte Province)

Nursery management using raised benches and sterile soil to control *Phytophthora palmivora* disease in durian seedlings

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Abstract

The effects of using raised benches compared with the conventional practice of keeping pots on the ground as well as using sterilised soil with non-sterile soil were tested for the development of disease due to *Phytophthora palmivora* in a durian nursery. After 235 days, the highest disease incidence (24%) was observed in seedlings grown in sterile soil in pots maintained on soil on the ground, followed by the conventional practice of using non-sterile soils in pots maintained on the ground (19%). The lowest disease incidence was obtained in seedlings grown in a sterile soil medium on raised benches (3%), followed by seedlings grown in non-sterile media on raised benches (6%). These results indicate that using sterile soil medium and benches in raising durian seedlings reduces the incidence of root rot and seedling dieback.

Introduction

Durian (*Durio zibethinus* L.) is called the 'king of all fruits'; it smells like hell but tastes like heaven, as everybody describes it. Durian is one of the most widely cultivated fruits in the Philippines, particularly in Southern Mindanao. An estimated 8,000 hectares are planted with durian in Region X and Region XI (BAS 2005). Durian is considered to be a high-value crop by the Philippine Government. Many local government units (LGUs) in Mindanao have a 'Plant now, pay later' program to entice farmers to plant durian in their area. It is highly profitable, with farm-gate prices ranging from 30.00 pesos/kg to as much as 60.00 pesos/kg. However, due to the presence of *Phytophthora,* which causes disease at all stages of the plant's growth, the production is not as high as it could be.

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Even at the seedling stage, *Phytophthora* infection is commonly observed as dieback and seedling death. *Phytophthora* thrives well in a moist or wet environment. It is a ubiquitous organism in the soil. Most nursery operators in the Davao region of Mindanao arrange their bagged seedlings on the ground, with no protection from direct contact with the soil. As a result, seedlings may be in direct contact with *Phytophthora*-infested soil and ponded water. The incidence of seedling dieback caused by *Phytophthora palmivora* in nurseries can be as high as 40% in the Davao region (C.E. Soguilon and C.B. Montiel 2008 unpublished data). Based on a baseline survey (C.E. Soguilon and C.B. Montiel 2008 unpublished data), only a few durian nursery operators use raised benches, cracked stone or plastic covering sheet to keep their bagged seedlings off the ground. Even the use of sterile soil is not a common practice for many nursery operators in Davao. Most of the nursery operators in the region are small backyard enterprises with no certification from the Department of Agriculture.

Phytophthora is a natural soil-borne pathogen. Drenth and Guest (2004) reported that rain splashes can carry *Phytophthora* propagules up to 0.75 m above the ground. Kuske and Benson (1983) reported a 7% mortality of *Rhododendron* seedlings raised on pine-bark beds 5–7 cm above the ground compared with gravel beds. The gravel reduces the rain splashes from the soil that carry inoculum of *Phytophthora parasitica*.

Placing seedlings on raised, slatted benches away from infested soil and water splash is one of the recommended nursery practices to minimise spread of *Phytophthora* (Drenth and Guest 2004).

Methodology

Durian seeds of uniform size were washed and air-dried for a day to be used as rootstocks. Philippine native rootstocks were used due to their well-developed seeds. To ensure vigorous growth, only well-developed and mature seed was selected.

Equal proportions of sawdust, coir dust and carbonised rice hulls were used as medium for the seedbed. Seeds were sown 1 cm apart, with the concave side pointing down to minimise crooked stem growth. The seeds were covered with about 2 cm of the abovementioned medium (Figure 1). The seeds were watered 3 times a week using potable water.

The soil was sterilised by heating it in a container made of galvanised-iron sheet (Figure 2). One cubic metre of soil was placed in the container, below which firewood was burned to produce the desired heat. The soil was mixed manually using a shovel every 20 minutes to avoid overheating. The soil was sterilised for 1–2 hours at 50–60°C.

Figure 1. Durian seedlings in seedbed made up of coir dust, sawdust and rice hulls

There were four treatments tested in this experiment (Figure 3):

1. sterilised soil on a raised bench
2. unsterilised soil on a raised bench
3. sterilised soil on ground-level soil
4. unsterilised soil on ground-level soil, the common practice in durian nurseries.

There were 10 plants per treatment with five replicates per treatment.

Transplanting of the seedlings from the seedbed took place after a month, or as 2–3 leaves appeared on the seedlings.

From the time of transplanting until graftable stage, disease incidence was monitored daily. Percentage disease incidence was computed as the number of mortality over the total number of plants per treatment. Diseased plants were collected and examined in the laboratory for possible *Phytophthora* infections. Soil medium and roots from infected seedlings were collected and placed in a plastic cup with water. After thorough mixing of the contents, a rose petal was placed above the cup as bait. After 2–3 days, discolouration of the petal indicates possible *Phytophthora* infection. A 2 cm piece of the petals was plated on potato dextrose agar (PDA) and incubated for 3 days at 28°C. Colony growth was observed for possible presence of *Phytophthora.*

Leaf disease severity was also assessed using arbitrary rating scale: 1, 0–20% blight; 2, 20–40% blight; 3, 40–60% blight; 4, 60–80% blight; 5, 80–100% blight. Ten plants per treatment were tagged as the test plants for the severity rating. Ratings were gathered for 90 days.

Results and discussion

Replanting stress caused mortality in all treatments with no isolation of *Phytophthora*, confirming that the pathogen was not involved. Twelve plants were dead due to stress from replanting.

Fifteen days after pricking, mortality due to *Phytophthora* was observed in treatments 3 and 4 with 0.5% disease incidence and 1.0% disease incidence, respectively. At that time, no disease symptoms were observed in seedlings growing in sterilised soil on the raised bench. Symptoms appeared as yellowing of the leaves and leaf fall, stunted growth and, eventually, death of the seedling. The feeder roots were few and were black (Figure 4). Sixty days after planting, treatment 1 still had no recorded disease incidence, while treatment 2 had 0.5%. Treatments 3 and 4 had

6% and 5% disease incidence due to *Phytophthora,* (Figure 5). Confirmation of *Phytophthora* was detected by baiting with rose petals and after plating on PDA for 3 days. Colonies formed were whitish and like fluffy cotton in appearance. Sporangia were observed in the infected seedlings (Figure 6).

After 235 days, disease incidence was highest in treatment 3 (24%), followed by treatment 4 (19%). This result indicates that, even with sterile soil medium, when it was placed on the ground the infection rate was still high. Treatments 1 and 2 have the lowest disease incidence with 3% and 6%, respectively. The probable explanation would be that rain splashes from the ground carry inoculum to the seedlings.

Seedlings in bags on the ground have less aeration around the plants and there is waterlogging and ponding on the ground, conditions which are favourable

Figure 2. Soil steriliser made of galvanised metal sheet. Firewood is burned below it to produce the heat required

Figure 3. Durian seedlings on raised benches (left and right) and maintained on ground soil (middle)

for the production of inoculum of *Phytophthora palmivora*. Using steel raised benches, irrigation water easily flows from the bags and there is a free flow of air between plants, reducing humidity. The use of steel mesh has the advantages of sturdiness and ease of cleaning. Wood structure can also be used but should be painted with copper naphthenate to suppress growth of fungi (Baker et al. 1957).

The use of heat for soil sterilisation was also successfully tested in the trial. Treatment 1 (sterile soil on a raised bench) had the lowest disease incidence of 3% (Figure 5).

Figure 4. Effects of *Phytophthora* infection: blighted leaves, less-fibrous roots and defoliated seedlings

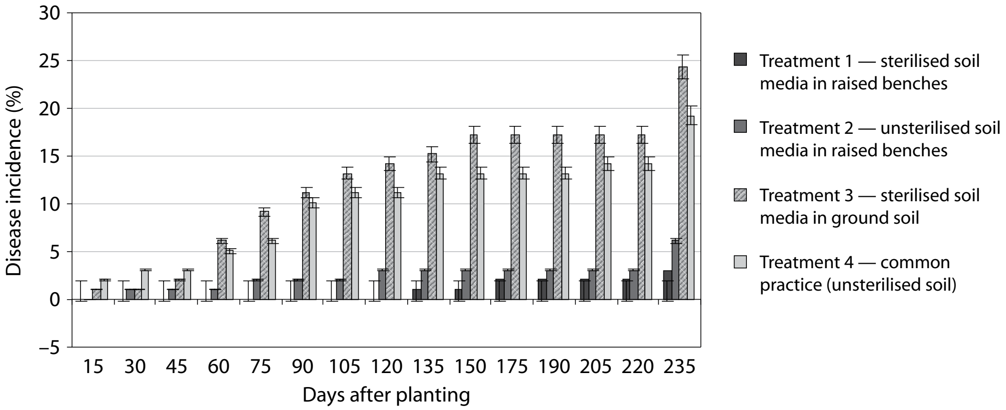

Figure 5. *Phytophthora palmivora* disease incidence in durian seedlings raised in sterile or unsterile soil media and held on raised benches or on the ground (error bars give standard deviations)

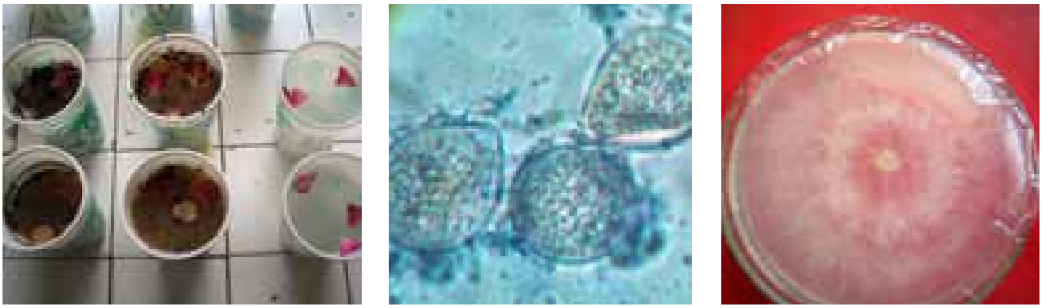

Figure 6. Baiting of infected soil with rose petals; sporangia; and colony appearance of the *Phytophthora* isolated

In Treatment 3, the use of sterile soil media did not significantly reduce the disease incidence caused by *Phytophthora*, because the seedlings were raised on the ground (Figure 5). The ground soil serves as an inoculum source and there is a high likelihood of water ponding, which favours disease infection. Newhook (1988) reported that the duration of free water in the soil favours an increase in the population of *Phytophthora*.

It should be noted that, aside from eliminating pathogenic fungi, heat also has an effect on the population of antagonistic bacteria and thermo-tolerant fungi which suppress *Phytophthora* in the soil (Stapleton and Devay 1986). Indeed, not all seedling media can be heat-sterilised. When eucalyptus bark is steam sterilised it becomes conducive to *Phytophthora* disease since most of the antagonistic micro-organisms in it are lost (Hardy and Sivasithamparam 1991).

Foliar blight was also assessed in all treatments (Table 1). The highest level of foliar blight (4.1%) was observed in treatment 4, followed by the seedlings planted in sterile soil maintained on the ground (3.2%). The least infection was observed in treatment 1 with 1.2% foliar blight. The results indicate that, due to the effect of moisture and relative humidity in the seedlings bed, leaf blight caused by *Phytophthora palmivora* is most severe in seedlings maintained on the ground. Grove et al. (1985) showed that high foliage wetness of strawberry plants led to high infection by *P. cactorum*.

Table 1. Severity of foliar blight disease caused by *Phytophthora palmivora* in durian seedlings

Treatment	Disease severity
T1—sterilised soil, raised benches	1.2a*
T2—unsterilised soil, raised benches	1.6a
T3—sterilised soil, on ground	3.2b
T4—unsterilised soil, on ground (control)	4.1c

* Values within columns followed by the same letters are not significantly different.

Raised benches serve as barrier against direct rain-splash from the soil, which carries inoculum to the leaves. Foliar blight is most common in nurseries due to high humidity, monoculture and low aeration (Lim 1990). The presence of scarring caused by beetles can also be observed in seedlings maintained on the ground (Figure 7).

The cost-effectiveness of using raised benches, as compared with the conventional nursery practice, was computed (Table 2). The highest return on investment (33%) was recorded for treatment 2, followed by treatment 1 (32%). The conventional nursery practice had the lowest return on investment (20%). Mortality caused by *Phytophthora palmivora* is considered as loss in terms of investment and capital. The relatively high cost of using steel to make raised benches did not affect the return on investment of the treatments with raised benches. As shown in Table 2, initial expenses of using raised benches are half the price compares to the common practice.

Recommendations

The spread of *Phytophthora* disease from nursery to the field comes from infected seedlings (Hansen 1979). The use of raised benches and sterile soil media are good strategies for producing high-quality, healthy seedlings for field planting. Raised benches serve as a barrier against water splashes that carry the inoculum. Using raised benches also reduce infestations of insects that can carry the fungus from the soil to the plant. The use of steel benches is relatively expensive but is a worthwhile investment in the long term. Alternative approaches are the use of raised bamboo benches or, for seedlings raised on

Table 2. Cost and return analysis of using raised benches and sterile soil media in producing durian seedlings

Treatment	Total cost of producing 200 seedlings (pesos)	Selling price per seedling (pesos)	Seedling mortality (%)	Gross income (pesos)	Net income (pesos)	Return on investment (%)
T1—sterilised soil, raised benches	2,800	60	3	11,640	8,840	32
T2—unsterilised soil, raised benches	2,800	60	6	11,280	8,480	33
T3—sterilised soil, on ground	1,600	60	24	9,120	7,520	21
T4—unsterilised soil, on ground (control)	1,600	60	19	9,720	8,120	20

Figure 7. Scarring caused by beetles found in seedlings grown on the ground

the ground, doing so on a bed of cracked stone to reduce rain splash.

The proliferation of non-accredited nursery operators in the Davao region is a result of incomplete monitoring by the authorities. Also, seedling buyers prefer to buy in non-accredited nurseries because of their lower prices. They generally have no inkling of the disease infection that may explode in the field. Pegg (1979) stressed that good sanitation and clean planting material are of primary importance to avoid disease development. Guidelines in nursery accreditation should be strictly followed, with the aim providing clean, high-quality planting materials to farmers.

Preventive measures such as using sterile soil and raised benches are part of the control measures in nursery management. Coffey (1987) enumerated a management approach in the nursery: steam sterilisation or chemical fumigation of the nursery mix; use of well-aerated, free-draining growing mixes; location of nurseries on well-drained sites where the risk of flooding is minimal; provision of foot baths to prevent transmission of disease organisms; and clean nursery equipment.

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Application of phosphonate to control *Phytophthora* patch canker of durian in the Philippines

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Abstract

The use of phosphonate to control *Phytophthora palmivora* patch canker in durian was tested by trunk injection and bark spraying. An annual 16 g a.i. per tree injection decreased patch canker. Application of either 10% or 20% phosphonate as bark spray with the surfactant Pentra-Bark® also reduced the mean canker rating 17 months after application. The use of phosphonate either as a trunk injection or a bark spray limited further canker damage. Phosphonate application can be integrated into the disease management strategy against *Phytophthora* in durian. Yield returns also significantly increased in all phosphonate treatments applied. At 210 pesos/tree/year ($US4.00) the cost of bark spraying is higher than trunk injection at 170 pesos/tree/year ($US3.00). The farmers can make further savings using phosphonate, in terms of not having to replace trees killed by canker.

Introduction

In durian production, *Phytophthora* disease is considered the most economically important disease in all durian-producing countries. Disease losses in the Philippines and other countries such as Thailand, Malaysia, Indonesia and Vietnam are estimated at 20–25% (Drenth and Sendall 2004). The disease is caused by the fungus *Phytophthora palmivora*. This pathogen is capable of infecting all parts of the durian tree in all stages of its development, causing multiple diseases such as root rot, collar rot, patch or stem canker, leaf blight, dieback of seedlings and mature trees, and pre- and postharvest fruit rots (Lim 1998).

In the Philippines, Magnaye (1993) reported patch canker as the most serious disease of durian. Surveys showed that patch canker or stem canker of durian is the most prevalent (100%) among the *Phytophthora* diseases of durian in Region X1. The incidence of patch canker ranged between 21 and 37% with disease severity in the range 8–19% (Dionio and Comas 2007).

Theret are practically no references to the use phosphonate for the control of *Phytophthora* in the Philippines. The aim of the study reported here was to evaluate the efficacy against *Phytophthora* in durian of phosphonate as a trunk injection or bark spray and to determine its cost-effectiveness.

Review of literature

Patch canker can cause serious tree decline due to the damage to the cambium. It reduces tree vigour and yield due to severe restriction of water and nutrient flow to the connecting branches, leading to wilting (Drenth and Guest 2004). Girdling of the trunk results in more widespread dieback in the crown, followed by loss of leaves.

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The use of chemicals to control plant diseases has evolved over the years from the discovery of Bordeaux mixture (Millardet 1885) to the use of protectant (Erwin and Ribeiro 2005) and the systemic fungicides. One systemic fungicide is phosphonate for use against oomycetes such as *Phytophthora*. Fungicide application against *Phytophthora* in durian did not change a lot since the 1980s in the Philippine industry. Copper fungicides are the first-line chemicals to be used against *Phytophthora* in many crops, followed by fosetyl–aluminum (fosetyl-Al; trade name Aliette). Fosetyl-Al is a phosphonate fungicide.

Fosetyl-Al use requires scraping of the infected bark, which often results in damage to the trunk or bark and, while the treatment proves effective, it is time-consuming and laborious.

Phosphonate has been used in other countries as a trunk injection and foliar spray against *Phytophthora* disease in crops such as avocado (Darvas 1984), pineapple (Rohrbach and Schenck 1985), citrus (Laville 1979) and walnut (Matheron and Mircetich 1985). Phosphonate is a simple, inexpensive, inorganic compound that operates in conjunction with physiological factors in the plant and has been found to be highly effective.

The phosphonate fungicides include fosetyl-Al and its breakdown product phosphorous acid (Erwin and Ribeiro 1996). Fosetyl-Al (as Aliette) is widely used in the Philippines to treat canker damage of *Phytophthora* in durian but is applied by painting on the cankered part of the trunk where it is prone to rain wash-off and wastage. Aside from this, the scraping of the cankered parts of the tree prior to chemical application is detrimental to the tree and serves as an entry point for further infection. Cook (1975) stated that the removal of the cankered tissue and painting the wound with chemical gave inconsistent results, probably as there is limited penetration of the chemical into the woody tissues and the fungicides are easily washed away. Also, an aluminum salt of phosphonate in Aliette is highly acidic and causes burning of the crop (Cohen and Coffey 1996).

The mode of action of phosphonate is the disruption of phosphate metabolism in the pathogen, which causes the release of pathogen stress metabolites that activate host defence responses (Guest and Grant 1991). The key step in plant defence responses is the activation of the enzyme phenylalanine ammonia-lyase (PAL) involved in biosynthesis of phenylpropanoids including phytoalexins, salicylic acid and lignin. Guest et al. (1995) observed that in response to phosphonate treatment the mode of action is complex, because results obtained differ from one host to another due to great variations in sensitivity of the crops. Phosphonate efficacy differs among hosts due to differences in the type and extent of defence responses. Leaf blight of potato caused by *Phytophthora infestans* is poorly controlled by phosphonate (Erwin and Ribeiro 1996).

Phosphonate can be applied to the foliage or as a soil drench but these methods prove to be ineffective, for several reasons: poor uptake by the plants, degradation of the chemical by soil microbes and losses due to leaching and wash-off (Drenth and Guest 2004).

Materials and methods

The experimental area was located in Dacudao, Calinan, Davao City, the Philippines. It is strategically located in the durian-growing areas of the Davao region. It has an area of 6.5 hectares (ha) planted with the local variety 'Arancillo', which is 10 years old. Baseline data such as disease incidence, cultural practices and previous crop planted were gathered. The experimental design used was a randomised complete block design with four treatments, with each treatment replicated three times. The treatments were:

1. Trunk injection (40 mL or 16 g active ingredient (a.i.) of phosphonate)
2. Bark sprayed with 10% phosphonate
3. Bark sprayed with 20% phosphonate
4. (control) Treated with water

Preparation of treatments

For treatment 1, Agri-Fos® 400 (Agrichem, Australia). Phosphonate was diluted with 45% water. Four injectors were used, each containing 10 mL of phosphonate. Holes were drilled in the trunk 2 metres (m) from the base or above the diseased part of the tree. Spring injectors (ChemJet, Australia) were placed in the holes and the chemical was released. Trunk injection was done every year, with the injection made early in the morning.

For treatment 2, phosphonate was diluted to 10% and 1.5% surfactant (Pentra-Bark®) added. Phosphonate was thoroughly mixed with Pentra-Bark® to give a uniform solution. The solution was sprayed 2 m above the base of the trunk. One litre of solution per tree was sprayed.

For treatment 3, the same procedure as treatment 2 was used but with the phosphonate concentration at 20%. Both treatments 2 and 3 were applied every 4 months.

For the control, water was sprayed on the trees every 4 months.

Table 1 gives the treatment schedule.

Data gathered

Baseline data on patch canker infection in every experimental tree were gathered before application. These served as benchmark data for determining the effect of the applied treatments in controlling patch canker in the observed trees. Canker severity rating was recorded using the following scale: 1. no lesions; 2. 1–5 lesions; 3. 6–10 lesions; 4. 11–15 lesions; and 5. ≥ 16 lesions. Tree health status was also monitored using an arbitrary scale of 1 to 5, as follows: 1. sickly or dying; 2. 25% healthy; 3. 50% healthy; 4. 75% healthy; and 5. 100% healthy. The time of treatment, ease of application and yield data per treatment were also recorded.

Results

The experimental area was previously planted with bananas, which are grown on poorly drained land that retains rainwater. Baseline data in the area recorded 10–15% canker damage due to poor drainage. The poor site selection of the area led to high *Phytophthora palmivora* disease pressure on durian (Figure 1). Good site selection is critical in durian establishment. Durian orchards should have an effective drainage canal to minimise infection by soil-borne diseases such as *Phytophthora.*

Symptoms of patch canker of durian caused by *Phytophthora palmivora* were observed in the trial area (Figure 2), as a dark-brownish colour on the trunks of trees. Some trees have severe canker girdling the trunk.

Before the application of the treatments, canker ratings were more or less the same (rating of 2–3) in October 2009 in the experimental trees subjected to the 4 treatments (Figure 3). After only 3 months of application (December 2009), the mean canker infection using trunk injection or bark spraying at 10 and 20% phosphonate had fallen compared with the control. Canker damage fluctuates monthly in phosphonate-treated trees, by less than 5% to more than 15%, depending on variations in rainfall and climatic conditions.

As shown in Figure 3, there was an increase in the lesions rating for January 2010 in phosphonate-treated trees and the control. This coincided with the high rainfall during that month, which was 176.70 mm (Figure 4). The lowest rainfall was observed in June 2010 at 93.80 mm and the highest

Table 1. Phosphonate injection and spraying schedule

Treatments	1st application	2nd application	3rd application	4th application	5th application
Trunk injection	October 2009	October 2010			
Bark spraying	October 2009	February 2010	June 2010	October 2010	February 2011
Control	October 2009	February 2010	June 2010	October 2010	February 2011

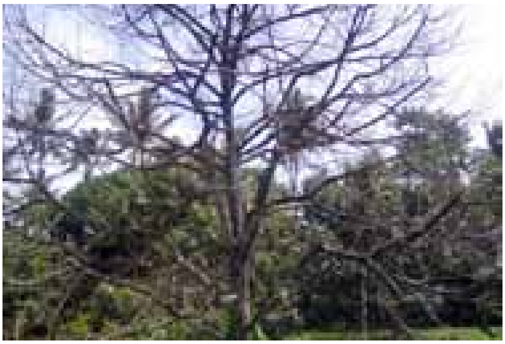

Figure 1. The durian area in Calinan, Davao City (left), and an example of a tree with high disease infection in the area (right)

Figure 2. Dark-brown coloured symptoms of patch canker of durian caused by *Phytophthora palmivora*

in November and December 2010, with 209.20 and 201.80 mm, respectively. During these rainy months there was an increase of lesions observed in all treatments except trunk injection with phosphonate. At this stage, the injected trees have already received two doses of phosphonate, giving them more protection from infection. The months of September to February are the beginning of rainy season in Davao City, which is also a favourable time of water-loving fungi such as *Phytophthora* to cause infection. The timing of application should be based on the environmental conditions prevailing in the area.

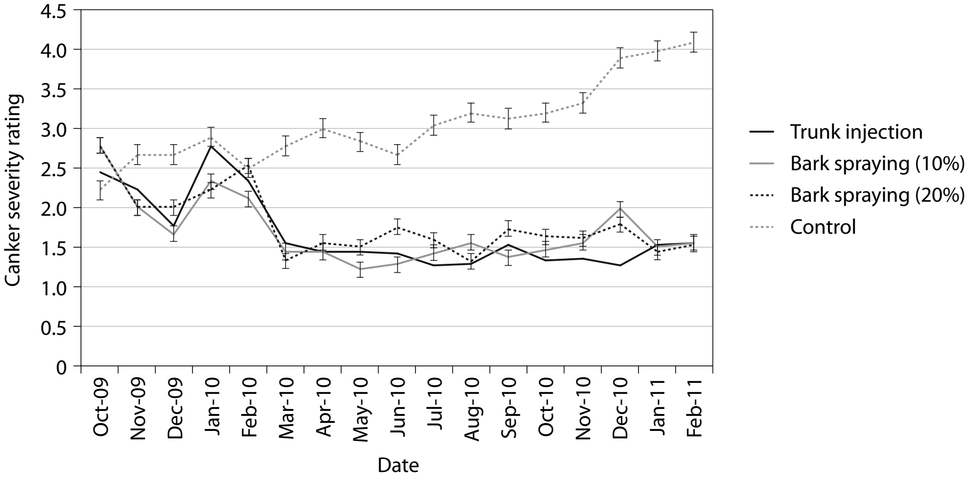

Figure 3. Mean canker ratings (see text for explanation of rating scale) for phosphonate-injected and bark sprayed trees, October 2009 – February 2011 ($n = 36$) (vertical bars give standard errors)

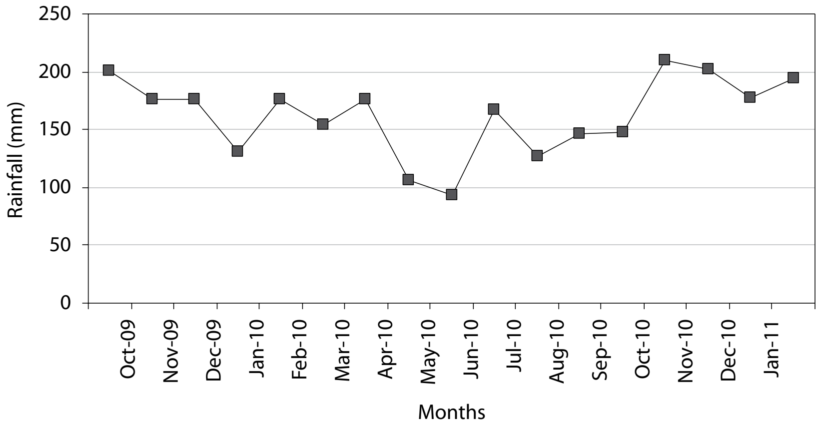

Figure 4. Total monthly rainfall (mm) recorded at Dacudao, Calinan, Davao City, for the period October 2009–February 2011 (data courtesy of Sumitomo Fruits Corp, Dacudao)

As shown in Table 2, there was a decreased in canker rating in all treatments compared with the control. After 1 year of application, mean canker damage in the treated trees was only to 1.6, or 1–3 canker lesions per tree, whereas in the control (applied with water) the mean was 4, or 11–15 lesions per tree.

The average yield of fruit per tree was highest in trunk-injected trees (Table 2). The yields of the trees sprayed at two different concentrations of phosphonate did not differ. The lowest yield, 19.78 kg, was obtained in the water-treated control.

The overall health status of the experimental trees at the beginning of the trial was rated at 3 (50% healthy) on the scale used in this study. As shown in Figure 5, there was a decreasing trend in the overall health status in the water-treated control. The experimental trees applied with phosphonate by trunk injection or bark spraying exhibited good health recovery (from 3 to 4+ rating). Further, it can be observed that trees applied with phosphonate by trunk injection and bark spraying started to show recovery on April 2010, 6 months after application.

The injected trees showed new foliar development and robust growth after 1 year (Figure 6). Some of the recovered trees were bearing many fruit with less incidence of fruit rot compared with the control. Timing of chemical application is crucial depending on the severity of infection in the field.

Table 3 shows that it takes only 5–7 minutes to spray a tree, compared up to 25 minutes for trunk injection, depending on the tree size and age, and the time of injection. The use of phosphonate by trunk injection has the lower cost at 170 pesos/tree compared with 210 pesos/tree for bark spraying. These costs include labour, and the chemical and other materials used. The farmer collaborator rated the process of trunk injection treatment as difficult due to the process of drilling and insertion of the injectors.

Table 2. Average mean canker rating and fruit yield from 10-year-old durian trees in Calinan, Davao City, 1 year after treatment

Treatments	Mean canker rating	Average yield (kg/year)
Trunk injection (40 mL or 16 g a.i. of phosphonate)	1.60a	23.00c*
Bark sprayed with 10% phosphonate	1.62a	21.30b
Bark sprayed with 20% phosphonate	1.67a	20.04 b
Treated with water	3.97b	19.78a
cv	13.80%	6.72%

Values within columns followed by the same letters are not significantly different at $P = 0.05$.

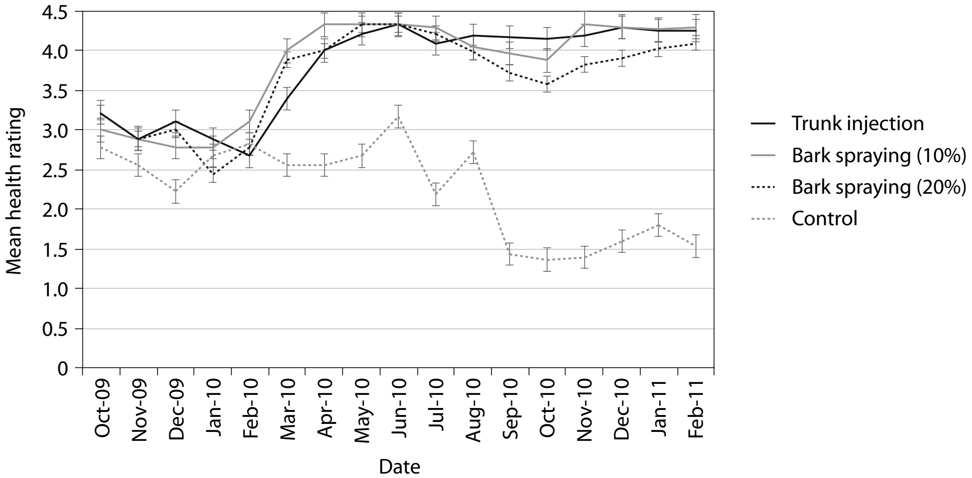

Figure 5. Health status (see text for explanation of rating scale) of *Phytophthora*-infected durian trees treated with phosphonate or water (control) (n = 36) (vertical bars give standard errors of the means)

Figure 6. *Phytophthora*-infected durian tree (left) before treatment and (right) the same tree 1 year after phosphonate-injection treatment

Discussion

In this trial, the use of pressurised injectors proved to be an effective way of applying systemic fungicides such as phosphonate. The use of pressurised injectors greatly influences the efficacy of phosphonate as a systemic fungicide, as it forces the chemical into the tree's cambium and is thereby translocated to other parts of the tree (Darvas 1984). Also, using injectors minimises chemical contamination in the soil and the environment, although phosphonate is essentially a non-toxic and environmentally friendly material.

Due to the drilling of holes in trunk injection there are some concerns regarding the detrimental effect of the hole to the tree. Agrichem, an Australian chemical company, has developed Pentra-Bark®, a bark-penetrating agent that can be used as an alternative to drilling and injection.

Drenth and Guest (2004) found in Vietnam that a dosage of 40 mL or 16 g a.i. annually of phosphonate

Table 3. Comparative costs and other features of the use of phosphonate trunk injection or bark spraying (Calinan, Davao City 2009)

Features	Trunk injection	Bark spraying (1 L of solution/tree
Duration of treatment application	20–25 minutes	5–7 minutes
Ease of treatment	Difficult	Moderate
Cost of treatment: chemical, materials and labour	170.00 pesos/tree/year	70.00 pesos/tree or 210.00 pesos/tree/year[a]

[a] 10% phosphonate was used for the calculation.

suppressed further *Phytophthora* disease infection. In our trial, the same dose effectively lowered patch canker damage to durian. Similar canker reduction was obtained using bark spraying at 10 or 20% phosphonate supplemented with 1.5% Pentra-Bark®. Lim (1992) reported that, at a dosage of 25 g a.i./year, phosphonate was phytotoxic in durian.

Phosphonate as a systemic fungicide moves easily upward and downward to other parts of the tree, which hastens the recovery of the durian trees. The development of new leaves and branches in phosphonate-treated trees clearly shows that it not only controls trunk canker per se but also improves the health status of the crop, as observed in this trial.

The recommended time for injection is early in the day due to higher metabolic activity of the plant at that time. This is generally true in all plants but, as observed by Whiley et al. (1995), since shoot and root growth is continuous through the year in durian, translocation to developing meristem is possible regardless of time of injection. Application of chemicals should also take account of prevailing weather conditions. Timing is crucial to obtaining a good result. Drenth and Guest (2004) suggested that to have a better control in the application of chemicals, they should be applied before the onset of the rainy season to protect the crop during the wet.

Conclusion

The use of phosphonate as a trunk injection and bark spray is technically feasible and economically viable with added costs of 170.00 pesos/tree/year and 210 pesos/tree/year, respectively. For these relatively low costs, long-term benefits can be observed, especially in yield returns.

Yield return was also high in all phosphonate-treated trees compared with a water-treated control. These results will not only raise the incomes of durian farmers but also improve the durian industry in Davao region. Durian being considered as a high-value crop in the region, the trial results can be considered as one of the strategies for controlling *Phytophthora* in durian.

Durian growers in the southern Philippines now have the option of including phosphonate in their control strategy against *Phytophthora* in durian, though, unfortunately, phosphonate is not yet available locally. The use of phosphonate lowers disease damage and thereby increases yield but it has to be used in conjunction with good site selection, improved orchard hygiene, canopy management and good drainage (Drenth and Guest 2004).

The effectiveness of using phosphonate in durian may translate to other crops in the Philippines, such as cacao, coconut, potato and citrus, which are also affected by *Phytophthora* diseases.

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Sustainable nutrient management strategies for papaya production in the southern Philippines: nitrogen fertilisation program

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Abstract

Yellow, processing-type papaya hybrids were tested in Bgy. Sto. Niño, Manolo Fortich, Bukidnon, under a 15, 150, 300, 450 and 600 kg N/ha nitrogen fertilisation scheme applied periodically from 1 to 22 months after planting. The total yield of yellow papaya hybrids was highest when nitrogen was applied at a rate of 450 kg N/ha since fruit production per tree was highest at this rate. Fruit production as well as total yield declined when nitrogen was applied at 600 kg/ha. Average fruit weight, Brix, fruit flesh thickness and percentage cavities were all unaffected by varying nitrogen rates. At 0.09% (900 mg/L), petiole NO_3–N determined using a Merck Reflectoquant® *RQflex 10*, was considered detrimental to papaya, while 0.02–0.04% was considered limiting.

Introduction

The increasing cost of farm inputs, specifically fertilisers and pesticides, has led some papaya growers to neglect regular fertiliser and proper pesticide applications. These lapses in farm management practices have caused a decline in their yield and profitability and, at the same time, resulted in poor fruit quality. Hence, proper nutrient management and control of pest and diseases are needed to support and help the papaya industry to achieve desired yields and fruit quality of papaya.

This trial, conducted in collaboration with the Australian Centre for Agricultural Research (ACIAR) and the University of Southeastern Philippines, aimed to establish the best rate of nitrogen fertilisers to maximise the yield of papaya (yellow, canning type) and establish leaf nitrogen level as an indicator of the crop's nitrogen status. At the same time, the results of this trial can hasten the capability of farmers to become effective papaya growers able to detect and correct nitrogen deficiencies in a timely manner.

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Materials and methods

Technical description of the experimental site

The experiment was conducted on a papaya grower's farm in Barangay Sto. Niño, Manolo Fortich, Bukidnon (124°50'E; 8°23N) during the period May 2010–May 2012. The experiment area had an average annual rainfall of 2,032 mm, evenly distributed throughout the year. The soil of the grower's farm, taken from 24 cm depth before planting, had a clayey texture and initial pH of 5.70 following a 20-tonne application of lime 3 months earlier. Mineral levels were: phosphorus 15 ppm; potassium 155 ppm; calcium 823 ppm; and magnesium 151 ppm.

Experimental procedure

Field planting and establishment

In May 2010, 300 seedlings of hybrid, yellow-fleshed, canning-type papaya were planted at a spacing of 3 m between beds and 2 m between hills, giving a planting area of 0.22 hectares (ha). Five papaya seedlings constituted one treatment. The nitrogen rates used in this trial were 15, 150, 300, 344, 450 and 600 kg N/ha, applied over a period of 21 months. The 344 kg N/ha represented existing farmer practice. Fertiliser application started 4 months after planting using ammonium sulfate (21% N) as the nitrogen source and potassium chloride with analysis of 50% K (61% K_20) as the potassium source. During the scheduled fertiliser application (Table 1), the required amounts of ammonium sulfate and potassium chloride were applied separately in a band around each papaya seedling. Calibrated plastic containers were used and the fertilisers were applied 15 cm from the base of the papaya tree base to prevent fertiliser burn.

Flowering started 3 months after planting. It was at this time that thinning was started, leaving 1 hermaphrodite seedling per hill. In the absence of hermaphroditic trees, female trees were retained to maintain the plant population. To monitor growth, the height of individual papaya trees within each treatment and corresponding trunk girth were measured every quarter, starting at 3 months after planting (MAP). Plant height was measured from the ground to the shoot apex using a metre stick while trunk girth was measured 15 cm from the base using calipers. Other cultural management practices of the trial area, such as manual weed control, chemical pest control, soil conservation and drainage maintenance, were undertaken by the farmer–grower according to his usual practice.

Fruit harvesting, preparation and evaluation

Papaya fruit were harvested once per week starting at 6 MAP. At 8 MAP, when fruiting was at its peak, harvest frequency was increased to twice weekly at 3-day intervals. During each harvest period, 50% colour break (Figure 1) papaya fruit were picked from individual trees within the treatment and weighed. At 12 MAP, harvesting reverted to once per week, because of reduced fruit load. During each harvest, one fruit was collected from each of the 5 trees within each treatment plot, and taken to the analytical laboratory for measurements of cavity, flesh thickness, flesh colour and quality assessment such as fruit Brix and nitrate-N content. During processing, each fruit sample was immersed in a plastic container filled to the brim with water. The displaced water collected in a catchment was measured using a graduated cylinder. The fruit were then sliced in half and deseeded. Subsequently, the cavity of papaya was filled with water, the volume of which was measured, again using a graduated cylinder. Percentage cavity was computed based on volume of water contained in the fruit cavity against volume of water displaced by the entire fruit. Flesh thickness was measured using a ruler. Flesh colour was rated using the yellow colour chart of the International Society for Horticultural Science (ISHS; Figure 1). For fruit Brix, a 3-cm-thick section of the fruit flesh was sliced lengthwise, peeled, cubed and pureed using a blender. Sap was extracted successively using cheese cloth, and read using a refractometer.

Leaf sample preparation and analysis

For total nitrogen and petiole NO_3–N analysis, the youngest, recently matured leaf subtending a freshly opened flower was collected between 0600 and 0700h from one representative tree per treatment at 4, 9, 14, 17 and 20 MAP. The leaves were then taken to the laboratory, washed with tap water and air-dried. When leaf samples were dry, a 15-cm portion at the middle part of the petiole was cut and sliced thinly. Ten grams of sliced petiole were macerated using a

Table 1. Nitrogen rate scheduled according to plant age (months after planting; MAP), and total rate applied over the duration of the trial

Nitrogen (kg/ha)	Total amount of nitrogen applied by crop age (kg/ha)					
	4 MAP	8 MAP	12 MAP	15 MAP	19 MAP	21 MAP
15	1.2	3.8	7.5	10.5	12.5	15.0
150	12.0	37.5	75.0	105.0	124.5	150.0
300	24.0	75.0	150.0	210.0	249.0	300.0
344	78.0	180.0	289.0	344.0	344.0	344.0
450	36.0	112.0	225.0	315.0	374.0	450.0
600	48.0	150.0	300.0	420.0	498.0	600.0

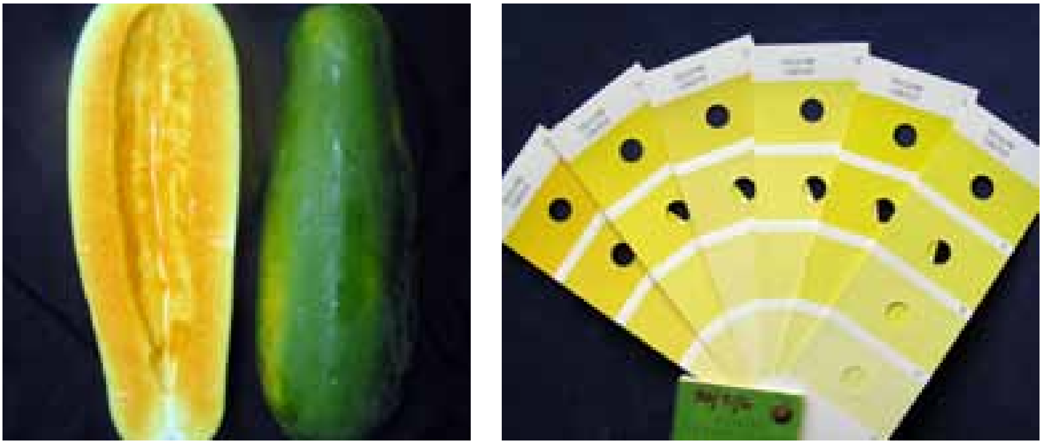

Figure 1. Appearance of yellow papaya fruit at 50% colour break and evaluated for flesh colour rating using the ISHS colour chart

mortar and pestle, gradually adding distilled water until 100 mL of sap solution had accumulated in a volumetric flask. Ten millilitres of the sap solution volume were transferred to a beaker. Two-band nitrate indicator strips (Reflectoquant®, 5–225 mg/L NO_3^- range) were immersed for in the solution for 5 seconds, then placed in a Merck Reflectoquant® RQflex10® meter for 15 seconds until the reading was displayed on the monitor (Figure 2). Readings were multiplied by 10 to account for the dilution of petiole sap. The rest of the petiole samples were analysed by the Kjehdahl method of total nitrogen analysis, using a Kjeltec auto distiller 2200.

Figure 2. Measuring papaya petiole sap NO_3–N content using the Merck Reflectoquant® RQflex10® meter

Results and discussion

Soil pH in the trial area did not decline as a result of the nitrogen application rates and remained within the range 6.0–6.3, irrespective of treatments. The stability of soil pH a year after planting was attributed to the high calcium concentration in the location, which buffered the acidifying effect of high nitrogen application. Other soil nutrients were not significantly affected by nitrogen application, except for phosphorus, which increased significantly with increasing nitrogen application rates up to 225 kg N/ha (Table 2).

Plant height and trunk girth did not vary significantly between treatments in all crop stages measured (Figure 3). Looking at the 15 kg N/ha treatment, papaya trees treated such grew just as well with those that received rates of 150 kg N/ha and above. These results suggest that papaya invested more in building up its structure and biomass.

The most noticeable effect of increasing nitrogen fertilisation on yellow papaya hybrid was on fruit production. Though statistically insignificant, increasing nitrogen fertilisation up to 450 kg N/ha correspondingly increased fruit production, at which it peaked at an average of 76 fruit per tree (Figure 4.) Beyond this rate, fruit production declined and, correspondingly, so did total yield. In contrast, fruit production was lowest when nitrogen was applied at less than 300 kg N/ha, with total fruit in the range 61–62 per tree. The difference of 15 fruits accounted for the yield difference between these rates equivalent to 30 t/ha. Other parameters—average fruit weight,

Table 2. Soil pH and soil P, K, Ca and Mg levels 1 year after planting, as affected by nitrogen application

Nitrogen (kg/ha)	pH	Phosphorus (ppm)	Potassium (ppm)	Calcium (ppm)	Magnesium (ppm)
At planting	5.7	15	155	822	150
15	6.0 a	9 b	106 a	1,538 a	151 a
150	6.3 a	10 b	101 a	1,596 a	125 a
300	6.2 a	11 b	142 a	1,401 a	139 a
344	6.1 a	12 ab	186 a	1,493 a	144 a
450	6.4 a	20 a	121 a	1,749 a	137 a
600	6.1 a	15 ab	192 a	1,297 a	147 a

In a column, means not followed by a common letter are significantly different ($P < 0.05$).

Figure 3. Plant height and trunk girth of yellow, processing-type papaya hybrid, as affected by increasing nitrogen fertilisation rates.

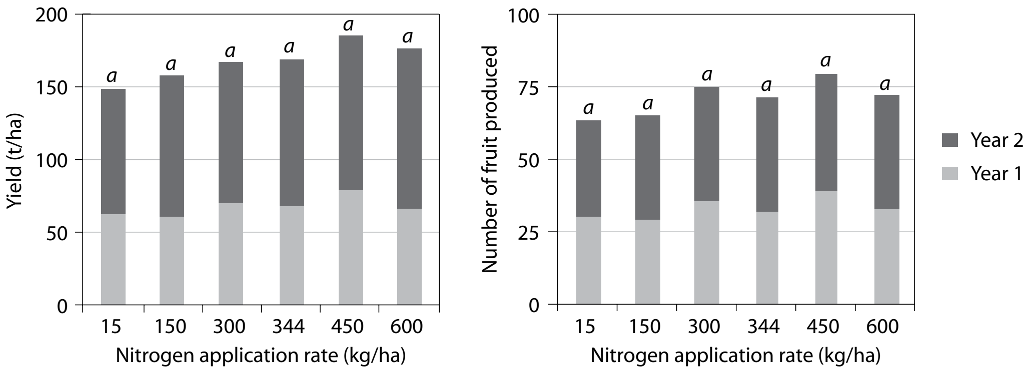

Figure 4. Yield and average number of fruit produced per tree of yellow hybrid papaya as affected by various levels of nitrogen fertilisation

fruit Brix, NO_3–N content, percentage fruit cavity, flesh thickness and flesh colour—were not significantly affected by varying nitrogen rates.

One of the objectives of this trial was to establish a procedure for assessing the nitrogen status of papaya at various growth stages. The petiole NO_3–N analysis through the use of nitrate strips and analysis using the Merck Reflectoquant® RQflex10® meter proved to be better than the Kjehdahl total nitrogen analysis, at least for this trial. With this procedure, a more definite trend was obtained, since a consequent increase in petiole NO_3–N concentration was obtained as a result of increasing nitrogen application (Table 3). Starting at 9 MAP up to 20 MAP, petiole NO_3–N differed significantly between 15–150 kg N/ha and 450–600 kg N/ha. Incremental increase in petiole NO_3–N was negligible when nitrogen was applied from 450 to 600 kg/ha. Presumably, the 600 kg N/ha which resulted in 0.09% NO_3–N in the petiole might already be a detrimental concentration. Such NO_3–N levels in the petiole may have an impact on the physiological functions of the tree as a whole. Accordingly, high nitrate contents are of limited use for nitrogen metabolism in plants. They are stored nearly exclusively in vacuoles and their release from vacuoles into the cytoplasm can become a rate-limiting step for the utilisation of nitrate in growth processes (Marschner 1995). Moreover, NO_3^- assimilation requires additional energy to convert it into the NH_4^+ form, hence growth may be more limited in high NO^{3-} conditions (Bloom et al. 1992). A similar physiological phenomenon might be applicable with papaya and more plant energy may have been diverted to convert NO_3^- to NH_4^+ form instead of producing more flowers that will ultimately develop into fruit. This event could explain the decline in yield starting at 11 MAP (Figure 5) In contrast, petiole NO_3–N levels of 0.02–0.04% are considered limiting.

Table 3. Nitrate content of papaya petiole using Kjehdahl method and Merck Reflectoquant® RQflex10® meter in response to nitrogen (N) fertilisation

Nitrogen (kg/ha)	Papaya petiole total (%)					Papaya petiole NO_3–N (%)				
	4	9	14	17	20	4	9	14	17	20
	(months after planting)					(months after planting)				
15	–	5.5 *a*	4.3 *c*	4.3 *c*	4.4 *a*	0.04 *a*	0.04 *b*	0.03 *b*	0.02 *b*	0.02 *c*
150	–	5.2 *a*	4.6 *bc*	4.1 *abc*	4.5 *a*	0.06 *a*	0.06 *ab*	0.04 *b*	0.03 *ab*	0.04 *bc*
300	–	5.4 *a*	5.1 *ab*	5.0 *bc*	4.8 *a*	0.11 *a*	0.07 *ab*	0.05 *ab*	0.04 *ab*	0.05 *abc*
344	–	5.5 *a*	5.6 *abc*	4.7 *abc*	4.0 *a*	0.16 *a*	0.09 *a*	0.07 *ab*	0.05 *a*	0.04 *abc*
450	–	5.2 *a*	5.4 *a*	5.2 *a*	4.9 *a*	0.11 *a*	0.08 *ab*	0.09 *a*	0.06 *a*	0.07 *ab*
600	–	5.5 *a*	5.3 *a*	4.8 *ab*	4.4 *a*	0.12 *a*	0.09 *a*	0.09 *a*	0.06 *a*	0.08 *a*

In a column, means not followed by a common letter are significantly different ($P < 0.05$).

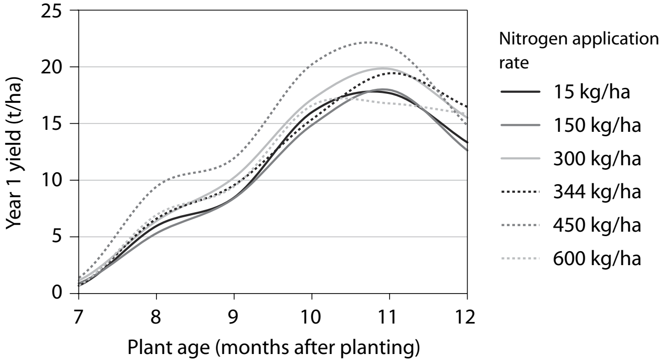

Figure 5. Monthly yield performance of yellow hybrid papaya as affected by varying levels of nitrogen fertilisation

Conclusion

A nitrogen application rate of 450 kg/ha for a 24-month cycle of papaya is recommended to commercial papaya growers to optimise fruit production and yield. Whenever possible, petiole NO_3–N should be analysed using a Merck Reflectoquant® RQflex10® meter since this instrument was more sensitive in measuring variations in response to different rates of nitrogen application.

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Recovery and pathogenicity of *Corynespora cassiicola* in papaya and field evaluation of fungicides for its control

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Abstract

A study on the recovery and pathogenicity of *Corynespora cassiicola,* the causal organism of brown spot of *Carica papaya,* and the field evaluation of fungicides for its control, was conducted at the Bureau of Plant Industry, Bago-Oshiro, Davao City. *Corynespora cassiicola* was shown to have pseudoseptate conidia with a basal hilum, the conidium germinating from terminal cells, and indeterminate conidiophores often with circular basal cells. The pathogenicity of *C. cassicola* was demonstrated on young papaya seedlings and on fruit. The three test solo papaya lines (PPY 7, PPY 14 and 'Mestiza') proved to be susceptible to brown spot. Results showed that propineb, cupric hydroxide, azoxystrobin, tebuconazole and chlorothalonil provided a level of significant control against brown spot disease, compared with the other fungicides evaluated and the control. Plants treated with these promising fungicides produced a 35–114% increase in marketable yield compared with the untreated plants.

Introduction

Papaya is an important crop in the Philippines, ranking fifth in terms of volume produced (140,000 t/year) and sixth in terms of area planted (9,125 ha) according to the Bureau of Agricultural Statistics (BAS 2007). Papaya are grown either in backyards for home consumption, on small-scale farms for local markets or in large–scale commercial plantations. Different papaya cultivars are grown commercially, including the 'Solo' varieties, 'Cavite special', 'Legaspi special', 'Morado' and the hybrid 'Sinta' (PCARRD–DOST 2004). Up to 98% of the volume of fruit produced is consumed locally, providing significant amounts of antioxidants, vitamins and minerals to the local diet. The enzyme papain, which is obtained from the latex, is used as a meat tenderiser, in beer processing, in fabric softeners and the manufacture of toothpaste, and is nowadays exploited as the main ingredient in many whitening products such as soaps and lotions (PCARRD–DOST 2004).

The 'Solo' variety is a dessert type of papaya, eaten readily when ripe and is fast becoming a lucrative business for most farmers. In 2009, the average papaya consumption was reported to be 2.0 kg/person per year in the Philippines (BAS 2009). It is a highly valued commodity with a farm-gate price of 8.61 pesos ($US0.21)/kg, depending on season and market demand (BAS 2010). In 2007, the Philippines was the tenth largest exporter of fresh papaya, contributing 1.78% (164,234 t) to the world's total production (FAO 2009). From 1996 to 2000, multinational companies in the country were exporting the 'Solo' variety to neighbouring countries such as Japan (66% of the total volume of Philippine fresh papaya) and Hong

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Kong (29%). Other importers of Philippine fresh papaya are Saudi Arabia, the United Arab Emirates, Singapore, China, South Korea, the United States and the Canary Islands (PCARRD–DOST 2004). New Zealand is a relatively new export market, taking some 1.9% of the fresh papaya produced.

Papaya, like any other crop, is vulnerable to many diseases. One of these diseases, papaya brown spot (PBS) caused by *Corynespora cassiicola,* affects both the leaves and fruit. An Australian Centre for International Agriculture Research (ACIAR) survey on papaya conducted during 2008–09 showed this disease could cause extensive leaf spots and lesions on fruit. In the Philippines, this disease was first recorded in December 2008 causing 80% damage on plants bearing fruit in a commercial 'Solo' papaya plantation in Hagonoy, Davao del Sur (Mr Alicarte, farm supervisor, pers. comm. 2008). Due to the severity of this disease in the Philippines, studies on the pathogenicity of *C. cassicola* and the field evaluation of fungicides were conducted at the Bureau of Plant Industry, Bago-Oshiro, Davao City, from December 2008 to February 2012.

Review of literature

Corynespora cassiicola, a plant-pathogenic fungus, has a wide host range within tropical and subtropical countries (Holliday 1980; Farr et al. 1980; Romruensukharom et al. 2005). It has become an increasingly important plant pathogen in Australia (Silva et al. 2003), Italy (Martini et al. 2007), Japan (Oka et al. 2006), South-East Asia (Kwon et al. 2001, Darmano et al. 1996; Jacob 1997; Jayasinghe and Jayaratne 2001) and the United States (Pernezny et al. 2002). Quimio and Abilay (1979) reported that substantial losses of papaya, caused by the fungus *C. cassiicola*, have been observed in the Philippines.

Defoliation caused by PBS can lead to the development of fruit blemishes due to sunburn and severe fruit infections that can make the fruit unmarketable. Symptoms of the disease include light-brown circular spots up to 5 mm in diameter on leaves, long elliptical lesions (several cm in diameter) on leaf petioles, and small, dark, sunken lesions that may develop on fruit (Vawdrey et al. 2008).

In Australia, Vawdrey et al. (2008) conducted disease-control experiments which showed that azoxystrobin, pyraclostrobin and chlorothalonil fungicides provided effective control. These chemicals are known to be highly effective against a range of foliar diseases of many crops (Ypema and Gold 1999; Infopest 2003).

A study conducted by Peterson and Grice (1996) led to off-label permits being obtained for the use of the protectant fungicide mancozeb for the control of PBS. However, they expressed concern that high disease pressure may influence the efficacy of these chemicals. For many years, the issue of poor disease control under high disease pressure has been reported by many growers. In addition, there is the possibility of a loss of sensitivity to tebuconazole, which has already been reported in the management of yellow Sigatoka of banana (Grice and Peterson 2002).

Furthermore, environmental and health concerns regarding the use of mancozeb, which is known to have detrimental effects on beneficial predatory mites on papaya, are factors limiting its widespread use. The protectant dithiocarbamate fungicides metiram, propineb and ziram are known to be not as toxic to predatory mites as mancozeb (Angeli and Maines 1997).

Materials and methods

Disease survey

A survey of PBS disease incidence was conducted on December 2008 in two 'Solo' papaya-growing regions in Southern Mindanao, namely Tagum City, Davao del Norte (1 ha) and Hagonoy, Davao del Sur (110 ha). The disease incidence was assessed by calculating the percentage of plants with brown spot.

Isolation of the pathogen

PBS-infected plant parts such as leaves, petioles and fruit, collected in Hagonoy, Davao del Sur, were placed in plastic bags and taken to the plant disease laboratory at the Bureau of Plant Industry – Davao National Crop Research and Development Center (BPI – DNCRDC), Bago-Oshiro, Davao City, for diagnosis. Diseased plant parts were washed in tap water to remove debris. Direct microscopic examination was made of the diseased plant parts.

Using standard laboratory procedures, necrotic tissues from leaf and petiole were sectioned (0.5–2 mm), disinfected with 70% ethanol for 2 minutes, washed three times with sterile distilled water, blotted dry with sterile paper and transferred to potato dextrose agar (PDA) culture plates. Pure cultures of *C. cassicola* were maintained in PDA test tubes and kept for 14 days at 28°C.

Preparation of inoculum

A pure culture of *C. cassicola*, obtained from the margin of a colony from the previous fungal culture, was used in the preparation of the inoculum. The spore suspension was prepared by adding 10 mL sterile distilled water to the pure culture, scraping the mycelial growth of the fungus with the aid of a sterilised wire loop and collecting the spore/mycelial suspension in a small, sterile beaker. The suspension was then filtered using four layers of gauze cloth to remove the unwanted mycelial fragments. The spore concentration was adjusted to 10^6 conidia/mL with the aid of a hemacytometer viewed under the microscope.

Inoculation experiment

A. Inoculation of papaya seedlings and fruit

Spores from a 2-week-old culture of *C. cassicola* were atomised onto healthy papaya fruit, and 3-month old papaya seedlings (cultivar PPY14) were inoculated using the 'swabbing method'. The inoculated fruit and seedlings were covered with clean transparent plastic cellophane to maintain a high humidity for 24 hours. Inoculated fruit were kept on the laboratory bench, and inoculated seedlings were placed in the screen house for symptom observation. Plants were fertilised with complete fertiliser (14-14-14) at 2 g/pot and watered as needed during the duration of the experiment.

B. Susceptibility of three 'solo papaya' lines

The inoculum from 2-week-old isolates of *C. cassicola* was applied to the leaves of 3-month old plants of the papaya cultivars PPY 7, PPY 14 and Mestiza using the swabbing method. Ten plants per treated cultivar were used and 10 untreated plants served as a control. The inoculated papaya seedlings were covered with clean transparent plastic cellophane to maintain moisture for 24 hours. Inoculated seedlings were placed in the screen house for symptom observation. Plants were fertilised with complete fertiliser (14-14-14) at 2 g/pot and watered as needed during the duration of the experiment.

Field experiment

A field experiment (0.8 ha) was established at BPI – DNCRDC in February 2011. 'Solo' papaya (PPY14) were used as test plants. There were eight treatments (seven kinds of fungicides plus an untreated control, as shown in Table 1) with four replications and 10 plants per replication laid out in a randomised complete block design. Row spacing was 2 m and plants were transplanted 3 m apart. Chemical application started on 17 August of the same year (i.e. 6 months after planting). Nine fortnightly foliar sprays were applied during the experiment, and the spray volume increased from 333 to 430 L/ha as the plants matured. All plants received a basal application of ammonium sulfate (21% N, 24% S) at the rate of 1,116.5 kg/ha and diammonium phosphate (18% N, 46% P) at 67.5 kg/ha, muriate of potash (50% K, 46% Cl) at 819.5 kg/ha, boron at 27 kg/ha and zinc sulfate at 40.5 kg/ha applied as a side-dressing throughout the growing season.

As there was only a low level of natural infection in the field experiment, the site was artificially inoculated with *C. cassiicola* early in the morning of 13 July 2011. The upper and lower surfaces of leaves of plants within each guard row were sprayed with spores of *C. cassiicola* using a knapsack sprayer.

Disease assessment

The disease development and the efficacy of each treatment were assessed after five, seven and nine spray applications of the fungicides in the field experiment. The youngest leaf spotted (YLS) was determined by counting from the most recent fully expanded leaf to the first leaf with 10 or more fully developed spots. The total number of leaves per plant

Table 1. Details of fungicides used in experiments to control papaya brown spot disease

Common name	Product name	Formulation	Supplier
Azoxystrobin	Amistar 25 SC	250 g/L	Syngenta Phils.
Cupric hydroxide	Kocide®	538 g/kg	Agway Phils.
Difenoconazole	Score® 250 EC	250 g/L	Syngenta Phils.
Chlorothalonil	Free	750 g/L	Bayer Phils.
Tebuconazole	Folicur® 430 SC	430 g/L	Bayer Phils.
Propineb	Antracol® 70WP	700 g/kg	Bayer Phils.
Dithane M45 WP	Mancozeb	800 g/kg	TropiCuke Inc.

was also counted. Yield data were recorded by weighing the number of marketable fruit (those without brown spot lesions) per treatment.

Data analysis

The software package SPSS 17.0 for Windows® was used (Kinnear and Gray 2009). Post hoc test using Tukey's Honestly Significant Difference test was performed.

Results and discussion

Disease survey

The survey of papaya plantings conducted during December 2008 – March 2009 in Hagonoy, Davao del Sur, showed that PBS disease was infecting about 80% of fruit. In Tagum City, Davao del Norte, PBS was not observed due to weather conditions unfavourable to its development and the wider plant spacing of 2 m × 3 m being used by the grower. Field observations by growers in Hagonoy, Davao del Sur, suggested the disease was more prevalent during hot, wet weather, when temperatures ranged between 21.8 and 31°C. These conditions greatly favoured the appearance and spread of the disease on leaves and fruit. This observation confirms the findings of Vawdrey et al. (2008) which showed warm, wet weather favoured the ongoing development of severe epidemics of PBS disease in the field. In addition to this, the close plant spacing of 2 m × 2 m being used by growers was likely to have enhanced the high incidence of brown spot.

Isolation and morphological characteristics of *C. cassiicola*

The fungal isolates recovered from papaya leaves and petiole and grown on PDA in test tubes showed greyish mycelial threads and hyphae at 2 weeks of age. Under the microscope, the characteristics of the genus *Corynespora* were observed. These included pseudoseptate conidia with a basal hilum, conidium germinating from terminal cells and indeterminate conidiophores, often with circular basal cells (Figure 1). These observations aligned with the findings of Schlub and Smith (2007) on the morphological characteristics of *C. cassiicola*.

Inoculation experiment

A. Inoculation on papaya seedlings and fruits

Five days after inoculation, leaves on inoculated seedlings displayed small, light-brown, near-circular spots 1 mm in diameter and elliptical lesions on the

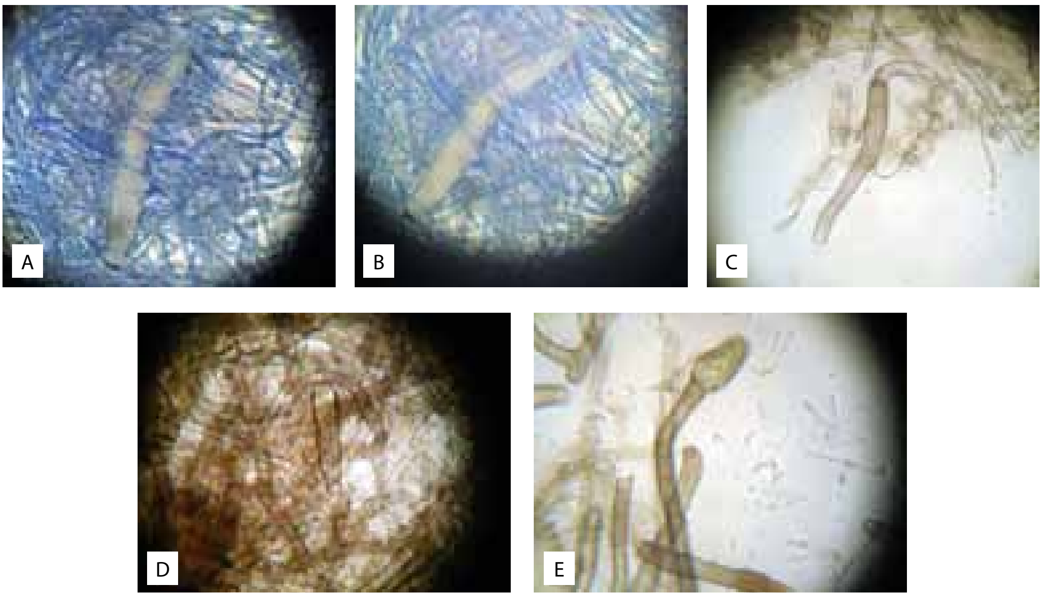

Figure 1. A and B, pseudoseptate conidia with basal hilum; C, conidia germinating from terminal cells; D and E, indeterminate conidiophores often with circular basal cells

leaf petiole (Figure 2). Brown circular spots also developed on the fruit. *Corynespora cassicola* was re-isolated from affected leaves, petioles and fruit.

B. Susceptibility of three 'Solo' papaya lines

The first symptoms of PBS were observed 5 days after inoculation. After 14 days, leaf necrosis and defoliation were observed (Figure 3). All 10 inoculated plants per cultivar expressed symptoms of brown spot. No differences in susceptibility were recorded in any of the three test 'Solo' papaya lines.

Field experiment

PBS was evident in the field due to natural and artificial infection with spores of the brown spot organism. The hot, wet, weather conditions, with temperatures ranging between 21.9 and 31.0°C, began in July and continued until September 2011, favouring the development of PBS.

The assessment of YLS after seven spray applications revealed that there was significantly less disease in all chemically treated plants than in the untreated control. It was also recorded that there were more leaves on plants treated with propineb, cupric hydroxide, azoxystrobin or tebuconazole than on the untreated control (Table 2). After nine spray applications, plants treated with propineb, cupric hydroxide, azoxystrobin, tebuconazole or chlorothalonil had less brown spot and more leaves than plants treated with mancozeb or difenoconazole, and the untreated control.

All fungicides tested provided a level of control against PBS disease. The study conducted by Vawdrey et al. (2008) on the chemical control of brown spot showed that chlorothalonil significantly reduced the disease, compared with other chemicals evaluated. However, in our experiment, propineb seemed more effective than other fungicides tested in terms of YLS and total number of leaves per plant. The results of this study showed that several fungicides can be used as an alternative to mancozeb in controlling brown spot. There are known environmental and health concerns regarding the use

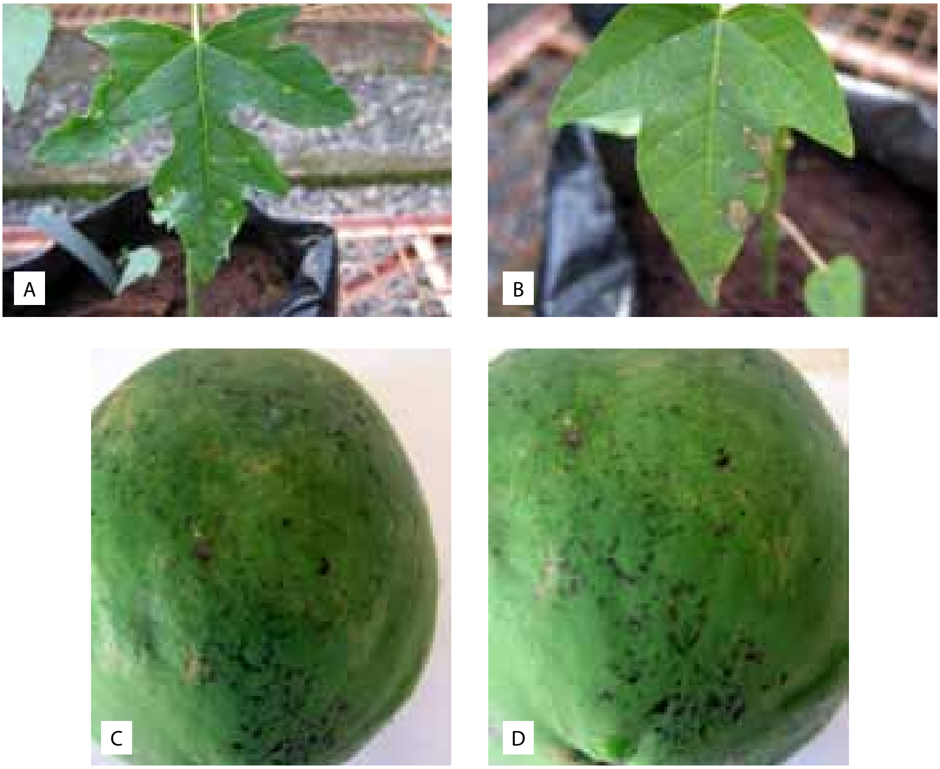

Figure 2. A and B, light-brown spots on the leaf of inoculated papaya seedlings; C and D, brown circular spots on the fruit

Figure 3. A and B, light-brown, near-circular spots on the leaf of solo papaya lines; C, defoliation at 14 days after inoculation

of mancozeb. It is also known to have detrimental effects on beneficial predatory mites (Angeli and Maines 1997; Bernard et al. 2004) and other arthropods preying on the two-spotted mite (*Tetranychus urticae*), which is a major pest of papaya. The protectant dithiocarbamate fungicides metiram, propineb and ziram are known to be not as toxic to predatory mites as mancozeb (Angeli and Maines 1997).

Yield data also showed that propineb-treated plants had the highest (30 kg/ha) marketable yield followed by those treated with azoxystrobin (27 kg), chlorothalonil (22 kg), tebuconazole (21 kg) and cupric hydroxide (19 kg). Treated plants produced 35–114% more marketable fruit than the untreated control (Table 2).

Conclusions

The disease survey revealed that 80% of the papaya plantings in Hagonoy, Davao del Sur, were infected with brown spot disease. Microscopic examination showed that the causal organism, *C. cassiicola*, has pseudoseptate conidia with a basal hilum, a conidium germinating from terminal cells and indeterminate conidiophores, often with circular basal cells. Pathogenicity of *C. cassicola* was shown on young seedlings and on fruit. The three 'Solo' lines (PPY 7, PPY 14 and Mestiza) all proved to be susceptible to PBS. Results showed that propineb, cupric hydroxide, azoxystrobin, tebuconazole and chlorothalonil provided a level of significant control against brown spot disease compared with the other fungicides evaluated and the control. Plants treated with these promising fungicides produced a 35–114% increase in marketable yield over that of the untreated plants.

A similar study in Australia conducted by Vawdrey et al. (2008) showed that chlorothalonil was the most effective fungicide in controlling this disease. In the Philippines, propineb, cupric hydroxide, azoxystrobin, tebuconazole and chlorothaloni can be used as alternatives to mancozeb for the control of PBS.

Table 2. Effect of different fungicides on brown spot disease of papaya in a field experiment at BPI – DNCRDC, February 2011–February 2012

Treatment	Rate of application	Youngest leaf spotted (YLS) after[a,b]		Total leaves per plant after[a]		Marketable yield (kg/ha)[c]
		seven sprays	nine sprays	seven sprays	nine sprays	
c-Propineb	50 g/16 L water	13.98a	15.65a	25.06abc	28.28a	30.32a
Cupric hydroxide	40 g/ 16 L water	12.84a	14.4ab	26.98a	27.53ab	19.23ab
Chlorothalonil	128 g/16 L water	12.64ab	14.29ab	23.52cd	25.96ab	21.61ab
Azoxystrobin	19 mL/16 L water	12.35ab	13.94ab	26.77ab	27.42ab	27.08ab
Tebuconazole	12 g/16 L water	11.57ab	13.97ab	24.66abc	26.09ab	20.61ab
Mancozeb	128 g/16 L water	11.31ab	13.5bc	24.22bcd	25.53bc	14.47b
Difenoconazole	10 mL/16L water	11.29ab	12.89bc	23.51cd	23.17c	16.31b
Untreated		9.8c	11.71c	21.89d	23.51c	14.40b

[a] Means in the same column followed by the same letter do not differ significantly according to ANOVA or Tukey's Honestly Significant Difference test ($\alpha = 0.05$)

[b] YLS rated by counting from the most recent fully expanded leaf to the first leaf with 10 fully developed spots ($n = 16$)

[c] cv = 26.34%

Application of the results of this study would benefit papaya growers, since use of fungicides for the control of brown spot would increase marketable yields and hence incomes.

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Population dynamics of red spider mites *Tetranychus kanzawai* on 'Solo' papaya in Southern Mindanao

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Abstract

Seasonal periodicity of spider mites, *Tetranychus kanzawai* in 'Solo' papaya was conducted at the Davao National Crop Research and Development Center – Bureau of Plant Industry, Bago-Oshiro, Davao City, Philippines.

Initial population build-up of *T. kanzawai* Kishida occurred during March 2011 and progressed until May. Two population peaks were recorded, in August 2011 and January 2012. Nevertheless, correlation analyses showed that rainfall, relative humidity and temperature did not adversely influence the seasonal fluctuation of the spider mite in papaya during the entire period.

Infested leaves of papaya had the combined presence of the two most common predators of spider mites: the small black lady beetle *Stethorus pauperculus* and the phytoseiid mite *Neoseiulus longispinosus*. The populations of the predators were generally low throughout the period, but there was an increase when a surge in the population of spider mites occurred during January 2011. The predator showed a delayed density-dependent response to changes in the density of the spider mites.

Seasonal changes in the abundance of spider mites and its predators on a treated plot were also determined. After application of hexythiazox and abamectin (acaricides), and fungicides evaluated for the control of papaya brown spot, the predator population was very low. Mite density changes on treated and unsprayed plots showed a similar trend. However, population decline also happened after application of chemical pesticides.

Introduction

Papaya is a continually expanding cash and export crop in the Philippines, ranking fifth in terms of volume produced (140,000 t/year) and sixth in terms of area planted (BAS 2007).

In 2007, the Philippines was the tenth largest exporter of fresh fruit contributing 1.78% (164,234 t) to the world's total food production (FAO 2009). From 1996 to 2000, multinational companies in the country were exporting the 'Solo' variety to neighbouring countries such as Japan (66% of the total volume of Philippine fresh papaya) and Hong Kong (29%). Other importers of Philippine fresh papaya are Saudi Arabia, the United Arab Emirates, Singapore, China, South Korea, the United States and the Canary Islands (PCARRD – DOST 2004). New Zealand, which is relatively a new export market, took some 1.9% of fresh papaya,

The shifting of papaya from the domestic to the more lucrative international market inevitably requires a change in the technologies for growing and handling of the crop. While fruit of high quality is desirable, for the international market it is essential, and this is driving a trend to more judicious use of

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pesticides and effective integrated pest management (IPM) as tools for the control of serious pests attacking papaya.

Papaya is attacked by a complex of insect pests and herbivorous mites. Pantastico et al. (1977) listed mites as among the three major pests of economic importance in papaya, specifically mentioning the two phytophagous mites—cassava spider mite *Tetranychus kanzawai* and the red flat mite *Brevipalpus californicus* (Banks)—as being the most important. Based on a survey conducted in December 2008– March 2009 in several papaya growing areas in Davao del Sur, Davao del Norte and Davao City, mites were common and serious in most areas in both processing-grade and 'Solo' papaya. In Hagonoy, Davao del Sur, more than 20% infestation of mites was observed (Alicarte 2008; farm supervisor, pers. comm.). In Tagum City, Davao del Norte (Ma. Asuncion Salibay, agriculturist, University of Southeastern Philippines, pers. comm. 2009) 50% mite infestation was observed.

While there is no doubt about the serious consequences attributed to mite infestation in papaya the investigation reported here aimed to determine: 1. the seasonal periodicity (abundance and distribution) of red spider mites in solo papaya and its relationship to rainfall, relative humidity and temperature; 2. the role played by the mite's natural enemies in the field; and 3. the effects of chemical pesticides on the density of mites and their predators, particularly in Southern Mindanao.

Review of literature

The spider mite *Tetranychus kanzawai* is an important and widely distributed pest throughout East and South-East Asia, attacking over 100 species of plants, including many food crops and ornamental plants (Bolland et al. 1998; Zhang 2003). This species is also responsible for a trade barrier preventing the export of fruits (pears, apples, mandarin oranges etc.) to countries in Europe and North America where *T. kanzawai* does not occur.

In the Philippines, *T. kanzawai* is a serious pest of cassava *Manihot esculenta* (Bernardo and Esguerra 1981) and papaya (Pantastico et al. 1977; Gavarra 1981). Severe mite infestation can cause complete defoliation of the plant, leading to 20–37% yield losses in cassava (Villacarlos 1986). Feeding damage of mites has a major impact on the health and longevity of papaya orchards. *Tetranychus kanzawai* feed by penetrating plant tissues. Uncontrolled infestations can initially result in yellow or bronze canopies and later complete defoliation (Fasulo and Denmark 2000).

There have been studies on the fluctuation of mite densities in tea plantations (Osakabe 1967), in papaya (Gavarra 1981) and in cassava (Bernardo and Esguerra 1981). Other studies have investigated their biological control by phytoseiid mites (Ho 1990; Vasquez and Gonzales 1994) and their life history parameters (Kondo and Takafuji 1985).

Control of mite pests on papaya currently depends mainly on chemical application. However, the intensive application of miticides, in combination with short life cycles and high reproductive rates, has led to the development of resistance to many miticides in both the kanzawai and citrus red mites (Goka 1996). Few pesticides are effective against spider mites and many even aggravate problems. In addition, many miticides produce unacceptable phytotoxicity to papaya (Lo 2002). It is therefore necessary to search for alternative approaches to controlling these mites on papaya.

Resurgence and rapid development of resistance through sole dependence on acaricides for mite control has become a common phenomenon in many advanced countries. Therefore, the ideal approach to the control of mites is through the application of 'pest management', which requires a proper understanding and integration of biological, cultural and chemical methods of control (Gavarra,1981).

Methodology

Population fluctuations of *T. kanzawai* and its associated biological control agents were monitored in 'Solo' papaya (PPY14 cultivar) at the Bureau of Plant Industry – Davao National Crop Research and Development Center (BPI – DNCRDC), Bago-Oshiro, Davao City, Philippines, from February 2011 to March 2012. Following the onset of mite infestation, assessments were done every 10 days on 20 randomly selected papaya trees from an untreated plot.

Counts were taken at three canopy positions (top, middle, bottom leaf) and mite infestation and damage rated as described in Table 1.

Mite density changes were also monitored on a treated block (experimental plot for the evaluation of the different fungicides for the control of papaya brown spot) using the mite infestation and damage

Table 1. Ratings used in monitoring mite infestation and assessing mite damage

Rating index code	Mite infestation index (MII)	Rating index code	Mite damage index (MDI)
1	No mites within a 2-inch (5 cm) circumference from the leaf petiole	1	No damage visible
2	1–10 mites present within a 2-inch circumference from the leaf petiole	2	Slight damage: water-soaked areas on leaf; pinhead spot chlorosis
3	11–20 mites present within a 2-inch circumference from the leaf petiole	3	Moderate damage; corky tissues/latex oozing; larger spot chlorosis
4	21–50 mites present within a 2-inch circumference from the leaf petiole	5	Severe damage: shot holes near the petiole; oozing latex; extensive necrosis
5	More than 50 mites present within a 2-inch circumference from the leaf petiole		

indexes mentioned above. Table 2 lists the chemical pesticides applied during the experiment.

Weather data (temperature, relative humidity and rainfall) for the period, and the occurrence of associated natural enemies, were also recorded.

Results and discussion

Seasonal periodicity of *Tetranychus kanzawai*

Population build-up started 1 month after transplanting 'Solo' papaya (PPY14) in the field. Initial infestation was observed in older leaves. *Tetranychus kanzawai* was the dominant species observed. The initial sign of injury is distinct, minute pinpricks, which eventually coalesce to form yellowish, irregular spots. These appear as small, irregularly shaped eruptions when viewed from the lower leaf surface. Severely damaged leaves desiccate, thus reducing the photosynthetic capacity of the plant.

The mite feeding injury could be easily distinguished from similar damage caused by other organisms on papaya.

Table 2. Fungicides and acaricides (common names) applied on the papaya brown spot experimental plot

(Fungicide)	Acaricide
Azoxystrobin	Abamectin
Cupric hydroxide	Hexythiazox
Difenoconazole	
Chlorothalonil	
Tebuconazole	
Propineb	
Dithane M45 WP	

Spider mite infestation began in March 2011 and the population built-up until April–May 2011, then fell in June when high rainfall was recorded. A similar observation was made by Osakabe (1967), who noted that the population of *T. kanzawai* infesting tea in Japan fell markedly during the rainy season.

The mite population started to rise again in July, peaking in August (MII = 4). Thereafter, the population fell in September and remained low in October–November (Figure 1a).

The little rain (3.6–4.6 mm) recorded during the sampling periods of December 2011 to January 2012 was accompanied by the highest peak in mite population (MII = 4; MDI = 5) and abruptly declined in February 2012. Most of the papaya plant damage was due to bacterial crown rot infection. Correlation analysis ($R^2 = 0.031$) showed that rainfall does not greatly affect the seasonal occurrence of spider mites. Although there was high rainfall recorded during the sampling periods, it was not uniformly distributed throughout those months. In Hawaii, Haramoto (1969) found that the number of active mites fell suddenly following heavy rain and increased gradually with the return of warm, humid conditions. In the Philippines, Pantastico et al. (1977) noted that papaya mites were abundant from October to February but did not report on weather conditions at the time. Mite infestation and its corresponding damage were observed to be generally higher on the bottom leaf canopy (mature leaf) than on the middle leaf and were lowest on the top leaf.

The temperature during the sampling period fluctuated within a narrow limit (26–28°C), and there was thus no indication ($R^2 = 0.124$) that temperature influenced the seasonal changes in spider mites on papaya. Similarly, the relative humidity during

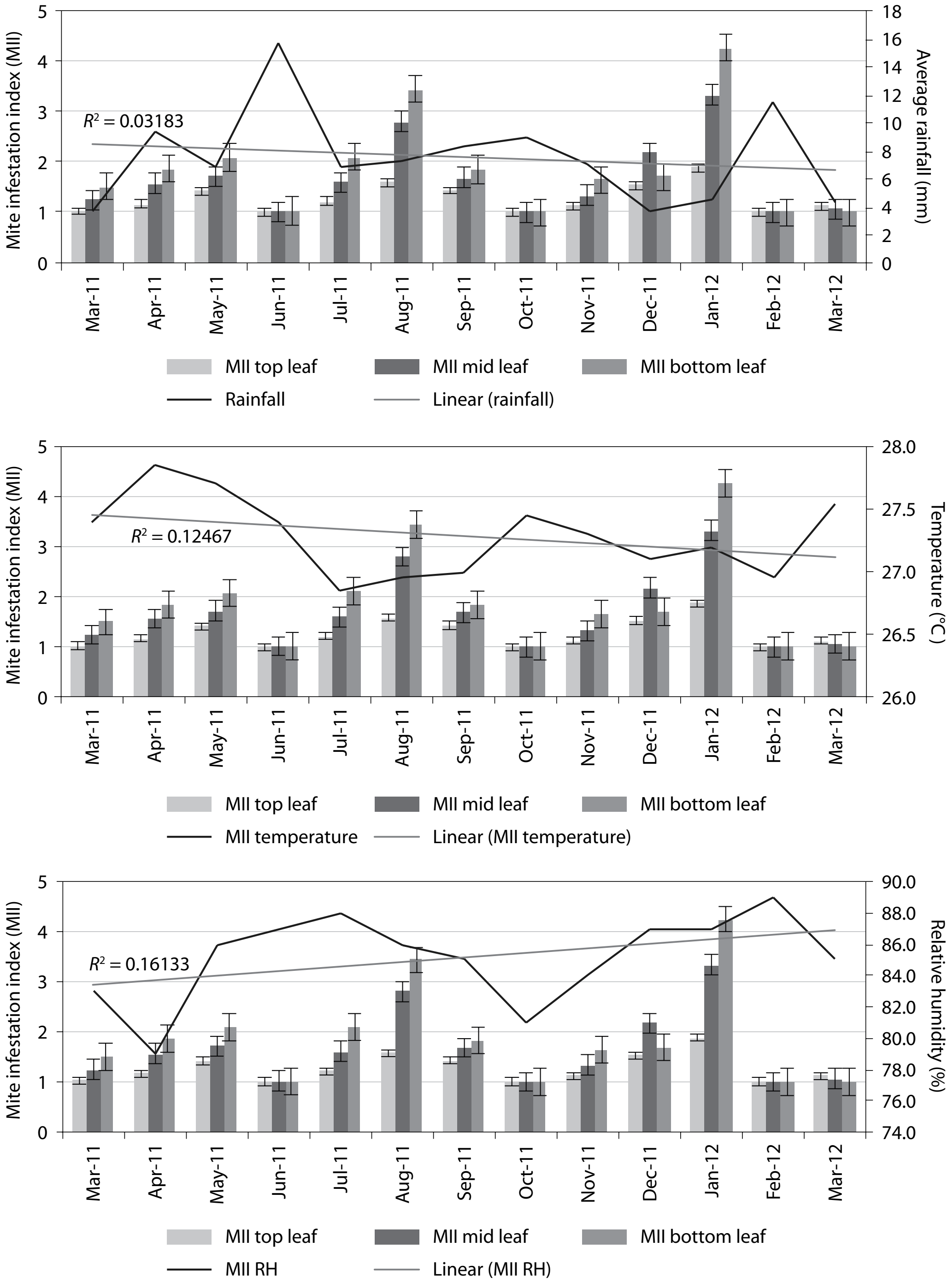

Figure 1. Seasonal changes in (a) rainfall, (b) temperature and (c) relative humidity (RH) and the spider mite population in 'Solo' papaya at BPI – DNCRDC, Bago-Oshiro, Davao City, Philippines (February 2011 – March 2012) (vertical lines give the standard error of measurements)

the sampling period (79–89%) showed negligible influence ($R^2 = 0.161$) on the spider mite population (Figure 1b and 1c).

Seasonal periodicity of predators

The predators associated with spider mites were *Neoseiulus longispinosus* phytoseiid mites, the small black lady beetle *Stethorus pauperculus*, larvae of predatory midges and several species of small spiders (Figure 2), the first two being the most important and present on all infected leaves. Ocular sampling of the two predators during the 12-month period indicated that they are consistently associated with papaya spider mites. The absence or low numbers of the two predators during the initial build-up of the spider mite population showed a delayed density-dependent response to changes in density of spider mite, as was found by Gotoh and Gomi (2000). The population of natural enemies was generally low throughout the observation period, but a high number of predators was observed during the months of December 2011 – January 2012 when the population of *Tetranychus* mites was on its peak and served as one of the factors limiting spider mite increase (Figure 3).

Seasonal changes in the abundance of spider mite and its predators on fungicide-treated plot

On a plot sprayed with hexythiazox and abamectin (acaricides), and seven fungicides for the control of brown spot in papaya, the density of the predators was low, despite the higher infestation of mites than in the unsprayed plot (Figure 4). Mite density changes on unsprayed and treated plots showed a similar trend. However, population decline of spider mites occurred after application of the acaricide and the various fungicides evaluated for the control of papaya brown spot.

Conclusion

The spider mite *Tetranychus kanzawai* was the most common and damaging phytophagous mite attacking 'Solo' papaya and other varieties grown in Southern Mindanao.

Initial population build-up of the spider mites occurred 1 month after transplanting in the field during the drier period and two population outbreaks were recorded.

Figure 2. Natural enemies commonly found associated with *Tetranychus kanzawai* in 'Solo' papaya: (a) *Neoseiulus longispinosus* phytoseiid mite; (b) larva and adult of coccinellid beetle, *Stethorus pauperculus*; (c) unidentified small spiders; and (d) larva of unidentified cecid fly (Bago-Oshiro, Davao City, Philippines; 20 November 2011)

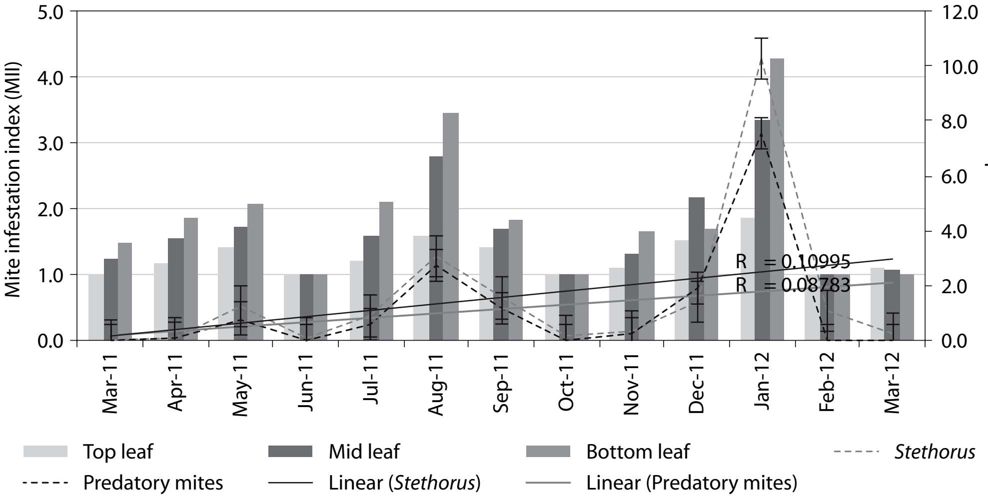

Figure 3. Seasonal changes in the abundance of spider mites and its two primary predators on 'Solo' papaya at BPI – DNCRDC, Bago-Oshiro, Davao City, Philippines (February 2011– March 2012)

There appeared to be no relationship between abiotic factors such as rainfall, relative humidity and temperature and seasonal changes in the population of mites during period.

Neoseiulus longispinosus phytoseiid mites and *Stethorus* beetles are potential natural predators limiting mite pest populations. Their population in the field should be protected and enhanced by avoiding hazards such as injudicious use of pesticides.

The information generated will help development of monitoring and control strategies for the pest, so as to reduce pesticide application over the growing season. Reduction in pesticide reliance will also help promote an environment favourable for developing biological control systems with the natural predators, as well as reducing maximum residues in fruits and improving health and safety of farm workers.

A more detailed understanding of the toxicity of the acaricides and fungicides commonly used in papaya is required before making any recommendations for their suitability for a pest control program.

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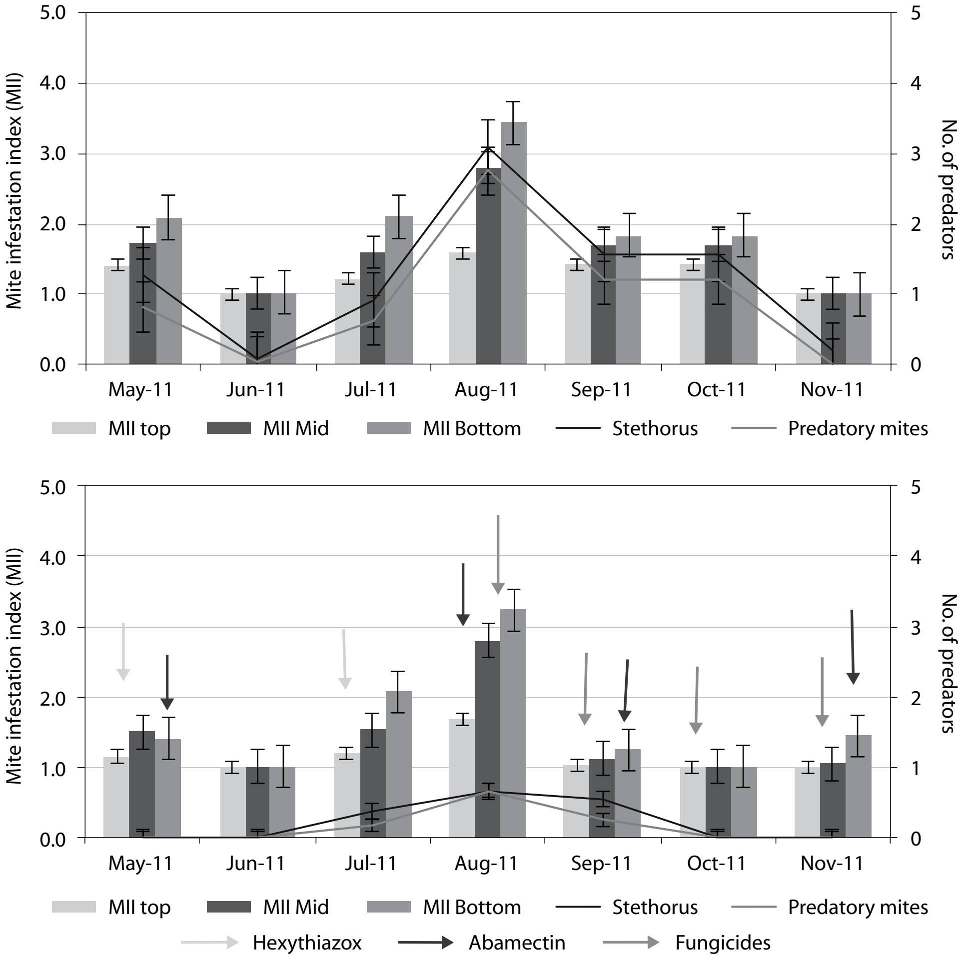

Figure 4. Seasonal changes in the abundance of spider mites and its predators in (a) an unsprayed plot and (b) a sprayed plot (papaya brown spot experimental plot; see text for details) at BPI – DNCRDC, Bago-Oshiro, Davao City (May 2011 – November 2011). Arrows indicate times of spraying

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Seasonal dynamics of mites infesting papaya in Northern Mindanao

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Abstract

Population monitoring of mites and damage assessments were conducted in May 2010 to March 2012 on transplanted hybrid papaya (crimson-red cultivar) using index guides for mite infestation and damage in Liboran, Baungon, Bukidnon. The main aim was to determine the identity of mite species associated with papaya and at what time of the year mite populations are at their lowest and highest density, and other basic information necessary for the formulation and timing of monitoring and application of control strategies.

Sampling and assessment were made every fortnight on 20 trees from a block receiving chemical treatments (abamectin and dimethoate) and on 20 trees from an untreated block. Stratified random sampling was conducted by taking three leaf samples per tree, taking assessments at the top, middle and bottom leaves on each tree.

Tetranychus kanzawai is the most common and serious mite species infesting papaya in northern Mindanao. The less common phytophagous species include *Eutetranychus africanus* and *Tetranychus piercei*. Two predatory species *Amblyseius tamatavensis* and *Neoseiulus longispinosus* were also collected from papaya.

The red spider mite *Tetranychus kanzawai* was already present in the field during sampling initiation. Mite infestation and damage were generally confined, and more serious on the bottom than the middle leaves; the top leaves are seldom infested. The progress in mite population development in the untreated block produced two population peaks, one in January 2011 followed by another in April 2011. A relatively low level of infestation was recorded between June to September of 2010 and 2011. In the treated block, the population also peaked in April 2011, when the total rainfall recorded was at its lowest. The small black beetle *Stethorus pauperculus*, a voracious feeder on spider mites, was common and relatively more numerous on the untreated block. The possible effects of chemical application, mite predators and the changing seasonal weather patterns on the overall mite population are discussed.

Introduction

The Philippines is one of the major papaya producers and consumers in the world. Most production areas are in Mindanao because of the favourable climate and are continually expanding despite the pressure of pests and diseases. In the Philippines, papaya is host to many insect pests and mite species. Seventeen insects and nine mite species belonging to six genera have been listed to be associated with papaya in the Philippines (Gabriel 1997). Insect pests such as mealybugs, scale insects, spiraling whiteflies and fruit flies may attack papaya at any time of the growing season.

Red spider mites (family Tetranychidae) are undoubtedly among the most destructive pests of papaya in many parts of the world (Johnson and Lyon 1991). Spider mites are primarily found underneath the leaves, where they pierce and feed on the

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leaf-cell contents. Feeding damage by spider mites occurs as they suck out the cell contents and cause the cells to collapse and die. This causes damage symptoms which can be seen on the leaves initially as translucent water soaking which eventually turns necrotic. Mite colonies tend to feed close to the main leaf veins. As populations increase, they spread out onto new leaves and move up the canopy. Feeding by mites reduces photosynthesis, which causes poor plant vigour, leading to a reduction in size, quality and quantity of fruits (Fay et al. 2001).

Mites are highly seasonal. Since the degree of incidence of red spider mites changes with season, it is imperative to have a thorough understanding of their seasonal incidence and population dynamics in papaya. Mite predators play a major role in bringing down mite populations in many cropping systems including papaya (Helle and Sabelis 1985; Fay et al. 2001).

Many growers and contractors, in their desire to protect papaya from phytophagous insects and mites, apply heavy calendar-based spray regimes that could also be killing the beneficial insect populations, thus promoting pest flare. With this in mind, studies were conducted to determine the seasonal incidence of spider mites and associated natural enemies in relation to climatic factors and pesticide use in the papaya-production system.

The field studies on papaya were set up to understand the seasonal population dynamics of spider mites and their interaction with natural enemies and pesticide inputs. The main aim was to identity the most dominant mite species and at what time of the year mite populations are the lowest and highest, because this will help to determine proper timing of monitoring and control strategies. Specifically, the objectives were to collect and identify pest mite species in papaya in northern Mindanao, to monitor mite infestations and assess the damage inflicted on papaya trees on plots with and without chemical treatments, and to identify and monitor natural enemies of mites on papaya as may be affected by pesticide use and prevailing weather.

Review of literature

Mite studies in the Philippines were started by Professor Leo C. Rimando at the University of the Philippines and were continued by his students L.A. Corpuz, who studied predatory mites of the families Phytoseiidae, Bdelidae and Cheyletidae (Corpuz 1964), and E.O. Pama, who studied the biology of the spider mite, *Tetranychus kanzawai* Kishida (Tetranychidae: Acarina) (Pama 1965). Many taxonomic studies on Philippine mites followed, including the checklist and bibliography of Philippine Acari (Corpuz-Raros 2001, 2005). Gavarra (1981) studied the biology, ecology and control of spider mite *Tetranychus kanzawai* on papaya and reported eight phytophagous mites associated with it, two of them—*T. kanzawai* and *Brevipalpus californicus* (Banks)—of economic importance. Also, he reported that a lady beetle, *Stethorus* sp., was a more important regulating factor of spider mite populations than the predatory mite *Amblyseius longispinosus*. Mite outbreaks during February and March 1980 were shown to be associated with periods of low relative humidity and low precipitation. Nine species of mites associated with papaya were included by Gabriel (1997) in his list of insects and mites injurious to Philippine crop plants. These include mites found on papaya leaves (*Eutetranychus orientalis*, *Schizotetranychus lechrius*, *T. kanzawai* and *Tetranychus piercei*) and on papaya fruits (*Calocarus briones*, *B. californicus*, *Brevipalpus phoenicis*, *Polyphagotarsonemus latus* and *Tetranychus urticae*).

The survival, consumption and reproduction of the predatory mite *A. longispinosus* on various food items, and its biology, were studied by De Leon-Facundo and Corpuz-Raros (2005). They found no difference in predator development and reproduction when reared on *T. kanzawai* or *Tetranychus truncatus* but the predator required significantly fewer eggs of the latter to produce an egg.

As part of the current horticulture project, this report covers only the mite seasonality study that was conducted in Northern Mindanao on a papaya cultivar for processing (canning). A parallel study was also conducted on the population dynamics of red spider mite *T. kanzawai* in Southern Mindanao on 'Solo' papaya for the fresh fruit market, and was reported separately (Arcelo et al. 2012).

Methodology

Two blocks at Liboran, Baungon, Bukidnon, each approximately 1,500 m^2, were planted with papaya hybrid crimson-red, representing the untreated and the pesticide-treated sampling areas. The pesticide-treated block was separated by three border rows serving as a natural barrier from the untreated block. Pesticides applied to the treated block included abamectin and dimethoate, applied by a contractor at a rate and frequency based on company recommendations. Kocide was regularly applied on both plots to prevent bacterial diseases. Stratified random sampling was initiated on 2-month-old papaya trees in May 2010 and was continued every fortnight (except during September 2010) until March 2012. Twenty plants were selected per block at random and were assessed using sampling protocols developed for papaya mites (Table 1).

A leaf disc sampler was also used to obtain subsamples (4 leaf-discs/leaf) from highly infested leaves, for close-up microscopic examination of mites and small predators in the laboratory. All sample specimens were collected and preserved in alcohol for identification. Representative mite samples collected were processed and sent to a local acarologist for identification. Monthly farm visits to papaya growers were conducted to supplement the observations from field studies and for additional taxonomic collections. Plants and weeds were inspected as possible alternative hosts. Weather data were obtained from the nearest government weather station (PAGASA) located at the Lumbia airport (8º26'N; 124º37'E) in Cagayan de Oro City.

Results and discussion

Species diversity, distribution and habits

Current field surveys show many species of spider mites are associated with papaya in Mindanao (Quimio et al. 2012a). Mites identified from the northern part of Mindanao include three phytophagous species (*T. kanzawai*, *T. piercei* and *Eutetranychus africanus* and the two predatory species *Amblyseius tamatavensis* and *Neoseiulus longispinosus*. *Tetranychus kanzawai* is the most common and serious mite species infesting papaya in many parts of Northern Mindanao. Cassava, one of the major crops widely grown in the region, is the primary host of this species. *Tetranychus piercei* is also a red spider mite very similar to *T. kanzawai* in appearance except for the morphology of the aedeagal knob in males (Bayubay and Corpus-Raros 2006). A dark-green spider mite, *Eutetranychus africanus*, was also monitored in the study area but its population did not persist and was observed from only July to November 2011.

Tetranychus kanzawai and *E. africanus* have different spatial distribution patterns and produce markedly different patterns of feeding injury in papaya. For instance, *T. kanzawai* has a more clumped distribution and aggregates more on the undersides of older leaves. Both immatures and adults feed on chloroplast cells, causing water-soaked appearance, chlorosis, necrotic lesions and, eventually, leaf shot-holes. The mite *E. africanus* spreads more evenly, both on the upper and lower surfaces of the leaves, their feeding damage causing the leaf surface to develop characteristic stippling, whitish to silvery-grey in general appearance. Eggs are laid usually along the groove of leaf veins located on the dorsal surface of the leaves. The green spider mite also infests cassava in Isabela (Corpuz-Raros 2001) and Nueva Vizcaya in Luzon, and was also collected on papaya and ornamental plants in Isabela (Bayubay and Raros 2006).

Population dynamics

The phytophagous mites were already in the field in small numbers when initial assessments were conducted in May 2010 (Figure 1). Highest mite

Table 1. Ratings used in monitoring mite infestation and assessing mite damage

Rating index code	Mite infestation index (MII)	Rating index code	Mite damage index (MDI)
1	No mites within a 2-inch (5 cm) circumference from the leaf petiole	1	No damage visible
2	1–10 mites present within a 2-inch circumference from the leaf petiole	2	Slight damage: water-soaked areas on leaf; pinhead spot chlorosis
3	11–20 mites present within a 2-inch circumference from the leaf petiole	3	Moderate damage; corky tissues/latex oozing; larger spot chlorosis
4	21–50 mites present within a 2-inch circumference from the leaf petiole	5	Severe damage: shot holes near the petiole; oozing latex; extensive necrosis
5	More than 50 mites present within a 2-inch circumference from the leaf petiole		

infestations and severe damage were concentrated on the bottom leaves, followed by the middle leaves, with the top leaves the least infested (Figure 2). The bottom canopies served as refuge for the pest mites to breed and multiply, often inducing cumulative damage to the tree, and also served as a haven for immature predators.

In the untreated block (Figure 1), red spider mite infestation was similarly recorded on transplanted seedlings as early as May 2010. The initial mite

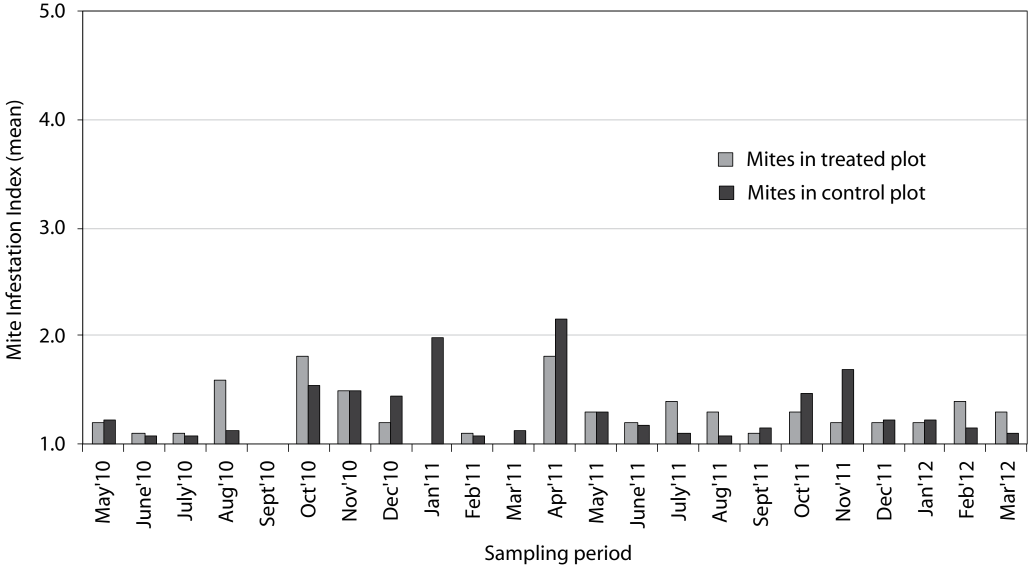

Figure 1. Population dynamics of the red spider mite *Tetranychus kanzawai* on papaya trees at Liboran, Baungon, Bukidnon, the Philippines

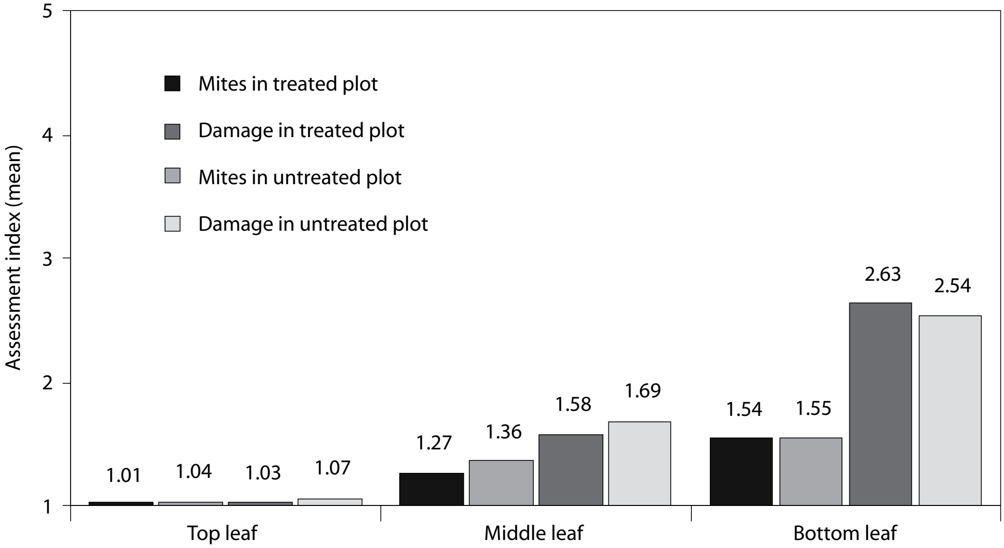

Figure 2. Spatial distribution of red spider mite *Tetranychus kanzawai* on papaya trees at Liboran, Baungon, Bukidnon, the Philippines

populations on both blocks were generally small from May to July 2010, increasing slightly in the treated block in August and October and then falling gradually until December 2010. In 2011, the population peaked in January, followed by sudden drop in February and March, and recovering for a second and highest peak in April 2011. The infestation subsided in May until October and November of the same year, when a slight population increase was recorded. The population crashed in December 2011, possibly due to excessive rainfall brought about by typhoon 'Sendong', which flooded and devastated the region. Thereafter, the mite population never recovered, probably due to the carryover effects of heavy precipitation in December, which is very uncommon in the region.

Population peaks of mites were recorded during the times that total rainfall was lowest, suggesting that rainfall suppressed population development of mites in the field. Two peaks of mite infestation were recorded in January and April 2011 and mite damage was also most severe during these months and May (Figure 3). The correlation between mite infestation and mite damage was highly significant, in both control (Figure 3) and treated blocks (Figure 4).

Weather influence

Among the weather factors, total rainfall had the strongest influence on the mite populations. Mite infestation was higher during dry months and sustained monthly rainfall of 200 mm or more seemed detrimental to mite population development (Figure 5). Mite infestations and relative humidity, temperature and degree of cloudiness were not significantly correlated (RH: Pearson correlation $r = 0.007$, $p = 0.49$; temperature: Pearson $r = -0.27$, $p = 0.112$; cloudiness: Pearson $r = -0.261$, $p = 0.12$).

Predators

Two predatory mite species were collected on papaya in the Bukidnon area: *Amblyseius tamatavensis* and *Neoseiulus longispinosus*, but they were uncommon in most study areas.

Stethorus pauperculus is a voracious mite-feeding beetle. Initial laboratory data showed an adult beetle can consume an average of 32 mite eggs daily (range 21–51) or an average of 9.3 adult mites (range 6.3–10.9) (Quimio et al. 2012b). In September 2009, to supplement the field study, a papaya orchard in Iponan, Cagayan de Oro, where a very high *Stethorus* beetle population was observed to be markedly reducing mite populations, was visited. At this particular orchard, minimal pesticides were used. Most of the *Stethorus* beetles counted from the top, middle and bottom leaves were already at the late larval and pupal stages, with average counts of 30.2, 90.5 and 76.0 beetles, respectively (Figure 6). Adults beetles were numerous and actively searching for the remaining mites all over the leaves. By counting only the larvae and pupae on the foliage of 10 trees ($n = 30$ leaves), averages per tree of 48.2 beetle larvae and 148.5 pupae were recorded. The mite infestation was effectively suppressed by the beetles.

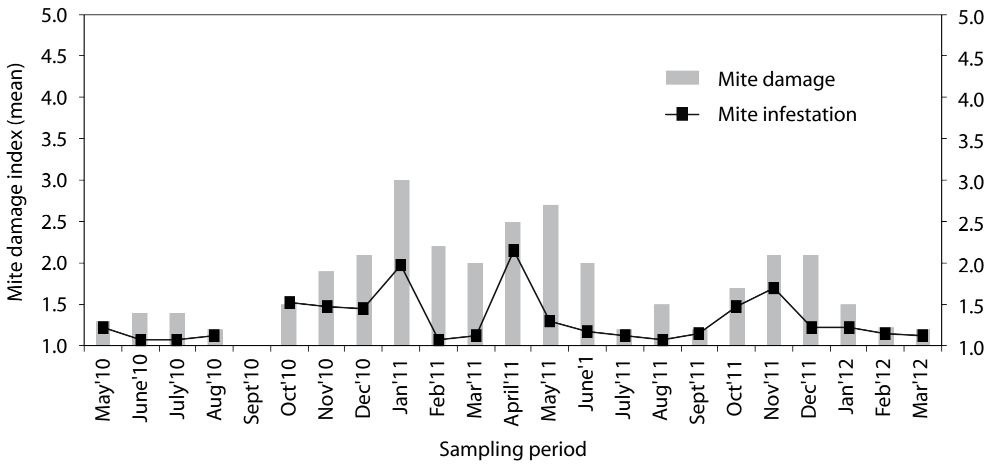

Figure 3. Population development and damage of *Tetranychus kanzawai* in papaya trees on the control (untreated) block at Liboran, Baungon, Bukidnon, the Philippines (Pearson correlation $r = 0.93$, $p = 0.01$)

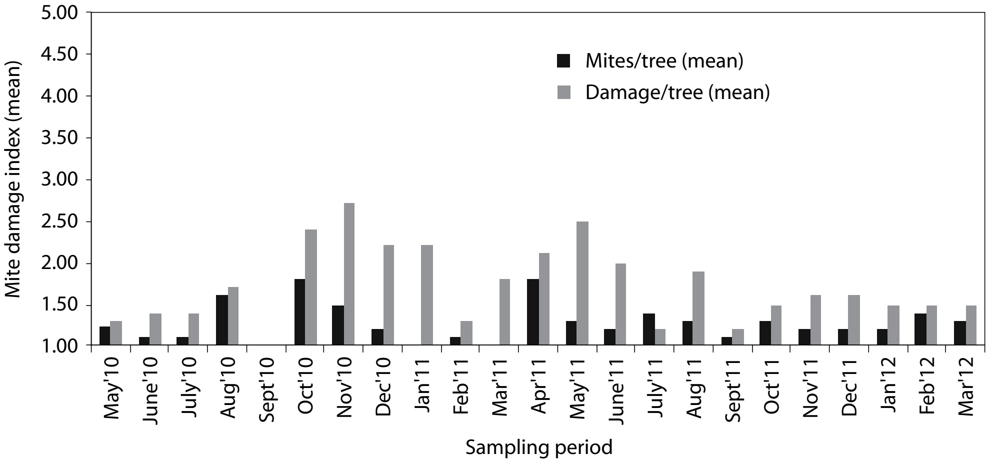

Figure 4. Population development and damage of *Tetranychus kanzawai* in papaya trees on the treated block in Liboran, Baungon, Bukidnon, the Philippines (Pearson correlation $r = 0.91$, $p = 0.01$)

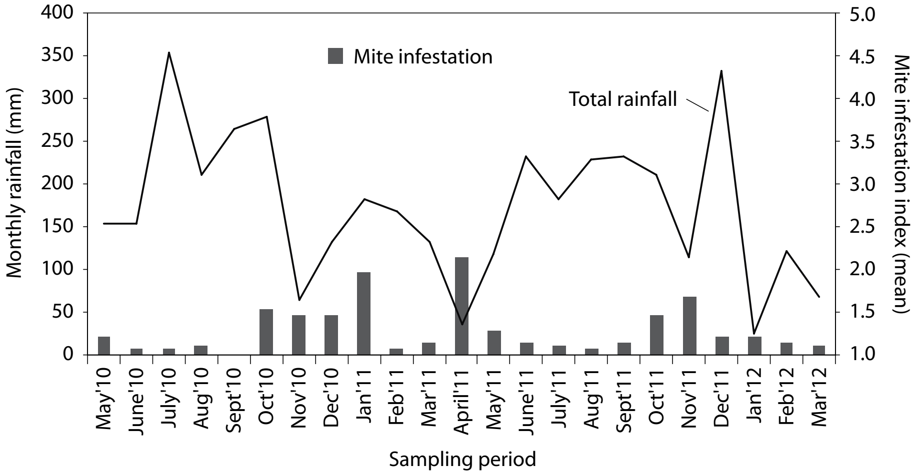

Figure 5. Effects of the total amount of rainfall on mite population fluctuations in Liboran, Baungon, Bukidnon (Pearson correlation $r = -0.30$, $p = 0.08$)

In 2010, a severely mite-infested papaya farm in Pagatpat, Cagayan de Oro City ('Red lady' cultivar; 9 months after planting) was documented. The farm was regularly sprayed with cocktails of pesticides for mites and insect control. Based on index ratings, the mite infestation level recorded was considered very high, with average ratings of 2.5 on top leaves, 4.1 on the middle leaves and 5.0 on the bottom leaves. The *Stethorus* beetle population count was very low at 1.4 beetles per tree. Pest flare-ups could have been triggered by pesticide applications reducing beetle populations.

In this study, mite infestations and *Stethorus* beetle populations are significantly correlated. In the untreated block (Figure 7), the initial population of the predatory beetle in August 2010 gradually increased, together with the level of mite infestation, from October to December, and the two peaked together in January 2011. However, the populations of both mite and beetle predator crashed in February and March 2011. The beetle population was not able to recover despite an abundance of prey in April of that year. Although the treated block (Figure 8) was also infested to some extent, the beetle predator was never able to re-establish its population to high levels, most likely due to pesticide exposures (Figure 9).

Very few beetles were found on the treated block over the season (Figure 8). Mites persisted despite periodic applications of the miticide abamectin and insecticide dimethoate (Figure 9). Both chemicals have been shown to be highly toxic pesticides to *Stethorus* in laboratory bioassays (James 2003). The possibility of involvement of miticide resistance should not be discounted. Also, the negative effects of other chemicals applied into the crop could have affected beetle reproduction and the sustained suppression of mite populations. The *Stethorus* population was negatively correlated with the frequency of abamectin applications in the treated block, and with temperature (Figure 10).

Summary and conclusions

This paper summarised the spider mite seasonality study conducted for 23 months (starting May 2010) in Liboran, Baungon, Bukidnon. The red spider mite

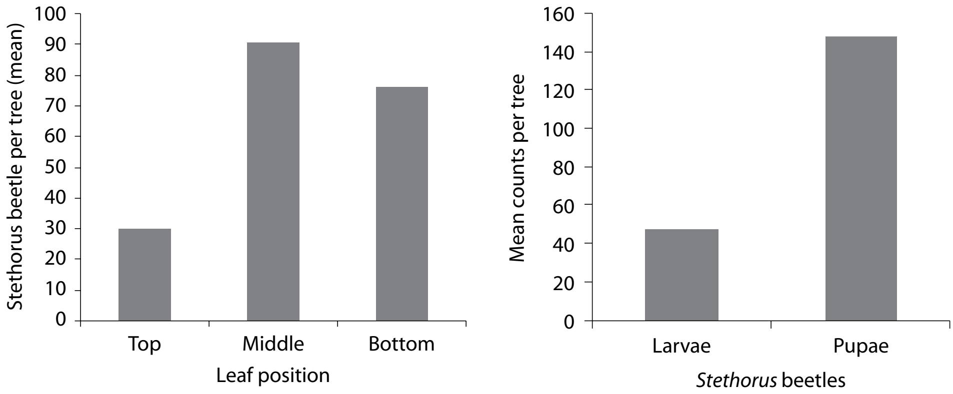

Figure 6. *Stethorus* beetle data gathered in a farmer's papaya field where pest mites were successfully suppressed by the beetle (Iponan, Cagayan de Oro, September 2009)

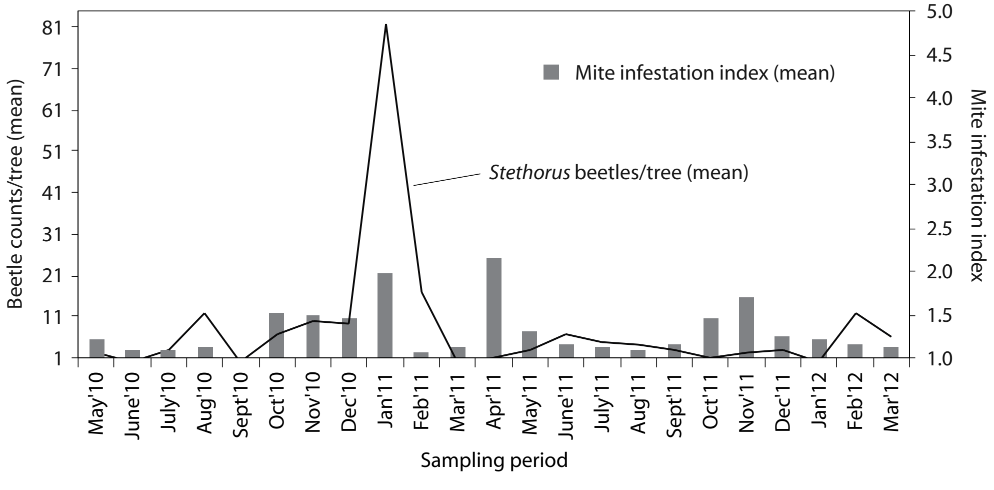

Figure 7. Mite infestation and *Stethorus* beetles counted on the untreated (control) block at Liboran, Baungon, Bukidnon (Pearson correlation $r = 0.42$, $p = 0.05$)

Tetranychus kanzawai persisted in the area but was present in relatively low number. The mite population reached peaks in January and April 2011 and mite damage inflicted on the crop was most severe during those months, including May 2011. A relatively low level of infestation was recorded between June and September of 2010 and 2011. The green mite species *Eutetranychus africanus* also infested papaya from July to November 2011.

The population of the predatory beetle *Stethorus pauperculus*, which was confirmed to be a voracious mite feeder, was severely affected by frequent miticide (abamectin) applications. An alternate approach to miticide use is the mass-rearing of

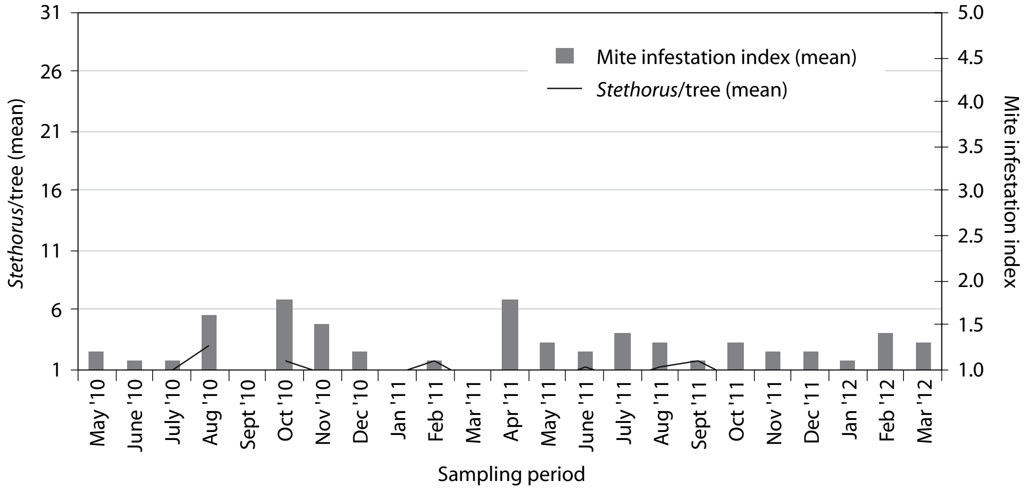

Figure 8. Mite infestation and *Stethorus* beetles counted on the treated block at Liboran, Baungon, Bukidnon

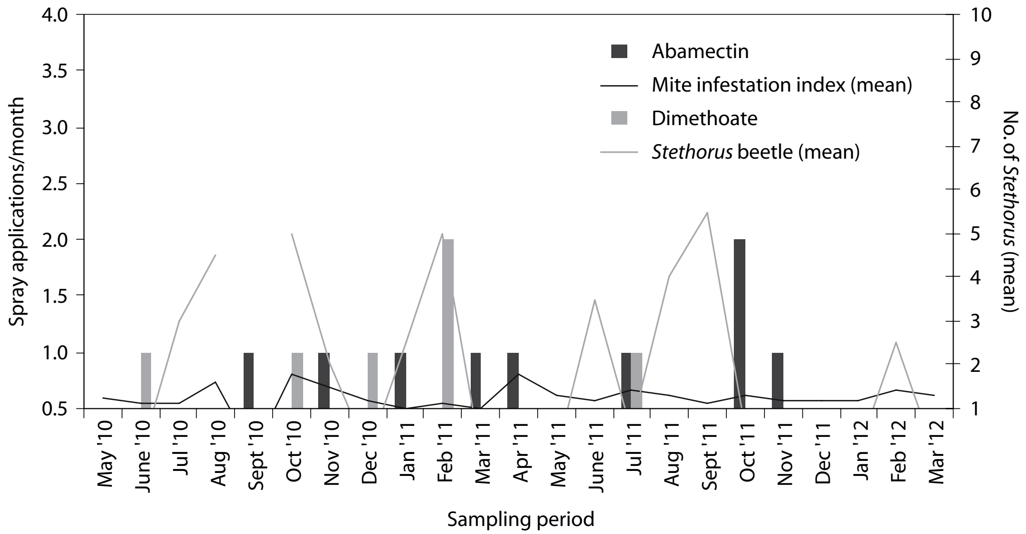

Figure 9. The effects of calendar application of pesticides on the *Stethorus* population and mite infestation on papaya treated with abamectin and dimethoate in Liboran, Baungon, Bukidnon (*Stethorus* and abamectin Pearson correlation $r = -0.40$, $p = 0.05$)

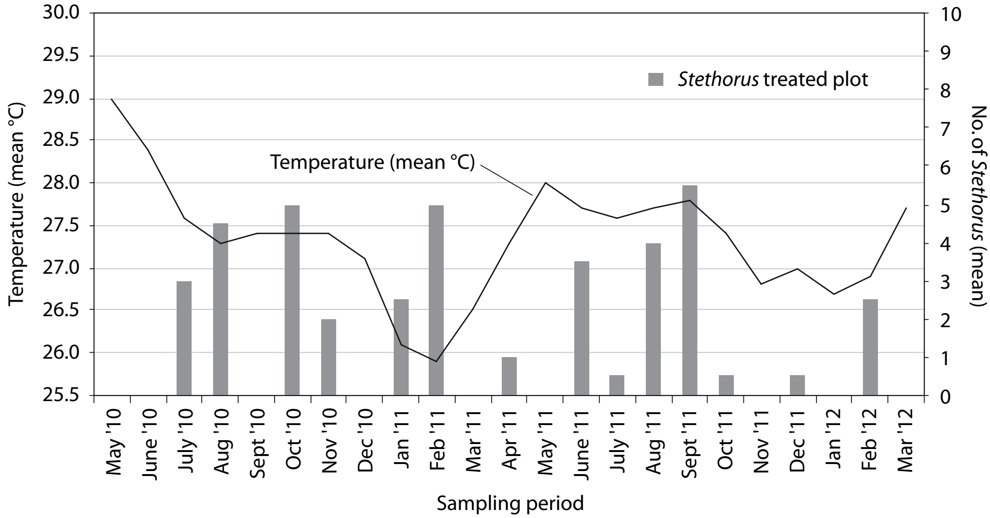

Figure 10. Influence of temperature on the field survival and success of the *Stethorus* population in Liboran, Baungon, Bukidnon (Pearson correlation $r = -0.47$; $p = 0.05$)

Stethorus beetle for augmentation of the field beetle population. However, development of an improved mass-rearing technique would be necessary to fully utilise the beetle's potential for mite biocontrol in the field and as a major component of an IPM program. De-leafing of severely infested older leaves, which are less important to photosynthesis, reduces the pest load in the tree. Non-chemical suppression of phytophagous mites on papaya offers big potential for a more sustainable, environmentally friendly management of mites, possibly at a lower production costs than chemical use.

High rainfall reduced mite populations in the field. The total amount of precipitation had cumulative effects not only on mite infestation but also on the predator population. The seasonal windows of peak mite populations are critical monitoring periods and decision points for miticidal interventions. Seasonal climatic variations that affect spider mite development (e.g. seasonal weather patterns of rainfall, temperature etc.) can be skewed by up to 2–3 months (forwards or backwards) as well as vary over different seasons.

The results of this study provided a much better understanding of the pest status and bioecology of red spider mites in commercial production of processing papaya. The grower-based monitoring system developed for mite and predator populations is a useful decision-support tool to help growers know when to apply acaricides only as a last resort. The main benefit is reduced pesticide use, which lowers the cost of production, helps delay pesticide resistance and avoids conditions that promote mite flares. An understanding of the importance of the role and conservation of predators and their impact on pest mite populations in reducing the reliance on acaricides to prevent mite flares provided a helpful foundation for the development and implementation of a grower-based IPM program for spider mites and beneficial insect management on papaya.

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Maximum residue limits: compliance issues and problems in Philippine mango exports

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Abstract

Mango is one of the major export products of the Philippines and ensuring mangoes conform to maximum residue limits (MRLs) in importing countries can be problematic for exporters. Difficulties arise because of limited information on how to prevent MRL violations. This study explored aspects of pesticide use, with the aim of identifying sustainable strategies to aid in achieving MRL compliance and thus to improve export competitiveness and profitability.

The decline of the concentration of residues of three of the most commonly used pesticides in Philippine mango production, i.e. cypermethrin, lambda-cyhalothrin and tebuconazole, was studied. Mango crops in Samal, Davao del Norte; Bansalan, Davao del Sur; General Santos City, South Cotobato (Mindanao); Cebu (Visayas); and Cavite and Batangas (Luzon) were sprayed with the pesticides and samples collected and analysed at regular time intervals post-application.

The analysis of the harvested samples found that, for the three pesticides, residues above the MRLs of key export destinations, such as Japan, could occur when current label directions were followed. On that basis, it is recommended that the concept of 'export harvest intervals', in which the harvest interval is extended, be considered for mango exports. Several recommendations, such as increasing analytical capacity for pesticide residues, are proposed with respect to mitigating residue violation risks. The communication of market requirements in terms of residues is important through the provision of targeted training to farmers and spraying contractors. Lastly, the implementation of a traceback regime in the mango supply chain, underpinned by the introduction of a farmer's notebook containing a detailed history of pesticide application, is proposed.

Introduction

The Philippines is the world's sixth-largest mango exporting country and is reliant on maintaining access to export markets to sustain economic viability and development. In fact, the Philippines Government has identified increasing mango export volumes as one element in a strategy to improve industry profitability and enhance farmers' incomes.[3] To sustain this growth, export-orientated agricultural industries need to gain and retain market access through compliance with importing country standards. Unfortunately, many importing countries are introducing increasingly stringent domestic food quality and safety standards. In consequence, ensuring compliance is becoming increasingly problematic with concerns expressed over the potential adverse impact where industries lack the systems or capacity to comply (Jaffee et al. 2005; Henson and Jaffee 2007).

Maximum residue limits (MRLs) of pesticides are one area in which the enforcement of more stringent

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3 Mango Industry Strategic Plan 2006, Philippine Department of Agriculture

standards has become a significant issue in the global trade of raw agricultural commodities. Breaches can occur through differences in MRLs set between exporting and importing countries, leading to trade irritants and residue violations. These disparities can arise due to a number of factors, such as different use patterns resulting in different national MRLs, through failure to adopt good agricultural practice (GAP) in use of pesticides, or as a result of misuse of pesticides by applicators.

As many importing countries, such as Japan and Taiwan, are applying increasingly stringent MRLs, it has been recognised that the Philippine mango industry needs to more effectively manage pesticide use and the resultant residues so as to ensure export market compliance, as failure to do so would jeopardise market access, to the detriment of exports and farmer profitability.

MRL violations detected in Philippine mango exports have previously been attributed to a combination of factors such as non-GAP use of pesticides, limitations of government and private laboratories undertaking residue analyses, and a misunderstanding by stakeholders over the concept of MRLs and how they are estimated and established. To tackle these shortcomings, the mango component of the ACIAR–PCAARRD horticulture program evaluated pesticide use from the perspective of MRL compliance, then undertook supervised residue trials to develop residue profiles for three pesticides commonly used in mangoes; i.e. cypermethrin, lambda-cyhalothrin and tebuconazole. The aim was to identify current aspects in pesticide use that have the potential to limit export market access and mango industry competitiveness, and propose sustainable pesticide management practices that would aid in reducing the occurrence and risk of MRL violations.

Philippine mango industry

Mango is an important crop in the Philippines. It is highly prized by Filipinos, both as consumers and producers. The country ranked as the world's seventh-largest producer and sixth-largest exporter. With a domestic production worth $US0.96 billion, mangoes support about 2.5 million farmers with a gross value-added contribution to agriculture of $US0.31 billion. Exports are valued at $US31 million for fresh mangoes and $US29.7 million for processed products (Pagkaliwagan 2012). An improvement in industry value would therefore provide a significant benefit to the population in general.

A key export market for quality Philippine mangoes has been Japan from a price consideration. However, in 2010 only 18.7% of fresh mango exports was shipped to Japan, while 76.3% was sent to Hong Kong (PCAARRD 2010). Based on partial data for 2011 (BAS 2011), 15.68 million tonnes of fresh mango were exported to Hong Kong, compared with 3.67 million tonnes to Japan valued

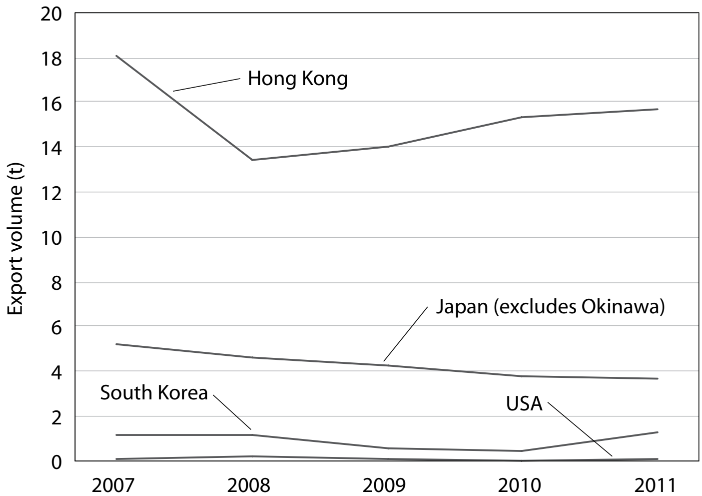

Figure 1. Volume of fresh mango exported from the Philippines to major destination countries (BAS 2011)

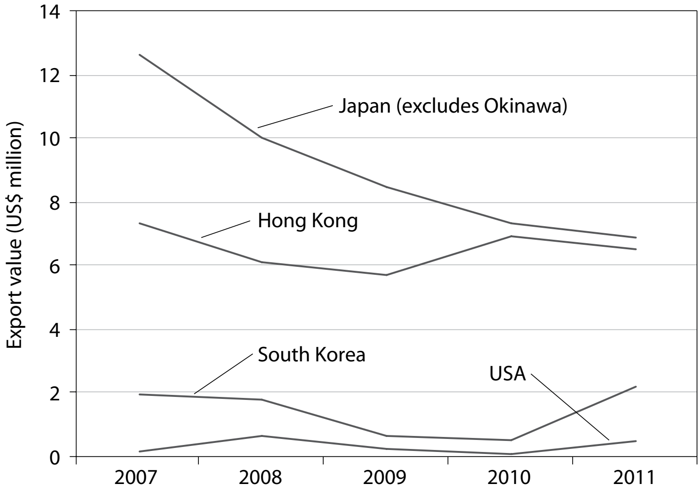

Figure 2. Value of fresh mango exports from the Philippines to major destination countries (BAS 2011)

at $US6.525 million and $US6.876 million, respectively. Historical data show that the volume and value of fresh mango exports to major destination countries are declining (Figures 1 and 2). Alternative markets are being developed, while the industry is encountering increasing difficulties in ensuring compliance with Japan's positive list MRL at a default value of 0.01 mg/kg. In addition, the alternative destinations for fresh fruit such as Hong Kong, and for processed fruit such as Korea, China and Singapore, have also started to become more stringent with respect to enforcement of lower MRLs. From a Philippine mango industry perspective, these developments are creating trade barriers.

Pesticide residues and MRLs

Approval of pesticides for use in Philippine mango production is regulated by the Fertilizer and Pesticide Authority (FPA). The FPA considers submitted data on specifications, bio-efficacy, toxicology, environmental fate and transport, environmental effects and residues of pesticides before a trade permit is issued. These submissions, which can include local residue data, are also used to determine suitable preharvest intervals of pesticide application and for local dietary risk assessments. The latter is based on local diet as published by the Food and Nutrition Research Institute. As part of this assessment, a MRL is proposed with the Bureau of Agricultural Product and Food Standards (BAPFS), which is mandated to implement such standards. Tables 1 and 2 list the pesticides currently registered for use on mango, with corresponding preharvest intervals (PHIs).

Pesticide residue analysis of export mangoes is currently being done by the National Pesticide Analytical Laboratory (NPAL) of the Bureau of Plant Industry (BPI) or its satellite laboratories. In Mindanao, the Davao Pesticide Analytical Laboratory (DPAL) is mandated to do analyses of mangoes for export. For exports to Japan, the pesticides chlorpyrifos, cypermethrin and profenofos are currently monitored. This list of analytes can be expanded should more violations of MRL standards occur. However, it is the exporter/consolidator/farmer who samples fruit, and all analyses are done on an 'as received' basis by NPAL. Positive detections of pesticide residues, irrespective of concentration, result in rejection for export, even if the value is below the MRL of the importing country.

Various pesticide residue laboratories are accredited by FPA, such as the National Crop Protection Center (NCPC), the University of the Philippines Los Baños (UPLB) – Pesticide Toxicology and Chemistry Laboratory (focused on research) plus a number of private laboratories. However, the capability, in terms of laboratory equipment and trained personnel, needs to be enhanced to provide the support required by the mango Industry, as well as other export-orientated agricultural industries in the Philippines.

Table 1. Fertilizer and Pesticide Authority registered insecticides for mango and corresponding preharvest interval (PHI) and maximum residue limit (MRL) in parts per million

Insecticide	Label PHI (days)	Critical GAP active ingredient/100L	Philippine MRL	Codex MRL (ASEAN MRL, year)	Japan positive list
Acetamiprid	14	3.75	5	x	1
Beta cyfluthrin	28	10.16	0.02	x	0.02
Beta cypermethrin	1	7.5	0.05	x	0.05
BPMC (fenobucarb)	14	109.38	x	x	0.3
Buprofezin	15	100	x	0.1	0.5
Carbaryl	1	425	3	x	3
Carbosulfan	14	80	0.05	x	0.3
Cartap	10	62.5	3	x	3
Clothianidin	10	2.5	1	x	1
Cyfluthrin	7	3.75	0.02	x	0.02
Cypermethrin	7	9.38	0.03	0.7 (0.5, 2008)	0.03
Cyromazine	14	35.16	0.2	0.5	0.5
Deltamethrin	1	1.56	0.5	x (0.2, 2010)	0.5
Diazinon	14	150	0.1	x	0.1
Dimethoate	14	75	1	1	1
Dinotefuran	7	25	1	x	1
Esfenvalerate	3	3.125	1	x	1
Fenvalerate	2	15	1	x (1, 2010)	1
Etofenprox	7	12.5	2	x	2
Fenthion	14	203	5	x	5
Gamma cyhalothrin	3	4.69	0.1	0.2	0.5
Imidacloprid	20	5 to 31.5	1	0.2	1
Lambda cyhalothrin	3	2.34	0.5	0.2 (0.1, 2009)	0.5
Methiocarb	21	156.25	0.05	x	0.05
Permethrin	4-7	18.75	5	x	5
Phenthoate	14	156.25	0.1	x	0.1
Profenofos	7	62.5	0.05	0.2 (0.2, 2010)	0.05
Pymetrozine	40	20.0	0.1	x	0.1
Thiamethoxam	65	3.9	1	x	0.2
Spinosad	7	2.0	0.1	x	0.3
Trichlorfon	7	297	0.5	x	0.5

x = no Codex MRL

Methodology

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

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

The pesticides investigated were prioritised on the basis of their significance to the Philippine mango Industry. The following pesticides were identified as important: cypermethrin was chosen to represent pesticides with high-volume usage; i.e. with more than 100 approved formulations in the market as well as potentially being applied close to harvest; i.e. a PHI of 7 days. In addition, violative residues of cypermethrin have previously been detected on Philippine mango exports to Japan. Tebuconazole was also selected due to its increased potential for use, and because the analytical methodology for its measurement was well known. Lambda-cyhalothrin

Table 2. Fertilizer and Pesticide Authority registered fungicides in mango and corresponding preharvest interval (PHI) and maximum residue limit (MRL) in parts per million ppm)

Insecticide	Label PHI (days)	Critical GAP active ingredient/100L	Philippine MRL	Codex MRL	Japan positive list
Azoxystrobin	3–7	23.44	1	0.7	1
Captan	14	250	5	x	5
Carbendazim/Benomyl/ thiophanate methyl	14	62.5	2	5	2
Chlorothalonil	7–14	270	0.5	x	0.5
Difenoconazole	14	15.6	1	0.07	1
Dithiocarbamates/mancozeb	5–7	300	2	2	2
Cyromazine	14	35.2	0.2**	0.5	0.3
Tebuconazole	22-25	18.75	1	0.1	1
Propineb	7	284.4	2	x	*
Thiram	14-21	200	0.05	x	*
Triforine	5	35.6	2	x	2

x = no Codex MRL
* If there is no indicative value under the column on the Japan positive list, the default value of 0.01 mg/kg will apply.
** Proposed by Croplife Philippines Syngenta

was also chosen as it is one of the few pesticides registered for thrips, a major pest of mangoes in Mindanao, and for late season use against fruit fly, with applications close to harvest.

The study aimed to generate residue data on selected pesticides, applied on the basis of current Philippine label recommendations in mango production. The intent was to develop a clearer understanding of residue decay in strategic production areas of the Philippines, such as Southern Mindanao, to help develop pesticide management strategies/systems with respect to achieving MRL compliance in export destinations. As a first step towards the final objective, a compilation of MRLs from countries to which Philippine mangoes are exported was prepared.

Supervised residue trials were established in Samal, Davao del Norte; Bansalan, Davao del Sur; General Santos City, South Cotobato (Mindanao); Cebu (Visayas); Cavite and Batangas (Luzon). The pesticide applications were based on the critical GAP; i.e. use of the highest label rate, the maximum number of applications and the shortest recommended interval. The spray application volume was pre-measured based on canopy height and diameter. Sampling was done after the last spray application, following the FAO protocols (FAO 2009). The analyses of the residues were done at NCPC–UPLB and BPI–NPAL, and at JefCor, a private Laboratory. All laboratories were accredited by the FPA.

Results

Management of pesticide residues in the mango supply chain: observations and recommendations

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

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

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

This lack of information was found to affect differing elements along the mango supply chain; i.e. both during and after production. To address these knowledge and capacity gaps, an effective residue management system is needed (see Figure 3). A first step to developing this would be the generation of the required information; i.e. determination of appropriate export GAP for priority pesticides. Integral to this would be an initial pesticide prioritisation process and the generation of residue profile data for the nominated pesticides.

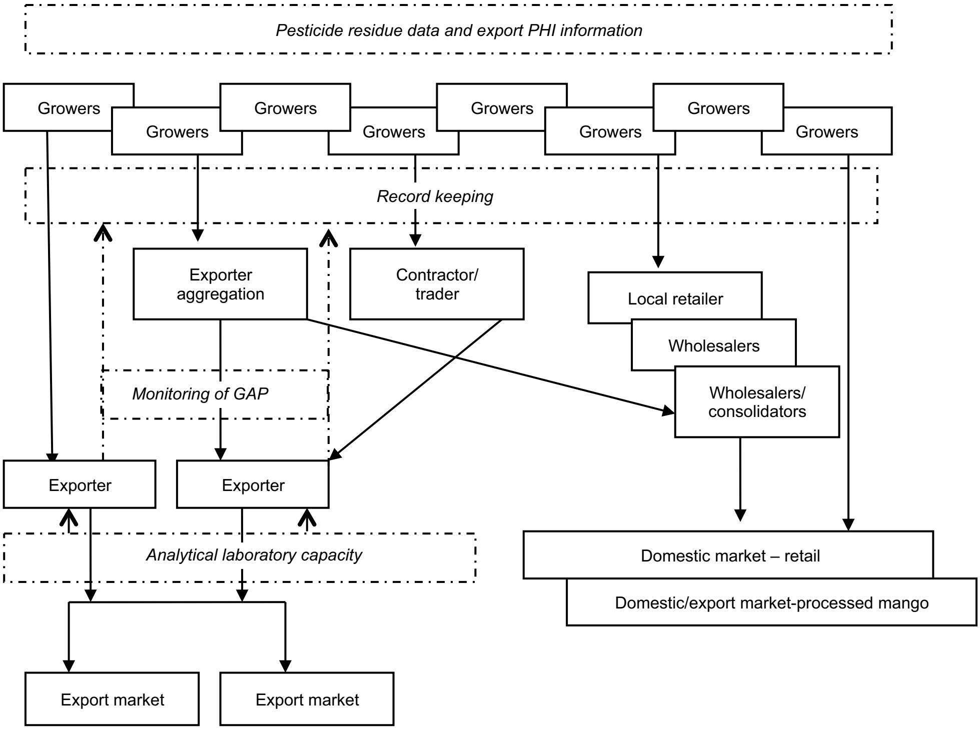

Figure 3. Simplified representation of the mango supply chain in the Philippines, outlining elements of a potential residue management system

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

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

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

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

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

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

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

Analyses of supervised residue trials

Cypermethrin

The cypermethrin residue study was done in five different sites. Residues at four sites were all below < 0.001 mg/kg at the label PHI of 7 days after spraying. However, at the General Santos, South Cotobato, site, the residues were 0.038 mg/kg; i.e. above the Japanese positive list MRL (0.03 mg/kg) but below the Codex or EU MRLs of 0.7 mg/kg. Considering the worst-case scenario, it is recommended that, if the export market is Japan, a lengthened withholding period be required. An alternative strategy, if an extended PHI is not possible, is to target alternative export destinations such as the EU or those countries adopting the Codex MRLs, such as Singapore.

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

Tebuconazole

Tebuconazole residues were not detected (< 0.001 mg/kg) at the Bansalan site (Davao del Sur) but were found at the limit of detection (0.001 mg/kg) from spraying at the Talikud site (Davao del Norte). In fruit sampled 7 DAS, the residues declined to non-detectable levels in Talikud and to 0.019 mg/kg in General Santos. However, in fruit from the Luzon site in Cavite, residues were still relatively high 14 DAS, with a concentration of 0.037 mg/kg, which would not comply with the Japanese MRL of 0.01 mg/kg. Therefore, it is suggested that an extended export harvest interval should be followed for mangoes grown in these regions.

Studies on tebuconazole were also done at Cebu, a mango-producing province in the Visayas. A residue level of 0.15 mg/kg was found 25 DAS, again higher than the Japanese MRL. However, this would be acceptable for exports to the USA, where that country's MRL is based on a postharvest usage dip. It is still recommended that, for this pesticide, the withholding period before export be doubled to ensure compliance with the Japanese MRL.

Lambda cyhalothrin

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

Suggestions for trade risk reduction due to pesticide residues

Bodnaruk and Bajet (2007) listed a number of major problems facing the Philippine mango industry, and their analysis is still valid. In addition, based on the interactions and observations made with stakeholders and farmers, in this study it is recommended that the extension of information dissemination and awareness should be strengthened, especially on the understanding of residues, MRLs, GAP and PHI, to those who are applying pesticides and how their practices can affect trade. This could be extended to other major players in the mango supply chain. Some of the misconceptions noted were:

1. that the Japanese MRL for chlorpyrifos of 0.05 mg/kg on mango was arbitrary, given there were higher MRLs for edible peel fruits such as grapes, apples and cherries at 1 mg/kg; i.e. it was not understood that MRLs are set on the basis of residue data resulting from use according to GAP
2. related to questions regarding MRLs being risk based; i.e. again it was not understood that MRLs relate to GAP and are not health limits per se
3. that MRLs apply to the commodity as it moves in trade not as it might be consumed; i.e. that residue analysis for MRL compliance is on the whole commodity not after the washing or peeling of mangoes.

Based on the results for cypermethrin and tebuconazole, extending the withholding time to double the recommended PHI is suggested, if the export destination is Japan. However, if PHI extension is not possible, selecting an alternative export destination with a higher MRL allowance would be needed.

In addition, a system of traceability of mango to the producer or source is highly recommended. This should also be coupled with a farmer's notebook as a requirement for farmer clusters supplying the export market. Continuous monitoring by the consolidator/exporter of pesticide applications by the farmer–supplier is also another strategy to reduce risk.

Lastly, generation of more residue data is needed to understand degradation of residues in major production areas. This should also be coupled with better laboratory facilities and engagement of personnel trained to do pesticide residue analysis.

Conclusions

The availability of information should be strengthened in the mango supply chain. Extension should be strengthened especially at the grassroots level and in major stakeholders on understanding residues and MRLs and how they are generated. Production of information and communication materials is essential, especially on the importance of following label directions. A system of traceability should be started, including a farmer's notebook on crop/pesticide management monitored by the consolidator/exporter. It is also proposed that local residue data be generated for the purposes of national MRLs and that these data be used to develop pesticide management strategies to minimize MRL violations and reduce trade risks. In this study, the data were used to propose an extended withholding period, where such is needed to ensure compliance with MRLs in export destinations such as Japan. For other export countries, such as Hong Kong, Korea and China and for local consumption, GAP should be strictly adhered to. For problematic persistent pesticides, it is recommended that the last application occur at 90 days after flower induction to allow degradation of residues to non-detectable levels.

Lastly, government support is needed in terms of regulation and promotion as well as provision of adequate pesticide residue laboratories to ensure that exports follow the standards of the importing countries. Part of the profit from mango exports should be ploughed back directly to the residue laboratories to maintain their sustainability and capacity to service the mango industry.

Acknowledgments

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Determining the profitability of modified IPM practice on the control of mango pulp weevil

Louella Rowena J. Lorenzana[1]

Abstract

Habitat disruption of the mango pulp weevil population (MPW) by the removal of 25% of the canopy diameter of MPW-infested mango trees, or open centre pruning, an improved component of integrated pest management (IPM), was initially evaluated in two demonstration trials at Brooke's Point, Palawan, the Philippines. A participatory action research (PAR) trial involving four mango growers was also conducted, following the same improved IPM work plan.

The IPM mango trees yielded an average of 175 kg fruit/tree and a net income of 1,729.50 pesos/tree in contrast to traditionally (farmers') managed trees, which yielded only 4 kg or an income of only 20.00 pesos/tree. In the PAR trial, a net income of 2,543.17 pesos/tree was achieved. The improved IPM offers a solution to the long-term problem of unproductive MPW-infested mango trees in southern Palawan.

Introduction

Mango trees in southern Palawan in the Philippines have been unproductive since the discovery of the quarantine pest *Sternochetus frigidus*, mango pulp weevil (MPW) in 1987 (Figure 1).

An integrated pest management (IPM) program was previously developed to address, in particular, the management of this key pest (Medina et al. 2005). Recent behavioural studies found that MPW adults remain in the main branches of mango trees at quiescent stage (Golez et al. 2008). Further improvement of the method for MPW habitat disruption through open-centre pruning, an IPM component, was needed. The economic benefits of removing 25% of the canopy diameter, rather than only the topmost branch as previously done, were determined through participatory action research (PAR) involving selected mango growers.

The objectives of the research reported here were to evaluate the results of a habitat disruption study on MPW and conduct PAR trials on mango IPM.

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Methodology

Evaluation of habitat disruption on MPW populations

Evaluation of habitat disruption of MPW populations was through cost–benefit analyses comparing improved IPM versus farmer practices (FP) for MPW control. The improved IPM work plan (Table 1) incorporates open-centre pruning or the removal of 25% of the canopy diameter (Figure 2a), pest monitoring, insecticide application and field sanitation in mango trees. Two demonstration trials (Figure 2b) with 10 MPW-infested trees per site in barangay Pangobilian, Brooke's Point, Palawan, were established to compare the improved IPM and farmer practices. Pest populations were recorded, marketable yield was determined and net income per tree was computed.

PAR trials on mango IPM

The IPM demonstration trial was successfully implemented so that the next phase was to conduct PAR trials in four test sites at Brooke's Point, with four farmer partners following the IPM work plan. Ten MPW-infested mango trees were used per site.

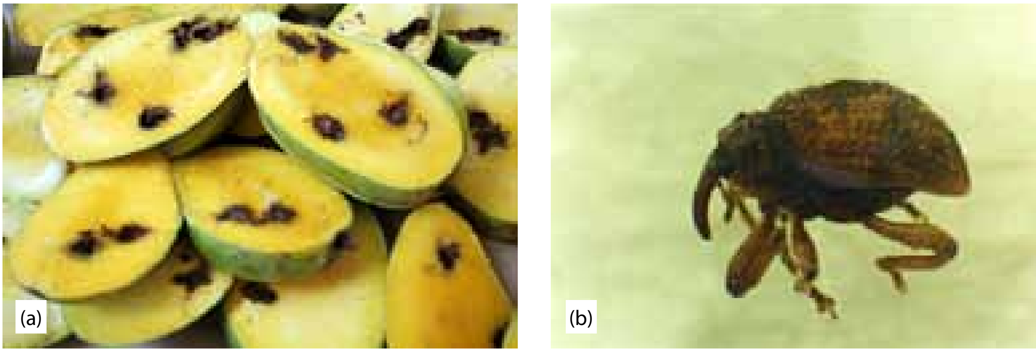

Figure 1. (a) Damage to mangoes caused by *Sternochetus frigidus*, mango pulp weevil (MPW); (a) adult MPW

Figure 2. (a) Open-centre pruning, removal of 25% canopy diameter; (b) Farmers' field day conducted on 16 June 2010 at Brooke's Point, Palawan

Marketable yield was determined and net income per tree was computed.

Results and discussion

Evaluation of habitat disruption on MPW populations

In IPM trees at demonstration site no. 1 (Espeleta's Farm), the insect pests were successfully controlled. Leafhopper populations remained low (Figure 3) and, as a result, fruit-set per panicle was high at 16.8 (Table 2). The MPW was zero, fruit fly reduced to 1.6%, anthracnose 3% and stem end rot 2.9%. In FP trees, the delay in chemical induction by the farmer-cooperator, and the frequent rain in February produced flushes on mango trees aborting the flowers (Table 2). Hence, trees on an adjacent farm, of about the same age as the FP test trees, were used for comparison. In this FP, the population of MPW was 3.8%, fruit fly 6.2%, anthracnose 14.5% and stem-end rot 4.2% which were all higher than in the IPM trees.

At demonstration site no. 2 (Ludin's Farm), the insect pests in the IPM trees were also successfully controlled. Adult leafhopper population remained low (Figure 4) and, as a result, fruit set per panicle was high at 20.2 (Table 3). MPW infestation was zero, fruit fly 0.8%, anthracnose 2.3% and stem end rot 1.7%. In the FP trees, leafhopper population control was high (Figure 4), but fruit set per panicle was low at 0.2 (Table 3). Only 20 fruit were harvested, of which 10% were infested by fruit fly, anthracnose and stem end rot. No MPW were found, but the sample size was too small.

The IPM trees yielded an average of 175 kg/tree and generated a net income of 1,729.50 pesos/tree. In contrast, the FP trees produced only 4 kg of mangoes or an income of only 20.00 pesos/tree (Table 4).

Table 1. IPM program for Pangobilian, Brooke's Point, Palawan

DAFI	Crop phenology	IPM strategy		
		Cultural control	**Pest monitoring**	**Chemical control**
7		Open-centre pruning		
8	Budbreak	Open-centre pruning		
13			√	
14	Panicle elongation			Confidor
17			√	
21			√	
22	Pre-bloom			Actara + Score + Hoestick
25	Full bloom		√	
35			√	
36	Fruit set			Solomon + Score + Hoestick
39			√	
41			√	
42	Marble size fruit			Bushwack + Score + Hoestick
45			√	
56	Chicken egg size fruit			Sevin + Score + Hoestick
65	Fruit development			Bushwack + Hoestick
76		Removal of fallen fruit and water sprouts; brush weeding		
77				Sevin + Score + Hoestick
92				Bushwack + Hoestick
107	Fruit maturity			Sevin + Score + Hoestick

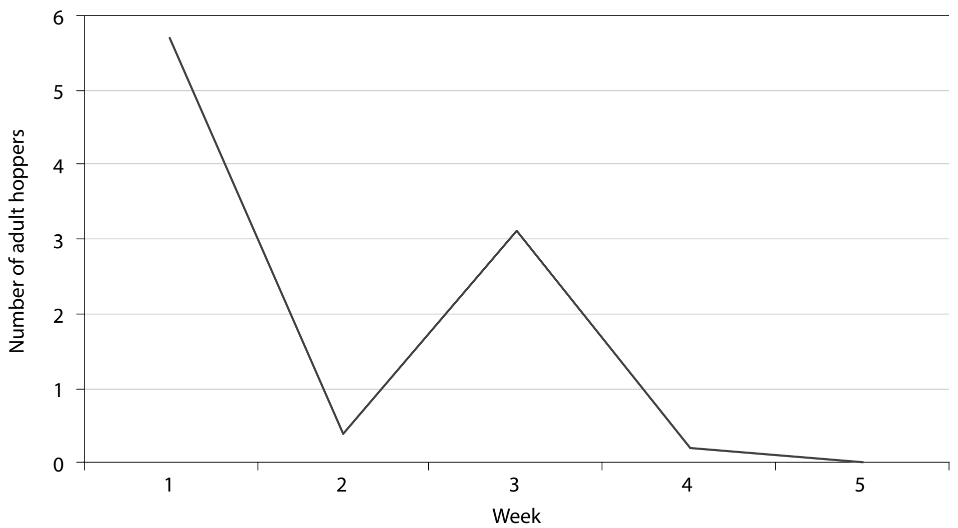

Figure 3. Number of adult leafhoppers on mango panicles in IPM site no. 1 (Espeleta's farm) at 1–5 weeks after chemical induction of flowering

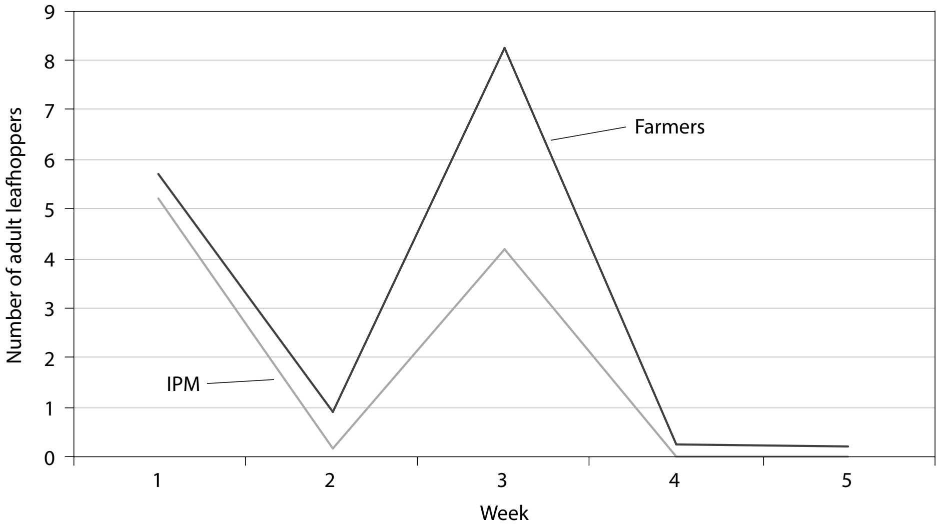

Figure 4. Number of adult leafhoppers on mango panicles in IPM and farmers' crop-protection practices at site no. 2 (Ludin's farm) at 1–5 weeks after chemical induction of flowering

Table 2. Comparison of fruit retention, the mango pulp weevil (MPW) pest population and disease infection in IPM and farmers' crop-protection practices (Espeleta's farm)

Parameter	IPM[a]	Farmers[b]
Fruit set per panicle	16.8	–
Fruit retention per panicle	0.9	–
Percentage infestation of MPW in fruits	0	3.8
Percentage infestation of fruit fly	1.6	6.2
Percentage anthracnose-infected fruits	3.0	14.5
Percentage stem end rot infected fruits	2.9	4.2

[a] Values are means from 10 panicles of 10 trees per treatment, or 100 fruit of 10 trees per treatment
[b] Because of crop failure at Espeleta's, based on another farm with trees of the same age as those in the IPM trial

Table 3. Comparison of fruit retention, the mango pulp weevil (MPW) pest population and disease infection in IPM and farmers' crop-protection practices (Ludin's farm).

Parameter	IPM[a]	Farmers[b]
Fruit set per panicle	20.2	0.02
Fruit retention per panicle	1.0	0.02
Percentage infestation of MPW in fruits	0	0
Percentage infestation of fruit fly	0.8	10.0
Percentage anthracnose-infected fruits	2.3	10.0
Percentage stem end rot infected fruits	1.7	10.0

[a] Values are means of 10 panicles from 6 trees per treatment, or 100 fruit of 6 trees per treatment.
[b] Based on only 20 fruit harvested

Conduct of PAR trials on mango IPM

The four farmer partners in the PAR trials (Figure 5) harvested an average yield of 140 kg of mango fruits per tree (Table 5). An average net income of 2,543.17 pesos/tree was achieved.

Conclusion and recommendation

Habitat disruption of MPW by removal of 25% of the canopy, or open-centre pruning, demonstrated control of MPW and its economic benefits in the PAR trial conducted. A net income of

Table 4. Analysis of costs and returns (in Philippine pesos) per tree for IPM and farmers' crop-protection practices

Item	IPM	Farmers' crop protection practices
Yield	175 kg	4 kg
Price	20.00 pesos/kg	20.00 pesos/kg
Gross return	3,500.00	80.00
Labour and power costs		
Application of chemicals (insecticide/fungicide/sticker)	744.30	
Pruning	96.00	
Monitoring	72.00	
Brush weeding/removal of fallen fruits	320.00	
Material costs		
Insecticide	364.10	59.20
Fungicide	144.10	
Sticker	30.00	
Total cost	1,770.50	
Net income	1,729.50	20.80

Figure 5. Farmer partners and their mangoes

Table 5. Summary of costs and returns (in Philippine pesos) for four farms in the PAR trial[a]

Items	Farmer–cooperator				Total	Mean
	Espeleta	Zabalo	Gavino	Abinque		
Yield (kg)	150	170	80	160	560	140
Price	25.00/kg	25.00/kg	25.00/kg	25.00/kg	–	25.00/kg
Gross return	3,750.00	4,250.00	2,000.00	4,000.00	14,000.00	3,500.00
Labour and power costs						
application of chemicals (insecticide/fungicide/sticker), pruning	390.00	390.00	195.00	330.00	1,305.00	326.25
Material costs						
insecticide	334.18	152.92	82.57	357.12	926.79	231.70
fungicide	235.80	188.64	102.20	212.22	738.86	184.72
sticker	56.10	56.10	21.50	51.00	184.70	46.18
foliar fertiliser	108.00	36.00	25.20	52.00	221.20	55.30
flower inducer	114.00	144.00	80.00	112.00	450.00	112.50
Total cost	1,238.08	967.66	506.47	1,114.34	3,826.55	956.64
Net Income	2,511.19	3,282.34	1,493.53	2,885.66	10,172.68	2,543.17

[a] Average values from 10 trees per cooperator.

2,543.17 pesos/tree was achieved. This showed that MPW-infested mango trees in Palawan could still be productive and provide income to mango growers. The improved IPM offers a solution to the long-term problem of unproductive MPW-infested mango trees in southern Palawan.

Acknowledgments

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Integrated disease management of stem end rot of mango in the southern Philippines

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Abstract

This research aimed to develop and evaluate pre- and postharvest management strategies to reduce stem end rot (SER) incidence and extend saleable life of 'Carabao' mango fruits in Southern Philippines. Preharvest management focused on the development and improvement of fungicide spray program, while postharvest management aimed to develop alternative interventions aside from hot water treatment (HWT). Field evaluation of systemic fungicides, namely azoxystrobin (*Amistar 25SC*), tebuconazole (*Folicur 25WP*), carbendazim (*Goldazim 500SC*), difenoconazole (*Score 250SC*) and azoxystrobin + difenoconazole (*Amistar Top*), reduced blossom blight severity and improved fruit setting and retention, resulting in higher fruit yield but failed to sufficiently suppress SER incidence. Based on these findings, an improved fungicide spray program was developed taking into account the infection process of SER pathogens and fungicide resistance. Timely application of protectant (mancozeb) and systemic fungicides (azoxystrobin, carbendazim and difenoconazole) during the most critical stages of mango flower and fruit development ensured higher harvestable fruit yield and minimally lowered SER incidence. Control of SER was also achieved by employing postharvest treatment such as HWT (52–55°C for 10 min), which significantly prolonged the saleable life of mango fruits. However, extended hot water treatment (EHWT; 46ºC pulp temperature for 15 min), rapid heat treatment (RHT; 59°C for 30–60 sec), fungicide dip and promising biological control agents failed to satisfactorily reduce SER and prolong saleable life. In contrast, the integration of the improved spray program as preharvest management practice, and postharvest treatments such as HWT and fungicide dips (azoxystrobin, 150–175 ppm; carbendazim, 312.5 ppm; and tebuconazole, 125–156 ppm), significantly reduced disease and extended marketable life for utmost 8 days.

Introduction

Mango stem end rot (SER) remains a major constraint in the production of 'Carabao' mango in the major supply areas in the Philippines, including Southern Mindanao. Infection starts in young fruit but no symptoms appear until the fruit is harvested and ripened. SER is caused by a complex of fungal pathogens making it difficult to manage. Its management is greatly dependent on the management practices for anthracnose but, once the disease is suppressed, SER becomes a major problem, thus reducing the potential storage life and limiting the market in which mango fruits can be shipped in fresh form.

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The preharvest disease management program includes sanitation, cultural practices and preharvest field sprays. Fungicide application is indispensible to manage SER. Previous research identified effective non-systemic fungicides against SER such as prochloraz (Peterson et al. 1991); mancozeb and copper oxychloride against *Diplodia natalensis* (*Botryodiplodia* sp.) (Pordesimo and Barredo 1976); and copper oxychloride, iprodione or propiconazole (Johnson et al. 1991). The systemic fungicide carbendazim (Bavistin) provided excellent protection against *Botryodiplodia theobromae* (Rawal and Ullasa 1988). To prevent development of fungicide resistance and ensure low level of SER infection at harvest, further research is required to develop a field spray program considering the proper positioning of fungicides in the phenological stages of mango development.

On the other hand, applicability of postharvest treatments is limited to mango exporters and processors (Aveno et al. 2006). Decay control during storage and marketing has principally relied on heat treatments, fungicide application, manipulation of storage conditions (Esguerra et al. 2004) and cool storage (McLauchan and Wells 1994). Controlled atmosphere (CA) storage for 26 days followed by air storage for 11 days at 20°C then hot benomyl and prochloraz effectively managed SER (Johnson et al. 1990).

Recent studies showed that the integration of pre- and postharvest quality management focusing on disease management in the northern Philippines (Region I) extended the storage life of 'Carabao' mango under CA condition for 29 days, with a marketable period of 6 days upon removal from CA (Esguerra and Opina 2007). Preharvest disease management involved cultural practices such as open centre canopy and sanitary pruning, nutrient management, flower induction technologies, sanitation and bagging, and an improved fungicide spray program. On the other hand, postharvest treatment relied heavily on hot water treatment (HWT) and fungicide dipping. However, these management interventions may not be sufficient to reduce SER incidence to an acceptable level considering the extremely favourable conditions for disease development in the southern Philippines.

This study was therefore conducted to develop and evaluate pre- and postharvest management strategies to reduce SER incidence and extend saleable life of 'Carabao' mango fruits in the southern Philippines.

Preharvest management

Evaluation of systemic fungicides

Systemic fungicides were used in this study, considering the endophytic nature of SER pathogens. These were azoxystrobin (Amistar 25SC), tebuconazole (Folicur 25WP), carbendazim (Goldazim 500SC), difenoconazole (Score 250SC) and azoxystrobin + difenoconazole (Amistar Top). All fungicides were applied seven times starting from flowering (pre-bloom) to fruit development stages following the manufacturer's recommended rate. Evaluation was done on 10–12-year-old full-bearing mango trees following the recommended integrated crop management practices. All the tested systemic fungicides reduced blossom blight severity and resulted in high fruit setting and retention. The fungicide sprays significantly improved the fruit yield as compared with the control. Among the chemical treatments, azoxystrobin, carbendazim and azoxystrobin + difenoconazole reduced SER incidence on 'Carabao' mango fruits maintained in ambient room conditions for 11 days after harvest but not significantly different from the untreated fruits. However, when fruits were subjected to HWT, difenoconazole and azoxystrobin + difenoconazole appeared to be more effective than the other fungicides.

Optimisation of fungicide spray program

An improved fungicide spray program was developed, taking into account knowledge on the infection process of SER pathogens, fungicide resistance management strategies and previous studies. Systemic and protectant fungicides were positioned during the most critical stages of phenological development of mango. During the anthesis stage (21–25 days after flower induction, DAFI) and full bloom to postbloom stage (28–30 DAFI), tank-mix of azoxystrobin and mancozeb was sprayed to control blossom blight and early infection of SER. Full doses of non-systemic fungicide mancozeb (30–35 DAFI—postbloom to fruit set) and systemic fungicides carbendazim (40–45 DAFI—young fruit; corn seed size), azoxystrobin (50–55 DAFI—young fruit; chicken egg size) and difenoconazole (70–80 DAFI—premature fruit) were successively sprayed at the most susceptible stages in mango fruit development (Figure 1). This improved spray program was implemented and evaluated in Bansalan, Davao del Sur, following recommended integrated crop management and pest

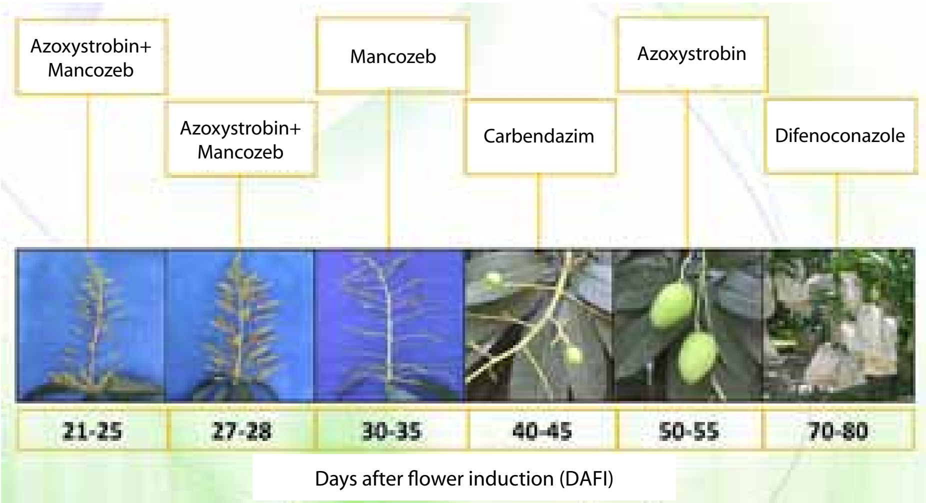

Figure 1. Strategic timing of fungicide spray based on the phenological development of 'Carabao' mango fruits

management practices of mango. Field evaluation indicated that, under extreme rainy events, the spray program sufficiently suppressed blossom blight, resulting in high harvestable fruit. Assessment of SER incidence on harvested fruits showed that the spray program minimised SER incidence 14 days after harvest, but prolonging the storage beyond 14 days after harvest resulted in a very high level of SER incidence.

Postharvest management

Heat treatments

In response to export requirement imposed specifically by Japanese importers, hot water treatment (HWT) technology has been used by export and processing corporations since the beginning of their mango operations (Aveno et al. 2006). This technology involves dipping the fruit at 52–55°C for 10 minutes within 24 hours after harvest (Quimio and Quimio 1974). HWT has proven effective against anthracnose and, at present, several types of heat treatments have been developed but they vary mainly in terms of the optimal time–temperature combination. Experiments were conducted at different mango seasons to investigate the effectiveness of heat treatments such as extended hot water treatment (EHWT) and rapid heat treatment (RHT) as compared with the conventional HWT against SER incidence on 'Carabao' mango fruits.

EHWT

This heat treatment was developed for disinfesting mango fruitflies as an alternative to vapour heat treatment (VHT) (Provido 2007). Fruit were subjected in hot water (48ºC) until the pulp temperature reached 46ºC, which was maintained for 15 minutes. An experiment was conducted to determine the efficacy of EHWT in reducing SER of mango and its effect on the saleable life of mango fruit. Results showed that EHWT and HWT significantly reduced the incidence of SER by 52–80% and prolonged the saleable life of mango fruit by 5–6 days as compared with the untreated fruits (Table 1). HWT appeared to be more effective than EHWT in reducing SER incidence. The inability of EHWT to sufficiently control SER may be due to its failure to reach the thermal death point of SER pathogen, which is in the range 53–55ºC (Quimio and Quimio 1974; Mortuza 1994).

RHT

Rapid heat treatment (RHT) is a modification of conventional HWT to allow treatment of a higher volume of fruit in a shorter time. Due to slow adoption and misapplication of HWT because of the long treatment time, RHT involving a combination of optimal time–temperature of 35–60 sec dip at 59–60°C without requiring hydrocooling after treatment, was developed (Esguerra et al. 2006). Results showed that RHT did not reduce SER incidence compared with the control

(Table 2). As expected, HWT significantly reduced SER incidence and extended saleable life of mango fruit. The failure of RHT to suppress SER incidence could be attributed to the deep-seated nature of infection in which a brief exposure to higher temperature may not be enough to inactivate SER pathogens. Heat treatments provide variable degree of disease control due to the alteration of dominance of SER pathogens (Portales 2008) and different levels of sensitivity of the pathogen (Ben-Yehoshua et al. 2000) to varying temperatures.

Table 1. Stem end rot (SER) incidence and saleable life of 'Carabao' mango fruits subjected to hot water treatment (HWT) and extended hot water treatment (EHWT) and ripened at ambient temperature at 19 days. Laguna, Philippines, 2008

Treatment	SER Incidence (%)	Saleable life (days)
EHWT	22.2b	11.6a
HWT	8.9c	10.8a
Untreated Control	46.7a	5.9b
CV (%)	25.36	7.82

Means followed by the same letter are not significantly different at 5% level, LSD.

Table 2. Stem end rot (SER) incidence and saleable life of mango fruits treated with rapid heat treatment (RHT) and hot water treatment (HWT) and stored in cold room (13°C) or at ambient room temperature (28°C) for 14 and 18 days, respectively. Laguna, Philippines, 2010

Treatment	SER Incidence (%)	Saleable life (days)
RHT	35.09a	2.0b
HWT	8.77b	7.3a
Untreated Control	36.23a	0.0c
CV (%)	26.13	0

Means followed by the same letter are not significantly different at 5% level, LSD.

Fungicide dip

Five systemic fungicides, namely tebuconazole, azoxystrobin, thiobendazole, carbendazim and benomyl, were evaluated as postharvest dips against SER. Newly harvested fruit were dipped in fungicide solution at the manufacturer's recommended rate for 5 minutes. Another set of fruit was subjected to HWT before being were dipped in fungicide solution. Treated fruit were stored in a cold room for 28 days and ripened at ambient room temperature for 3–6 days to allow further expression of SER symptoms. All the fungicide dips failed to suppress SER incidence (Table 3). However, significant reduction in SER incidence was observed among the fungicide dipped fruit subjected to HWT. Hence, the efficacy of fungicide dips was enhanced when integrated with heat treatment. Rappel et al. (1991) reported that hot water dip treatments did not eliminate the requirement for postharvest fungicides in mangoes cv. Kensington Pride, even though the thermal death point of the pathogen was reached. Treatment of the fruits with hot water/fungicides after harvest eradicates the remaining latent infections and SER pathogens (Eckert and Ogawa 1985) because HWT does not protect fruits against

Table 3. Stem end rot (SER) incidence on mangoes subjected to HWT and non-HWT coupled with fungicide, and stored for 28 days in a cold room (12°C) then maintained at ambient room temperature (28°C) for 6 days after withdrawal from cold storage, Laguna, Philippines, 2009

Fungicide	SER incidence (%)			
	3 days after withdrawal in cold room		6 days after withdrawal in cold room	
	Non-HWT	HWT	Non-HWT	HWT
Tebuconazole	43.33a	1.67c	68.33a	20.00bc
Azoxystrobin	58.33a	31.67a	81.67a	40.00abc
Thiobendazole	57.04a	35.00a	89.33a	48.33ab
Carbendazim	46.67a	6.67bc	62.59a	11.67c
Benomyl	64.21a	18.33ab	81.67a	38.33abc
Control	65.00a	33.33a	81.67a	70.00a
CV (%)	13.28	34.56	14.31	31.56

Means followed by the same letter are not significantly different at 5% level, LSD.

reinfection by *Dothiorella dominicana* (Sangchote 1991). Lurie (1998) suggested that the effectiveness of fungicide can be enhanced by applying the fungicide in a hot water bath, thus allowing more effective fungal control with a reduction in the rate of chemical.

Biological control

Seventy fungal isolates (49 endophytes and 21 epiphytes) were isolated from different plant parts of mango, such as fruit, leaves, pedicels and panicles. These endophytic and epiphytic fungi were screened against the SER pathogen using the dual culture technique (DCT) in which mycelial discs of the pathogen and the isolate were placed equidistantly on potato dextrose agar plates and incubated for 7 days under normal laboratory conditions. After the initial DCT, 16 of the 70 isolates were considered as potential antagonists due to the high degree of antagonism and antagonistic activity. After the second DCT, four isolates were established as potential antagonists and screened in vivo. Promising endophytic fungi (Epi 18, FI 3, and FI 5) produced clear zones of inhibition suggesting antibiosis as mode of action, while potential epiphytic fungi showed hyperparasitism. The control efficacies of the promising fungal isolates were assayed and compared against a biofungicide (Serenade) in vivo. Results indicated that the biofungicide and fungal isolates failed to control SER infection. However, dipping the mango fruit into the fungal isolates suspension extended the saleable life for 1 day.

Integrated pre- and postharvest management

The improved fungicide spray program was evaluated in production areas under high and low disease pressures as represented by Davao del Sur and Laguna, respectively. The spray program was implemented as part of an integrated crop management (ICM) program for mango. Fruit were harvested at mature stage (110 days after flower induction, DAFI) and subjected to postharvest treatments such as HWT and low-temperature storage (13°C). This study was conducted to determine the efficacy of integrated pre- and postharvest management practices under varying disease pressures. Since the improved spray program minimally reduced disease pressure at harvest, further exposure of the mango fruit to conventional HWT and storage at 13°C lowered and delayed the rate of SER infection and markedly prolonged the saleable life of the fruit. The integrated disease management (IDM) practices appeared more effective under low disease pressure.

Integrated postharvest management interventions such as heat treatments (RHT and HWT), fungicide dipping (azoxystrobin, 150–175 ppm; carbendazim, 312.5 ppm; and tebuconazole, 125–156 ppm) and low-temperature storage were refined and evaluated to determine their effect on SER incidence and saleable life of mango fruit sourced from Laguna. Implementing preharvest management practices alone did not substantially reduce SER incidence (Figure 2). However, when the fruit were treated with either HWT or fungicide dip, SER was further minimised. In contrast, when the preharvest practices were supplemented with HWT and fungicide dip, significant disease reduction was observed on mango fruit. The saleable life of fruit was extended for more than 8 days due to the significant disease reduction. Combinations of different postharvest regimes are promising tactics to control postharvest diseases such as SER.

Conclusion

The integration of preharvest management focusing on an improved fungicide spraying program and postharvest quality management directed to minimizing SER incidence extended the storage life and marketable period of 'Carabao' mangoes. This research proved that SER can be managed by implementing a holistic approach involving preharvest practices supplemented with postharvest treatments. Integrating the improved fungicide spraying program to the recommended crop management practices such as pruning, sanitation and bagging increased the marketable fruit yield and quality. Proper positioning and timing of fungicide spraying minimised the number of fungicide application,, thereby reducing production cost and increasing the margin of profit. Further integrating postharvest treatments such as HWT and fungicide dipping reduced postharvest losses, preserved fruit quality and extended the storage and marketable life of mango fruits, thus enabling producers, traders and consumers to obtain fair market prices.

Nevertheless, to further improve the efficiency of SER management, additional research is needed to elaborate the details of the infection process and factors that influence it. Such information would allow further improvement in the cost-effectiveness of the spraying program and the development of appropriate

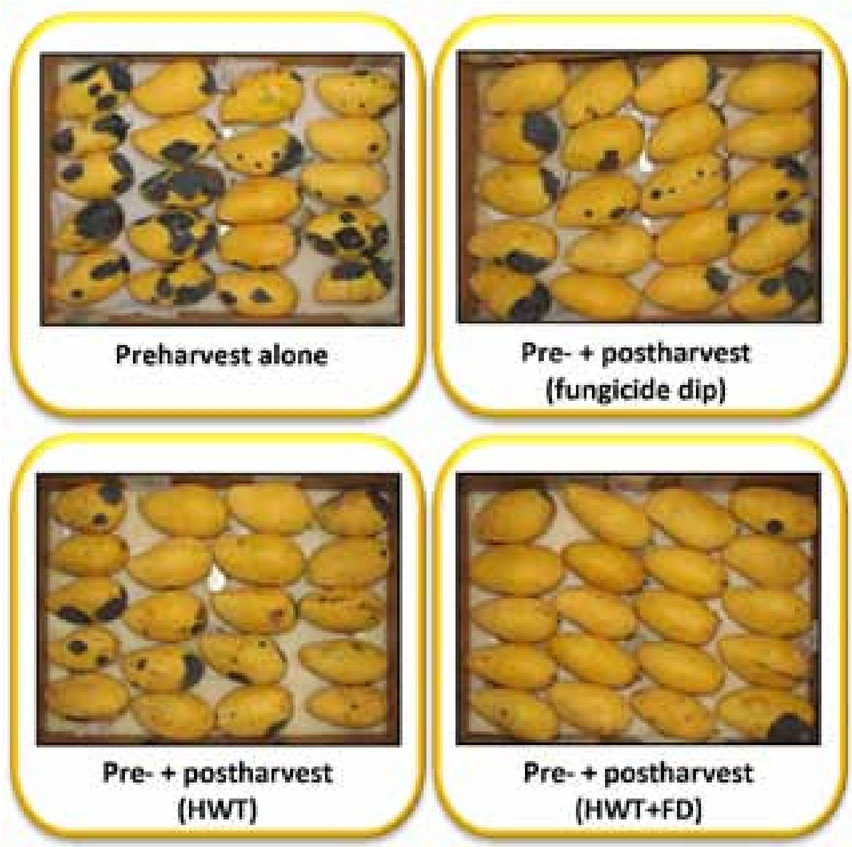

Figure 2. Effect of different pre- and postharvest treatments on shelf life of mangoes (HWT = hot water treatment; FD= fungicide dipping) stored at 13°C for 21 days after treatment

management strategies. Likewise, postharvest management interventions such as biological and physical means to extend storage and saleable life should be further explored.

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Vegetables

Bitter gourd (*Momordica charantia*) requires strong overhead support for its growth. Workers on a mixed vegetable farm near Tacloban, Leyte, construct an overhead trellis to support the vine and fruit. (Photo: John Oakeshott)

Economics of vegetable production under protected cropping structures in the Eastern Visayas, Philippines

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Abstract

Growing vegetables in the Eastern Visayas has always been problematic, especially in the wet season, due to heavy winds and rain. Protection from this harsh environment can be provided by various means, but there are obvious trade-offs between protection and cost. The practical reality is that there is minimal uptake of protected cropping in the region, and focus group discussions indicated that this was primarily due to the cost of the protective structures. Thus, in the project reported here, economics research, combined with agronomic and engineering, plays a significant role in trying to achieve a cost-effective, protected-cropping production system. The results of farmer-cooperator trials show that protected cropping can be economically feasible, and there has already been uptake beyond the auspices of the project. Farmer skill levels (including crop selection) are important in contributing to productivity and revenue. Also, basic inputs such a fertiliser and pest control are important. There is a negative correlation between rainfall and vegetable productivity. As experience is gained by farmers and local-government units in the region, economic feasibility should be further enhanced.

Introduction

The Eastern Visayas (Region 8) in the Philippines produces about 50,000 tonnes of vegetables per year. However, this production is only 45% of the consumption of vegetables in the region, and this consumption level at under 100 g/person/day is one of the lowest in the Philippines (FNRI 1993).

One reason for the inability of the Eastern Visayas to satisfy demand for vegetables is that year-round production is significantly limited by high rainfall (average 2.4 metres per year) and typhoons between June and February. This weather can also bring destructive winds in excess of 150 km/h, which physically damage leaves, flowers and fruit, encourage disease, and pose difficulties in planting, spraying and harvesting operations.

Due to these damaging winds and rain, vegetable prices tend to rise significantly in the wet season (Menz and Armenia, undated a). High costs of inter-island transportation and poor road transport infrastructure in the Visayas hamper the import of vegetables from other islands. While vegetable self-sufficiency for the Eastern Visayas is not an end in itself, these weather and transportation factors do provide an economic incentive for seeking a means of cost-effective vegetable production under a protective cropping regime.

The overarching aim of the research between Visayas State University (VSU) and Applied Horticultural Research (Australia) is to develop, evaluate and implement a protected-cropping production system, with a view to helping farmers gain

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higher farm incomes. If successful, this technology would enable farmers to produce crops (including high-value crops) during the wet season when prices are high.

There are many examples of economic analyses of protected-cropping and greenhouse structures in the developed world but few in the developing world and less than a handful in the Philippines. Sace (undated) analysed the economics of structures for vegetable growing in Central Luzon. These structures appeared to be profitable, but it must be said that the analysis was rather isolated from practical on-farm realities. A more realistic analysis was undertaken in the same area of the Philippines by Ramos (2008) and the economic outcomes were poor, apparently due to excessively high temperatures inside the structures. (The latter was not a serious problem in the project described in this paper since the structures were not fully enclosed which allowed for some ventilation and temperature reduction.) Some economic analysis of production under structures was undertaken by Asantos and Mocampo (2005) but the focus of their work was primarily on the growing medium for the plants rather the structure per se.

The objectives of the project reported here were:

1. to develop and test appropriate and effective protected-production systems for annual crops
2. to determine whether the production of vegetable crops using protected cropping systems in the province of Leyte in the Eastern Visayas is economically viable at both farm and market levels
3. to promote adoption/modification of protected cropping systems in Leyte.

Review of literature

Greenhouse technology or protective cultivation in temperate regions has been widely applied due to the adverse climatic conditions unfavourable to warm-season vegetable production. For instance, greenhouse designs (El-Aidy 1984; Brun and Lagier 1985; Bailey and Richardson 1990; Castilla et al. 1992) and the influence of greenhouse technology on the growth and performance of vegetables (e.g. Caruso 1986; Bakker 1990; Castilla 1994; Al-Kadi et al. 2000) have been documented and discussed in the scientific community for some time.

In tropical Asia, a review of the opportunities and constraints to protected vegetable cultivation (Everaarts and de Putter (2009) reported that, in India, production of vegetable crops in plastic houses was employed (Singh and Sirohi 2006; Singh et al. 2007). The review pointed out the 'utilization of plastic or net houses required relatively higher investments than open field cultivation but it was attractive to reduce pesticide use and to increase profits'. In Indonesia, a survey of sweet-pepper growers (Gunadi et al. 2007) also showed the utilisation of traditional, bamboo-framed plastic houses. It was also observed that relatively well-off farmers use a combination of wood and light metal for framing. In the Philippines, Aganon and Aganon (2009) articulated the required technical considerations on vegetable production and the economic potential of protected cultivation, based mainly from their research experiments conducted in Nueva Ecija and related studies.

The economics of protected vegetable cultivation have been widely addressed in more-advanced countries. Waterer (2003) looked into the viability of high and low tunnels to produce warm-season vegetables in Canada, and showed that the most economically attractive cropping option was peppers, primarily because of superior yields of mature red fruit, which commanded a price premium. The study concluded that it would take 2–5 years for the gross returns obtained with the high tunnels to cover their capital costs. In the UK, Schmutz et al. (2011) observed that organic protected cropping can be very profitable but that the economic returns are very sensitive to changes in price and yield. In India, Singh et al. (2007) found that the benefit:cost ratio of greenhouse cucumber cultivation was 2.29. They concluded that low-cost, naturally ventilated greenhouses were the most suitable and economical for year-round cucumber cultivation on the northern plains of India. Likewise, Kumar et al. (2009) found during a 2004–06 field experiment in mid-level hill country of the north-west Himalaya, India, that selected cropping sequences resulted in 1.45–2.80 times higher crop yields inside a greenhouse than did open field conditions. The highest benefit:cost ratio of 3.14 was obtained for the cropping sequence capsicum–tomato–spinach.

Econometric analysis was also employed by Al-Kadi et al. (2000) to determine the costs of production of vegetables grown under protected cropping in the highland area of Jordan. The model developed enabled farmers to find the optimal amount of production, by equating the marginal cost of production with price. Using regression analysis from a survey of 145 vegetable growers in the Spanish Mediterranean coastline, Bertuglia and Calatrava (2012) found that a farmer's level of horticultural training, the adoption of a quality system, the use of family labour for the greenhouse work and, to a lesser extent, the type of crop and the area planted, were positively related to productivity.

Prior to a protected-cropping project funded by the Australian Centre for International Agricultural Research (ACIAR), the technical and economic viability of low-cost, protected vegetable cropping using locally available materials such as bamboo had not been tested in any area within Leyte, Southern Leyte or other areas of the Visayas islands. As one of the areas prone to prolonged rainfall and other unfavourable climatic conditions, significant findings on the technical and economic viability of protected cropping arising from this project represent new information regarding possibilities for increasing farmers' incomes and climate-change proofing in the region and other parts of the country with similar climatic conditions.

Project approach

The functional and economic performance of low-cost protected-cropping production systems was assessed over a 4-year period from 2008. The investigations involved controlled field experiments at VSU (focusing on factors influencing performance) and commercially orientated systems on farmers' fields. More details are available in a companion paper in these proceedings (Capuno et al. 2012).

As a first step before the field work in the project began, a focus group discussion was held with farmers and representative local-government unit (LGU) staff in Cabintan and Ormoc to assess their knowledge levels and interest, and identify any constraints regarding protected cropping of vegetables. It turned out that some farmers were familiar with the concept, but many were not. Once exposed to the idea via photographs and diagrams, all farmers expressed an interest, but many said that the capital cost of building the structures would be a constraint. Consequently, the project went to great lengths to involve the farmers in the discussion about the building of the structures and they took primary responsibility for the construction, incorporating their own ideas about cost-saving or endurance-enhancing ideas for the structures.

Throughout the project, the assessment as to whether protected cropping would be an economically viable alternative to current practices was a major project driver. It was decided after about 18 months of the project that close monitoring of the economic performance of the VSU sites (i.e. non-farmer sites) would cease due to their more 'experimental' (i.e. less commercial) nature. Therefore, the economic data presented in this paper relate to farmer-cooperator sites only.

Selection of project site and farmer-cooperators

By project end, 18 farmer-cooperators were directly involved in the project from the different farmers' field sites: Ormoc City and Bato of Leyte province; and Bontoc and Maasin City in Southern Leyte province. Of the 18 farmer-cooperators, 10 came from Ormoc, six from Maasin, one from Bato, and one from Bontoc. At the start of the project, only two farmer-cooperators from Ormoc and Maasin were identified. As the project expanded, seven additional farmer-cooperators were identified by the project personnel, whereas the remaining cooperators were identified by LGU counterparts of the project in Ormoc (5) and Maasin (4).

The city/municipal agriculture officer or officer in-charge was consulted by the project team on the selection criteria for sites and farmer-cooperators. The basic criteria for selecting a farmer-cooperator were good farming performance and positive attitude. The farm of the chosen cooperator was further evaluated by the project team for its suitability in terms of soil type, water source, social stability and accessibility (farm-to-market road) since the set-up would also serve as a model farm to the community.

Farmers' field set-up

The project team provided advice on the design, establishment and other technical requirements in erecting the protective structures in the farmer-cooperator's field. However, farmers themselves made numerous suggestions in relation to the design, both at the initial design stage and establishment of the structures. The farmers' field sites were situated in lowland and upland areas as can be observed in Ormoc City and Maasin City. The project evaluated essentially two types of structures at the project sites (Figure 1): house-type structures, made mainly of bamboo or coco lumber covered with UV-proof plastic roofing and with an effective growing area of 200 m^2 (5 m × 40 m); tunnel-/igloo-type structures made of either bamboo or steel frames, with either plastic or net covering (Armenia et al. undated), and

Figure 1. Sample vegetable crops under a protective structure and in an open field, Bontoc, Southern Leyte

with a growing area of 60 m^2 (1.5 m × 40 m). Most of the sites used house-type structures and, except for the regression analysis results reported later in this paper, the economic data provided here relate to that type. The farmer sites were used to collect information to support the assessment of economic viability and to monitor for the emergence of new production challenges. At all field sites, plants in open field or a control set-up were provided for comparison with the protected crops. Drip irrigation systems were used at some of the pilot farms at Ormoc and Bontoc sites. Temperature, relative humidity and light intensity were monitored using either electronic sensor with loggers, or by manual recording of temperature from thermometers. Rainfall data were also collected.

Decisions on what vegetables to plant

The farmer-cooperators, in consultation with the project technical team and/or a field technician from the LGU, made the final decision on what vegetable crops to plant, when to produce them, and the planting plan for the successive croppings. In some instances, the technical project team intervened with advice on crop choice (e.g. to avoid pest build-up). Crops were grown under structures throughout the year—typically this meant that three crops were planted, but this was not always so.

Materials and technical assistance provided

The project provided all the materials, labour and related expenses for the protective structures at no cost to the farmer-cooperators. Also, material inputs for the first cropping, such as fertilisers and seeds, were provided by the project, as was technical advice regarding cultural management aspects, from land preparation to harvesting, and for controlling insect pests and diseases in preventive and curative control measures. These included cultural (e.g. sanitation, crop rotation, pruning), mechanical (hand-picking and bagging as in the case of ampalaya), chemical control (contact and systemic pesticides) with observance of withholding periods, and the use of botanicals or organic sprays.

Economic data collection and other farmer feedback

To backstop the technical component of the project, initial establishment costs of the protective structures at all project sites, including repairs and maintenance costs, were monitored and recorded. Labour and material inputs incurred by each farmer-cooperator relating to their vegetable production with and without a protective structure were regularly monitored and recorded. Farm receipts, expenses and gross margins were calculated for all farm sites.

Focus group discussions (FGDs) in which representative farmers and field technicians participated were conducted in Ormoc and Maasin sites, to solicit feedback on perceptions and experiences, as well as identify constraints to the adoption of the protective structures and vegetable production technology that were being introduced into farmers' fields. Subsequently, a number of further FGDs were held, such that there was considerable farmer input into the ultimate design of structures and crop management. With linkages to East-West Seeds and other related projects, such as the Enhancement of Food Security in the Visayas (EFOS), the project was also involved in the conduct of farmer field schools in Maasin, as well as in presentations on vegetable production under protected cropping made at VSU, which were attended by representative field technicians and farmers.

Seasonal price trends

Market price data from the Bureau of Agricultural Statistics were collected throughout the life of the project. It was found that price increases during the wet season (mid-year around June–July), and turn-of-year prices (around November–February) were routinely about 20% higher than in other months. There had been some suggestion that, in more recent years, a breakdown in the traditional weather patterns had occurred, but this was not reflected in a comparison between the 2011 data (Menz and Armenia undated b) and that for years preceding 2007, as shown in Menz and Armenia (undated a). A typical example of the more recent price data is shown in Figure 2.

Structure details and costs

Costs of structures varied with type and farmer/research sites. Full details of these can be obtained from the project working papers (http://www.protectedcropping.com/projects.php). However, to give an idea of the costs entailed, the initial (first year) set of cost data is presented in Table 1.

Initial establishment costs ranged from 14,000 pesos (igloo-type structures) to a maximum of 43,000 pesos (coco lumber-type houses) at the VSU experimental site, with the two initial farmers' sites costing 36,000 and 22,000 pesos in Ormoc and Maasin, respectively (Table 1). The bamboo structures in farmers' fields were generally less expensive than those at the university, due to design changes or lower input costs. The igloo structure costs at VSU were lower than the house-type structures, but the crop area was considerably smaller. The house-type (both coco lumber and bamboo) had an area of 200 m^2, while the area available for crops in the igloo type was 48 m^2.

After the first year, many additional structures were built within and beyond the auspices of the project, with the average cost of farmer-built structures being around 30,000 pesos to cover 200 m^2. The cost components of a fairly typical bamboo structure at Maasin, Southern Leyte, are shown in Table 2.

Economic analysis

A summary of the average receipts, expenses and gross margins for 3 years with and without a protective structure for the four most commonly preferred crops (tomato, sweet pepper, ampalaya and watermelon) grown by farmers is presented in

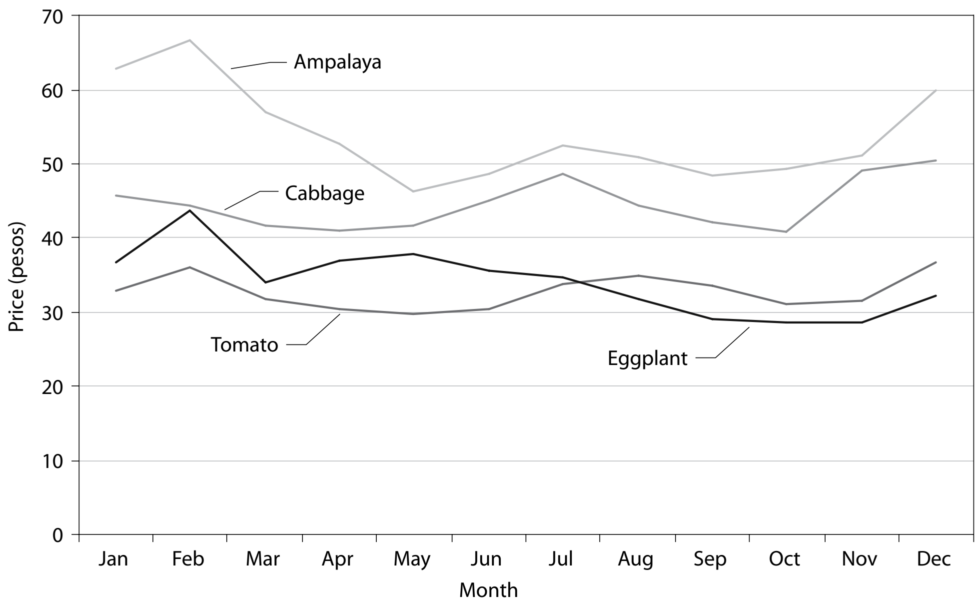

Figure 2. Monthly average prices of major vegetables in Southern Leyte, 2007–11

Table 1. Summary of initial costs incurred for establishing protective structures at the Visayas State University (VSU) site and in farmers' fields

Type of structure	Costs incurred in pesos		
	Materials	Labour	Total
VSU			
Coco lumber	34,081	8,311	42,392
Bamboo	14,931	13,719	28,650
Igloo net	12,912	773	13,685
Farmers' field			
Bamboo (Ormoc)	25,573	10,313	35,886
Bamboo (Maasin)	11,285	10,442	21,727

Table 2. Cost components (synthesised from various examples) of a bamboo house protective structure

Qty	Unit	Item description	Unit cost (pesos)	Extension (pesos)
Materials:				
34	pieces	Bamboo posts (Gu-od)	39	1,326
86	pieces	Bamboo poles (Kayali) regular	30	2,580
34	pieces	Bamboo poles (Kayali) small	15	510
5	bundles	Rattan ties	120	600
3	bundles	Rattan ties	150	450
2.5	kg	Common nails 4 inch	96	240
1.5	kg	Common nails 4 inch	93	140
2	kg	Common nails 2$^1/_2$ inch	102	204
1.5	kg	Common nails 1$^1/_2$ inch	102	153
0.75	kg	Common nails 1$^1/_2$ inch	90	675
1.5	kg	Common nails 1 inch	90	135
5.89	pieces	Used tyres	30	177
105	metres	Polyethylene UV film 110 inch × 0.005 inch × 150 m	100	10,500
		Subtotal		17,690
Labour:				
41.63	person-day	Construction of structure	250	10,407
9.38	person-day	Installation of UV plastic film	250	2,345
		Transportation cost for PE UV film		239
		Subtotal		12,752
		TOTAL COSTS (materials + labour)		30,681

Table 3. Gross margins were calculated for the test crops both within and outside the structures. Over the life of the project, the highest receipt and gross margin for a crop grown under structure were from sweet pepper. The information in Table 3 indicates the potential for significant gains (beyond what have been recorded to date) with an appropriate choice of crop and good management skills. It can be seen that watermelon gained no advantage from being grown under a structure and is therefore not an appropriate crop choice, yet it was tried by some farmers, thereby lowering the average economic advantage due to the structure. Comparing crops grown under structure with those outside, the highest average gross margin difference over the life of the project was 79 pesos/m^2 for sweet pepper followed by tomato at 30 pesos/m^2 and ampalaya at 23 pesos/m^2.

Table 3 covers the four most popular crops grown by farmers. Table 4 gives the results for the crop mix actually grown by farmers (not just the four 'most popular'). The results indicate that, over the 3-year period, the average gross margin for crops grown under a protective structure was 112 pesos/m^2, approximately double the gross margin for crops grown outside a structure.

Financial viability of protective cropping

Table 5 shows the 5-year cash flow based upon the average performance of cooperators (3 years

Table 3. Average receipts, expenses and gross margins (3 years) per cropping in pesos/m^2 for the four most-preferred crops (ampalaya, tomato, sweet pepper and watermelon), grown with or without a protective structure

Structure	Number of comparisons	Receipts (pesos/m^2)	Expenses (pesos/m^2)	Gross margins (pesos/m^2)
A. With				
Ampalaya	16	60	20	40
Tomato	14	57	21	37
Sweet pepper	11	159	36	123
Watermelon	5	76	31	45
B. Without				
Ampalaya	14	34	18	17
Tomato	13	25	17	7
Sweet pepper	9	69	26	44
Watermelon	3	75	25	51
C. Mean difference (A–B)				
Ampalaya	30	26	2	23
Tomato	27	32	4	30
Sweet pepper	20	90	11	79
Watermelon	8	1	7	–6

Table 4. Annual receipts, expenses and gross margins (pesos/m^2) for vegetable crops grown with or without a protective structure

Item	Receipts	Expenses	Gross margins
A. With structure			
Year 1	122	59	63
Year 2	142	41	100
Year 3	174	44	130
Mean	156	44	112
B. Without structure			
Year 1	56	49	7
Year 2	107	39	67
Year 3	93	34	58
Mean	95	38	57
C. Mean difference (A–B)			
Year 1	66	11	55
Year 2	35	2	33
Year 3	81	10	71
Mean	61	6	55

Note: The number of observations made each year was not the same. More farmer-cooperators entered the project over time, therefore the mean of all observations does not equal the average of years 1, 2 and 3.

Table 5. Projected cash flow and investment returns (pesos) from protected cropping of vegetables under a 200 m^2 structure

Item	Year				
	1	2	3	4	5
Cash inflow:					
Gross returns	24,016	32,410	34,770	34,770	34,770
Cash outflows:					
Establishment cost	30,681				
Materials	4,717	2,914	3,951	3,951	3,951
Labour	6,814	5,929	4,938	4,938	4,938
Transport and marketing	438	468	564	564	564
Repair and maintenance	110	689	12,142	142	142
Total cash flows	42,760	10,000	21,595	9,595	9,595
Net cash flows	–18,744	22,410	13,175	25,175	25,175
Net present value (@ *r* = 20%)	29,824.91				
Internal rate of return	103%				

Note: The table above incorporates the cost of replacing the plastic covering after 3 years and is based on the average returns achieved by farmer cooperators; high-achieving farmers obtained approximately double these returns

actual and 2 years projected). At a discount rate at 20%, the results indicate that it is financially viable to grow vegetables under protected cropping given the structure design and costs. The average net present value (NPV) from investment in structures is approximately 30,000 pesos, with an internal rate of return of approximately 100%. If we examine the results of the top three cooperators, they obtained higher gross margins both inside and outside the structures compared to the average, but their additional gross margin from investing in the structure is also twice that which was obtained by the average farmer-cooperator (112 pesos/m^2 as compared to the 55 pesos/m^2) as shown in Table 4.

Regression analysis on factors affecting productivity

The data in Table 4 are figures from the farmer-cooperators. Table 5 gives figures for 3 years (i.e. up to April 2012), and the projections for the remaining 2 years coincide with a total expected structure life of 5 years. In the previous paragraph, it was indicated that more-skilled farmers (as assessed by the project team) can gain more from investment in structures than can average farmers. And it was further suggested above that crop selection is an important component of success. In order to better elucidate the contribution that these and other various factors make, a multiple regression model (based upon individual crop input–output data) was utilised and subjected to rigorous diagnostic tests (Table 6). This approach also allows a more refined estimate on the relative contribution of the protective structures.

The results from the model indicated that, for the intercept shifter variables, the dummies for protective structure and sweet pepper crop planted by farmers were positive and considered statistically significant factors that affect productivity among farmers (Table 6). The management skills variable also has a positive coefficient and is statistically significant. As expected, rainfall and pest incidence variables have negative coefficients and were statistically significant. The coefficient for the ampalaya dummy variable, the farmers' second-most preferred crop, was positive but not statistically significant. The other relevant variables such as fertiliser and pesticides costs had positive coefficients and likewise were not statistically significant.

The coefficient of the 'structure' dummy variable is 0.61 but, because the dependent variable (total revenue) was specified in logarithmic form, the interpretation of this coefficient is as follows: take the exponential of 0.61 = 1.84, implying that under a structure and with other variables held constant, vegetable revenue is 84% higher than without a structure. This number is broadly comparable to figures shown in Table 4 for the raw data (i.e. raw data without any attempt to isolate the effect of the various individual inputs). The other dummy variables representing

Table 6. Multiple regression on factors affecting productivity (pesos/m^2) of protected-cropping systems for vegetables in Leyte and Southern Leyte, Philippines

Variable	Coefficient	*t*-values
Constant	2.564***	7.98
Dummy variable:		
With structure	0.610***	3.85
Sweet pepper	0.539**	2.24
Ampalaya	0.296	1.51
Management skills index (%)	0.010***	2.72
Pest incidence (%)	–0.012**	–2.20
Log of average daily rainfall (mm/day)	–0.184*	–1.85
Log of fertiliser cost (pesos/m^2)	0.321***	4.11
Log of pesticides cost (pesos/m^2)	0.194***	3.27
No. of observations = 107		
R-squared = 0.50, Adj-*R*-squared = 0.46		

*significant at 10% level, **significant at 5% level; ***significant at 1% level

sweet pepper and ampalaya crop can be interpreted in similar manner.

The coefficients of non-logarithmic management skills variable (0.010) can be interpreted as that a unit increase in skills index would bring about 1% increase in productivity or revenue. However, for pest rating variable with a negative coefficient (–0.012), a unit increase in pest incidence would reduce revenue by 1.2%.

The variables specified in logarithmic form can be interpreted directly as elasticities; thus, a 10% increase in daily rainfall would, on average, reduce vegetable revenue by 1.8%. Fertiliser and pesticide expenditure increases of 10% would increase revenue by 3.2% and 1.9%, respectively.

There are therefore various ways in which significant further economic gains can be made by using protected-cropping technology. With the available dataset, we were not able to discriminate between the (percentage) effects of some of these variables on protected versus non-protected cropping, but insofar as the percentage increases were found to be a similar, this implies a much greater absolute effect with protected cropping.

Discussion and conclusions

Investment in protected-cropping structures for vegetables is economically feasible in the Eastern Visayas, especially for skilled growers who apply appropriate inputs. Not all crops perform in a superior fashion under structures, so the investment in structures will have potential only if high-performing crops such as sweet pepper and ampalaya are chosen. These crops give above-average returns both within structures and in the open field, but they perform relatively better within structures.

Since there is little history of protective cropping in the Eastern Visayas, farmers are quite unfamiliar with the management techniques required to maximise returns. Based upon the regression results, a 10% increase in management ability would increase returns by around 10%, equivalent to about a 33% increase in NPV of the investment, or 10,000 pesos for a 200 m^2 structure (given the NPV from structures at current levels of skill of around 30,000 pesos, as shown in Table 5). This gives a strong indication of the value of farmer training. Strong economic benefits can be expected from increases in other inputs as well.

All farmer cooperators in the project had individual control over activities undertaken within the structure. Some efforts outside of the project have involved responsibility by farmer groups (rather than individuals), and some of these have foundered, because of the difficulties in equitable sharing of responsibilities and rewards.

With the dearth of empirical knowledge on the technical as well as the economic feasibility of low-cost protected-cropping system for vegetables in Leyte and Southern Leyte provinces, and the Philippines in general, the findings of this study have contributed to the existing pool of scientific knowledge about protected-cultivation of vegetables in the Philippine setting. The findings of the study may be used for further field verification in other areas and for possible dissemination to researchers and potential adopters. The findings may also serve as possible input to craft related research policy actions and recommendations pertinent to climate-proofing strategies.

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Low-cost protected cultivation: enhancing year-round production of high-value vegetables in the Philippines

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Abstract

Thirty-four protected-cropping structures of various designs were constructed and tested at five project sites in Leyte, the Philippines, to evaluate their technical feasibility for producing vegetable crops. Two types of structures were evaluated: house-type structures, built from either bamboo or coco lumber with an effective growing area of 200 m^2 (5 m × 40 m) and tunnel-/igloo-types made of either bamboo or steel frames, with either plastic or net coverings and a growing area of 60 m^2 (1.5 m × 40 m). The experimental sites at the Visayas State University were used mainly for research on crop suitability, pest and disease impacts, and nutrition. The farmer test sites were used mainly to collect information on yield differences between crops grown under structures and in the open field to support the assessment of economic viability, and production challenges. From 134 treatment comparisons, it was found that average yields were higher under protected cropping compared with the open field for cauliflower, green onion, lettuce, chilli pepper, tomato, sweet pepper, bitter melon (ampalaya), pechay (*Brassica rapa* cv. group pak choi), muskmelon, broccoli and string beans. There was no improvement in yield for sweet corn, cabbage, watermelon, bottle gourd, cucumber or winter squash. Farmers need a certain minimum level of skill to take advantage of protected cropping, especially in relation to effective management of irrigation and in controlling pests and diseases. Protected cropping can result in higher yields in both the wet and dry seasons. Foliage diseases were easier to control under protected-cropping structures but whiteflies, aphids and mites were more difficult to control.

Introduction

The Philippine vegetable industry contributes more than 30% to total agricultural production, and is a major component of gross domestic product (UNDP 2006). However, one of the important challenges to the vegetable industry in the Philippines is to develop a production system that adequately meets the need for year-round production of safe and high-quality goods. It is difficult to meet this need with conventional field production of crops because of high rainfall, which makes vegetable production difficult and leads to fluctuations in supply and prices of the commodities in the market. This is particularly true for Region VIII of the Philippines, the Eastern Visayas, where off-season production constraints are more severe considering its Type IV rainfall pattern. This rainfall pattern is characterised by high annual rainfall (at least 2 m per year), a distinct wet season (July–January), a significant amount of rainfall for the remainder of the year

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and frequent typhoons. This weather pattern makes vegetable growing difficult and, as a result, the Eastern Visayas produces only 47,000 tonnes (t) of vegetables per year, or about 45% of the local demand (FNRI 1993). The shortfall is met by importing from other parts of the Philippines, such as Mindanao and Luzon.

A production system that protects crops from rain and wind, and associated diseases, should improve the viability of vegetable crop production in the Eastern Visayas. Expected benefits include higher yields, better quality, more reliable supply and fewer problems with diseases and weeds. Some farming operations such as planting, spraying and harvesting are simpler but others such as irrigation and pest control can be more difficult under structures than in the open field (FFTC 2007).

The types of protective structures used by growers in Asia range from simple structures such as rain shelters, shade houses, mulches, row covers and plastic tunnels, to permanent structures covered in plastic or glass with computerised environmental controls which can be linked to soil-based or soil-less production systems. This diversity makes the selection of appropriate and cost-effective technology complex. It is essential for the development of an appropriate protected cropping production system that the entire production system be addressed, i.e. plant protection, irrigation, nutrition and types of cultivars.

Filipino farmers generally have low incomes, hence low-cost protected cropping is envisioned to be more attractive. Nevertheless, protected cultivation still requires farmers to invest money to build and maintain the structures. A project was therefore developed to build various low-cost protective structures in the Eastern Visayas, test their suitability under local weather conditions and evaluate the technical feasibility of growing vegetables under low-cost structures.

Review of literature

Protected cultivation in tropical climate creates awareness among growers and policymakers of the potential of the technology to improve yields and quality of vegetables grown in the difficult environment in the humid tropics. Horticultural production under a structure has become increasingly important in recent years. This trend is brought about by the demand for fresh horticultural crops even during the off-season when crop production is limited by adverse climatic conditions. Protected cultivation assures continuous supply of fresh vegetables and fruits throughout the year, particularly during the rainy months, when such products would be difficult if not impossible to grow.

The kinds of protective structures used by growers in Asia range from simple structures such as rain shelters, shade houses, mulches, row covers and plastic tunnels, to permanent structures covered in plastic or glass with computerised environmental controls. Growers in countries where typhoons are common over the summer tend to prefer low-cost structures that can be quickly and cheaply replaced. Greenhouses in such countries generally have walls and roofs of plastic rather than glass, over a metal or even bamboo framework (FFTC 2007). The extent to which these structures improve the yield of vegetable crops depends largely on the extent to which advances in crop protection, plant breeding and crop cultivation have been applied to the production system.

The beneficial effects of protective structures, whether house-type or tunnel, on the growth and yield of vegetable crops has been well documented. Plastic tunnels can be used as a nursery for young plants from sowing to planting in the open air. The low tunnels are more suitable to protect low-growing plants such as melons, squashes and salad crops. However, timing of planting must be considered as it was reported that a plastic cover can increase the air temperature by 10°C and the soil temperature by 2–10°C during daytime when ambient temperatures are comparatively high (Baudoin and Nisen 1990).

Rain shelters have also been observed to have a favourable effect on the quality of produce. Protective structures provide shelter vegetable crops from biotic and abiotic stresses (Palada 2011). This finding is similar to the one reported by Mangmang (2002) that the total fruit yield and high net returns of tomato plants were significantly enhanced by plastic covering.

Growing in a greenhouse enables the plants to mature at up to 30% faster than field-grown crops. Moreover, greenhouse carrots are a real treat because they are sweeter and more tender than those grown outdoors, while greenhouse cucumbers are less bitter in taste than those grown outdoors. Greenhouse lettuce produces fine solid heads and resists tipburn, rot and bolting (Baudoin and Nisen 1990; cited in Mangmang 2002).

Certain cultural practices, such as the use of a raised bed and rain shelter, improved survival following a period of intense rain and protect the root system from flooding and presumably anoxic conditions, leading to enhanced crop growth, vigour and fruit yields (Liaw et al. 1993). Likewise, protective structures affect the quality, yield and time of production (Baudoin and Nisen 1990). In tomato, protected cultivation prevented the flowers and pollen grains from falling during heavy rains, leading to an increase in the total number of marketable fruits and total fruit yield of the plants (Apilar 2002). Indeed, protected cultivation is advantageous as it spreads the demand for rural labour over a longer period, produces high-quality fruit as well and provides control over the date of harvest (Kim et al. 1990). Growers who cannot afford the high initial construction costs of net or plastic houses can grow vegetables under temporary net tunnels. The net tunnels are constructed over each bed, using U-shaped iron or aluminum bars, which are covered with nylon netting (Talekar et al. 2003). They normally have no temperature or humidity regulation of the kind generally found in greenhouses. Rain shelters are primarily intended to protect the crops grown beneath them from damage by heavy rain.

A number of insect pest and diseases has been found infesting and infecting vegetable crops. The tobacco thrip *Thrips tabaci* is a dangerous pest of vegetable crops, especially cucumber grown in greenhouses. The rust tick *Aculus lycopersici* is very harmful to 28 species in the Solanaceae family, including tomato, potato, eggplant, pepper, ground cherry and black nightshade. However, in a tunnel experiment on cauliflower, it was reported that insect populations under tunnels roofed with net were reduced by 80%, and that marketable yields were 1.5–2.0 times greater under than in the open field (Palada and Ali 2007). Likewise, growing head cabbage under net tunnels in Solomon Islands reduced insect incidence by 38–72% and resulted in significantly higher economic returns (Neave et al. 2011).

Rain increases the incidence of disease in vegetables by increasing plant wetness. High soil moisture enhances the development of soil-borne pathogens (Magdoff and van Es 2000) including *Phytophthora*, *Pythium* and the bacterial wilt pathogen *Ralstonia solanacearum*. By rain splashing, flooding or excess watering, dispersed spores of pathogens can affect all parts of the plant at all ages. Excess water also damages roots by depriving them of oxygen, and creates condition that favour infection by certain soil-borne pathogen (Graham and Timmer 2003). Thus, irrigation management based on plant needs will help create an environment unfavourable for pathogen survival and disease development. Use of tensiometers or other devises for irrigation scheduling, and avoidance of low-lying areas, can help in disease management strategies (Sammis 1980). Furthermore, the use of protective structures that allow moisture extremes to be regulated create conditions unfavourable to soil-borne pathogens such as *R. solanacearum*

The most prevalent diseases of tomato, sweet pepper and other solanaceous crops in the Philippines include bacterial wilt, damping-off, *Fusarium* wilt, early blight, late blight, leaf curl and tomato mosaic viruses (Soriano et al. 1989). In cucurbits such as bitter melon (ampalaya), diseases including *Cercospora* leaf spot and downy mildew (*Pseudoperonospora cubensis*) may have a drastic effect on yield if not controlled. Bacterial wilt (*Pseudomonas solanacearum*) also attacks the crop (Siemonsma and Piluek 1994). Dimabuyu (2011) reported 0% bacterial wilt infection in bitter gourd under house-type structure and 55% infection in the open field. In squash, anthracnose caused by *Colletotrichum lageranium* is the most destructive disease. It causes defoliation and lesions. Other diseases are powdery mildew (*Erysiphe cichoracearum*), downy mildew (*P. cubensis*), scab (*Cladosporium cucumerinum*) and leaf spot (*Alternaria cucumerina*). Important virus diseases are cucumber mosaic virus (CMV), watermelon mosaic virus (WMV-2), papaya ring spot virus (PRSV-W), zucchini yellow mosaic virus (ZYMV) and squash leaf curl virus (SLCV) (Siemonsma and Piluek 1994).

Materials and methods

The overall approach to answering questions on the technical feasibility of low-cost protected cropping in the Eastern Visayas was to first establish a research site at the Visayas State University (VSU) in Baybay City, Leyte, to test the proposed structure designs and production techniques. Promising designs and techniques were then evaluated on commercial farms in an action (farmers' participatory) research approach. Resistance of the designs to adverse conditions, particularly to the damaging effects of heavy rain and the strong winds that often accompanies it, was monitored. Likewise, incidence/severity of insect pest and diseases infecting vegetable crops under structures and in the open field were assessed and compared. An important part of this project was to test the technical feasibility of protected cropping under actual on-farm conditions; hence, the farm-based trials were a focus of activities.

Project site identification and selection

The identification of the project sites in Ormoc and Maasin was based on the results of a scoping study undertaken in Leyte and Southern Leyte in February 2007 by the Australian Centre for International Agricultural Research (ACIAR) through Dr Les Baxter, Dr Jose Bacusmo, Dr Gordon Rogers and other VSU experts. The project team coordinated first with the local government units (LGUs), especially the mayor and the Office of the City/Municipal Agriculture Officer or officer-in-charge in each identified project site to formalise linkages, including the administrative and technical requirements, and establishing the selection criteria for location sites and farmer-cooperators.

The basic criteria for selection were farming performance and attitude, soil type, availability of water, security and farm-to-market accessibility. Mixes of farmer skill levels were chosen. Nevertheless, the team was careful to include some leading, innovative farmers who would be likely to lead adoption should the protected-cropping techniques evaluated showed positive results.

Memorandums of agreement was signed by the project proponents and LGUs to formalise the project implementation. The agreements included the functions and responsibilities of participating institutions and, under this arrangement, the project proponent from VSU provided the technical expertise for project implementation. LGUs helped with the supervision of farm sites and also took on a coordinating role, especially in relation to farmer field school training.

Farmers' field set-up

The project team provided the technical expertise needed for the design, establishment and other technical requirements of building the protective structures in the farmer-cooperators' fields. The project field sites were situated in lowland and upland areas, as can be found in Ormoc and Maasin. Moreover, the project evaluated essentially two types of structures at the project sites: house-type structures, mainly made of bamboo or coco lumber covered with UV-treated plastic and having an effective growing area of 200 m^2 (5 m × 40 m); tunnel-/igloo-type structures made with either bamboo or steel frames, with either plastic or net coverings, and with a growing area of 60 m^2 (1.5 m × 40 m) (Figure 1). The house-type structure was used for taller and climbing vegetable crops like sweet pepper and bitter melon, while the low tunnel was used for low-lying and spreading crops such as lettuce and muskmelon. The farmer sites were used mainly to collect information on yield differences under structures and in the open field, to support the assessment of economic viability and to monitor for the emergence of new production challenges. On the other hand, the VSU site was used mainly for experimentation on crop suitability, pest and disease impacts, and nutrition.

Thirty-four protective structures of various types were constructed across all project sites at VSU, Ormoc, Cabintan (high-altitude site), Maasin and Bontoc. An open-field control site was included at each location. Drip irrigation systems were used at the VSU site and in some of the farmer-cooperators' fields at Ormoc and Bontoc sites. Data on temperature, relative humidity, light intensity and rainfall were collected at each site, using either electronic sensors with loggers or manually. Rainfall data collected during the early part of project implementation (2009, only VSU; 2010, Maasin and VSU) and at all the three sites in the third year of implementation are shown in Figure 2. The project team provided technical support to the farmers on crop selection and timing, crop rotation, pest and disease control, and other production issues.

All the materials for the protective structures, such as bamboo, nails, UV-stabilised plastic, labour and related expenses for the structures, were paid for from project funds for the first two cooperators; one in Ormoc and one in Maasin. In all succeeding constructions, a 50:50 split for the project and the LGU was agreed and implemented. The costs of materials and labour for minor repairs to the structure were borne by the farmer-cooperators. The costs of major repairs were borne by the LGU. Farmer-cooperators in Maasin city in particular were made to counterpart or return in pesos one-third of the total cost of the structure. Cropping inputs such as fertiliser and seed were paid for by the project for the first cropping cycle only. After that, farmers were expected to provide their own inputs, but would be subsidised if there was a crop failure due to the experimental nature of the production. Technical assistance was also provided by the project team in terms of the cultural management aspects from land preparation to harvesting, and for controlling insect pests and diseases in preventive and curative control measures. These include cultural control (e.g. sanitation, crop rotation and pruning), mechanical (hand picking and bagging as in the case of bitter melon),

Figure 1. House-type structures made of bamboo (A) or coco (B); and igloo-type structures covered with net (C) or plastic (D).

and chemical (contact and systemic pesticides) with observance of withholding periods, and the use of botanical or organic sprays. In total, there were 18 farmer-cooperators directly involved in the project at the various sites: Ormoc (10), Maasin (6), Bato (1), and Bontoc (1).

The experimental sites at VSU and farmer sites were set up following randomised complete block designs with four replications. Yield was separated into marketable and unmarketable, then numbers and weights of harvestable parts were recorded at each harvest. Individual treatment comparisons were analysed using ANOVA and the mean separations were tested at $P < 0.05$ least significant difference.

Crops were harvested multiple times according to normal commercial practice. Soils samples were taken before each crop was established and tested for total N, P and K, pH, EC, exchangeable cations (K, Na, Ca, Mg) and micronutrients. Plant tissue samples were taken during crop growth and the nutrient content measured as a guide to the nutritional status of the crops. The incidence (counts) of pests and diseases were recorded on crops in years 2 and 3 of the project.

Results and discussion

Effects of protective structures on yield

The average yields of vegetable crops grown under protected cropping over 3 years under house-type structures are shown in Table 1, which is a summary of over 134 separate comparisons. Each trial had an open-field control, and crops were harvested as commercial crops, and the harvested part classified as either marketable or non-marketable. Examples of yield outcomes from individual trials are shown in Tables 2 and 3 for tomato, and Tables 4–6 for sweet pepper, bitter melon and lettuce, respectively. The pooled yields show an increase in average yields

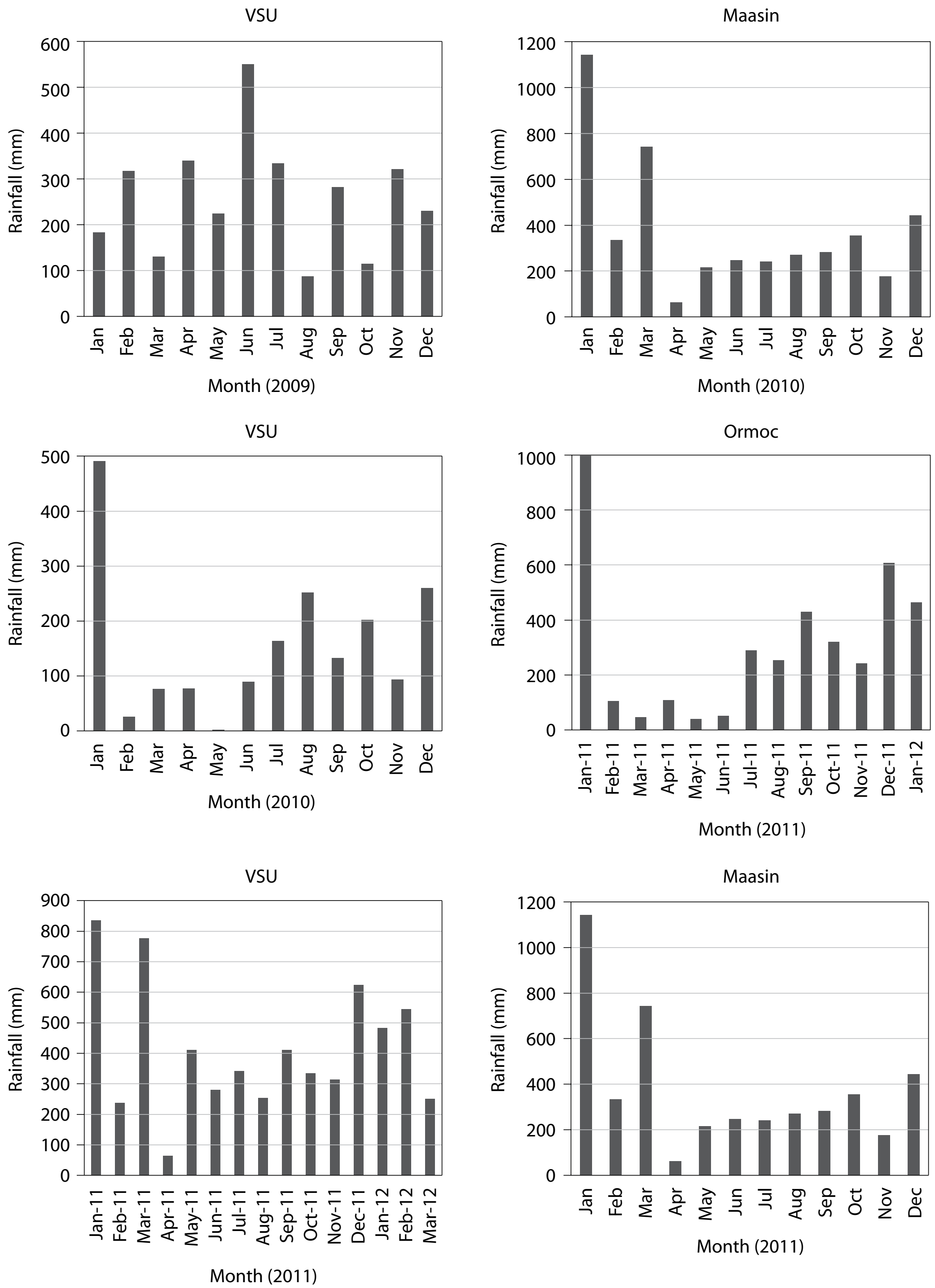

Figure 2. Total monthly rainfall at Ormoc, Visayas State University (VSU) and Maasin sites on 2009 2010 and 2011

under protected cropping for cauliflower, green onion, lettuce, chilli pepper, tomato, sweet pepper, bitter melon, pechay (*Brassica rapa* cv. group pak choi), muskmelon, broccoli and string beans. There was no improvement in yield for sweet corn, cabbage, watermelon, bottle gourd, cucumber or winter squash. Comparisons within sites for the four most 'successful' crops under protected cropping—tomato, sweet pepper, bitter melon and lettuce—have generally shown significantly higher yields under protected cropping, and the data shown in Tables 2–6 are typical. However, in some cases yields for these four crops were actually lower under protected cropping, or there were no significant differences. These results were included in the overall yield averages presented in this paper and could be attributed to either a low level of farmer skill, especially ineffective irrigation, or to uncontrolled pest or disease outbreaks. This issue has been examined and quantified by another paper in these proceedings (Armenia et al. 2012).

Four crops—tomatoes, sweet pepper, bitter melon and lettuce—consistently performed better under protected cropping than in the open field (Figures 3 and 4). The average yields for these crops were consistently higher under protective structures than in open field over the 3-year trial period in the Visayas.

Growing vegetable crops under protective structures is not new, and the reasons for yield increases are well documented. They include reduced periods of leaf wetness creating conditions less favourable for diseases to infect, fruit protected from direct contact with soil, reduced weed growth, moderate soil and air temperatures, and reduced leaching of nutrients from soils (De La Pena and Hughes 2007). The lower yields obtained from open-field-grown crops was attributed mainly to direct exposure to rain, especially during months with heavy precipitation (Figure 1). In tomato, clear plastic rain shelters prevent waterlogging and rain impact damage on developing fruit and consequently improved tomato

Table 1. Average yearly data of vegetables grown in Leyte during cropping years 2009, 2010 and 2011 under house-type protective structures and in the open field

Crops	Marketable yield (tonnes/ha[a])						Number of comparisons[b]
	2009		2010		2011		
	Open	Under structure	Open	Under structure	Open	Under structure	
Cauliflower	0	6.4	2	2.7	–	–	4
Green onion	–	–	–	–	17	60	2
Lettuce	4.6	13.3	21.3	22.7	–	–	10
Chilli pepper	–	–	6.9	16.8	–	–	2
Tomato	16.9	35.9	22.6	33.8	12.6	39.4	21
Sweet pepper	–	–	17.2	30	14	31	23
Bitter gourd	–	–	8.2	11.2	15.2	32.5	26
Pechay (pak choi)	–	–	7.1	29.7	–	–	3
Muskmelon	10.2	21.3	–	–	7	10.1	7
Broccoli	0.9	0.9	3	3.7	–	–	6
String beans	–	–	17.5	16.4	17.8	23.6	5
Snap beans	–	–	–	–	8	16	2
Sweet corn	–	–	2.9	3.3	–	–	2
Cabbage	8	8.1	8.8	12.2	–	–	5
Watermelon	–	–	17.1	8.6	57.4	56.2	8
Bottle gourd	–	–	41	41.1	–	–	3
Cucumber	–	–	–	–	89	76	2
Squash	–	–	44	36.5	–	–	3
Total							134

[a] Average yield in kg/plot from each crop. converted to tonnes/hectare pooled for 3 years across all sites
[b] Separate set-ups for 3 years across all sites
– = No trials conducted

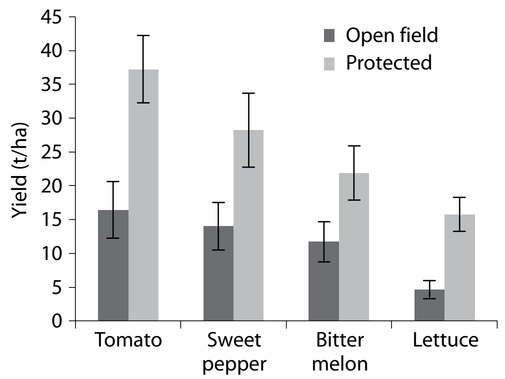

Figure 3. Yields of tomato, sweet pepper, bitter melon and lettuce under house-type protected cropping and in the open field, Leyte, Philippines (average of 3 years data). The vertical bars are standard errors (SE $P < 0.05$) and give an indication of the estimate of the amount that an obtained mean may be expected to differ by chance from the true mean.

yields (Apilar 2002; Mangmang 2002; Midmore et al. 1992).

Interaction between protected cropping and season

Despite there being a general trend for higher yields under protected cropping (Figure 3), the assumption has been that the main benefits occurred in the wet season, and that there was little advantage to growing crops under structures in the dry season, since there is no heavy rain or typhoons at that time of the year. To test this idea, the authors grouped yield data according to whether the crops had been grown predominantly in the dry season or the wet season. Wet season crops were those grown between July and January, and dry season crops were those grown between February and June. For tomato (Figure 4) the highest yields were obtained in the dry season rather than the wet season. While a reasonable yield of 22 t/ha could be obtained in the dry season in the open field, a much more impressive yield of 45 t/ha was obtained, on average, under protected cropping. During the wet season,

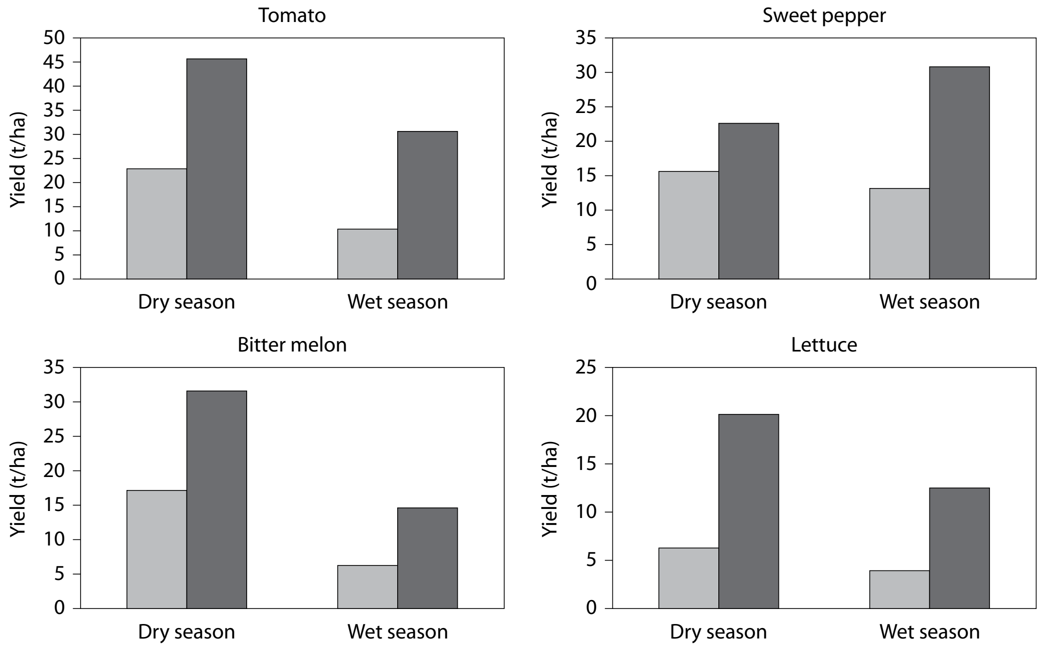

Figure 4. Yields of tomato, sweet pepper, bitter melon and lettuce under house-type protected cropping and in the open field during the wet and dry seasons in Leyte, Philippines. The data are an average of the results of 3 years of trials, with 21, 23, 26 and 10 datasets for tomato, sweet pepper, bitter melon and lettuce, respectively. The wet season is from July to January and the dry season from February to June.

open-field-grown, off-season tomatoes yielded less than 10 t/ha while, under protective covering, the same tomato cultivar produced 30 t/ha, which was higher even than that from regular dry-season tomato cropping in farmers' fields. Very similar trends were observed for bitter melon and lettuce (Figure 4). The result for sweet pepper was different from the other three crops, in that the greatest benefit of protected cropping was achieved during the wet season. The average wet-season yield was 30 t/ha, compared with only 12 t/ha in open-field production. This was because *Cercospora* leaf spot, a serious disease of sweet pepper during the wet season, was unable to infect the protected crop, since the dry and warm

Table 2. Yield data for tomatoes grown under a bamboo structure or in the open field (8 February – 24 June 2011) at Lao, Ormoc

Treatments	Marketable fruit/40 m^2		Non-marketable fruit/40 m^2		Total yield (t/ha)
	Number	Weight (kg)	Number	Weight (kg)	
Under structure	10,769a	401a	79b	1.9	100.79a
Open field	4,145b	133b	371a	6.8	34.88b
CV (%)	10.91	7.99	26.29	40.904	8.27

Means within a column having the same letters and those without letters are not significantly different at 5% level of significance based on DMRT.

Table 3. Yield data for tomatoes variety 'D' max' grown under a bamboo structure or in the open field (15 July – 21 October 2011) at Curva, Ormoc

Treatments	Marketable fruit/40 m^2		Non-Marketable fruit/40 m^2		Total yield (t/ha)
	Number	Weight (kg)	Number	Weight (kg)	
Bamboo	4,640a	211.00a	200.33	4.55	53.89a
Open field	1,522b	54.83b	84.33	2.17	15.52b
CV (%)	3.47	14.78	51.52	38.48	9.19

Means within a column having the same letters and those without letters are not significantly different at 5% level of significance based on DMRT.

Table 4. Yield data for sweet pepper grown under a bamboo structure or in the open field (22 June – 21 March 2012) at Lao, Ormoc

Treatments	Marketable fruit/40 m^2		Non-marketable fruit/40 m^2		Total yield (t/ha)
	Number	Weight (kg)	Number	Weight (kg)	
Under structure	8,592.00a	230.03a	368.67a	6.23a	59.06a
Open field	1,020.33b	23.55b	198.67b	2.35b	6.47b
CV (%)	0.50	3.20	17.90	18.90	3.30

Means within a column having the same letters and those without letters are not significantly different at 5% level of significance based on DMRT.

Table 5. Yield data for bitter melon variety 'Galaxy' grown under a bamboo structure or in the open field (23 March – 12 July 2011), Curva, Ormoc

Treatments	Marketable fruit/100 m^2		Non-marketable fruit/100 m^2		Total yield (t/ha)
	Number	Weight (kg)	Number	Weight (kg)	
Bamboo	1,895.00a	456.25a	69.50b	7.30	26.60
Open field	1,116.00b	255.00b	70.00a	6.02	15.55
CV (%)	2.86	3.44	12.19	10.88	49.82

Means within a column having the same letters and those without letters are not significantly different at 5% level of significance based on DMRT.

Table 6. Yield data for lettuce variety 'General' grown under coco house 1 or in the open field (25 May – 28 June 2010) at Visayas State University site

Treatments	Marketable yield/39.5 m2		Head size (cm)		Total yield (t/ha)
	Number	Weight (kg)	Polar	Equatorial	
Coco 1	269a	41.37a	13.75	12.40	10.47a
Open field	142b	22.04b	12.95	11.77	5.58b
CV (%)	4.65	15.44	2.80	2.78	15.62

Means within a column having the same letters and those without letters are not significantly different at 5% level of significance based on DMRT.

conditions under the structure are not conducive to its proliferation.

The rainfall pattern in the Eastern Visayas could explain the seasonal effect on crop yields. While there is less rain during February and March, and a period of high rainfall of between 400 and 1000 mm per month for the rest of the year, there is still sufficient rainfall during the so-called dry season to cause significant problems for growing vegetable crops such as tomato, lettuce, sweet pepper and bitter melon that are susceptible to waterlogging.

Another factor could be that the environment inside greenhouses is generally more favourable to plant growth and development, especially for warm-season crops. Environmental stress is the primary cause of crop losses worldwide, reducing the average yields for most major crops by more than 50% (Boyer 1982; Bray et al. 2000). The lower yields in the wet season, particularly for plants grown in the open field, were likely due to high rainfall. During the 3 years of trials, the rainfall distribution followed a distinct trend—higher from July to January (wet) and lower from February to June (dry). Frequent heavy rain during the wet season would mean high soil moisture, which enhances the development of soil-borne pathogens (Magdoff and van Es 2000). In addition, rain splashing or flooding can help to disperse disease spores and infect plants (Graham and Timmer 2003).

Arthropod pests and diseases

Table 7 shows the major arthropods pests (insect and mites) commonly infesting vegetables, both under structures and in the open field. The data revealed that the incidence of most of the arthropod pests was generally higher under structures than in the open-field-grown plants. The red spider mite (*Tetranychus kanzawai*) and broad mite (*Polyphagotarsonemus latus*) were found to be most damaging in sweet pepper, especially under structures. In string beans, the pod borer (*Maruca vitrata*), thrips (*T. tabacci*) and leafhopper (*Empoasca* sp.) were the dominant species encountered, with the first two species seriously attacking flowers and newly formed pods. In the bitter melon, the aphid (*Aphis gossypii*) and the leaf folder (*Diaphania indica*) were consistently observed in all the croppings, greatly affecting the performance of the crop when left unchecked. In the case of watermelon, the broad mite was observed to be very damaging, greatly affecting the growth of the crops at the early vegetative stage. On the other hand, the leaf miner was found to be quite serious in the musk melon, although the data were more or less comparable under structures and in the open field. Moreover, in tomato, the major species were the leaf miner and the fruitworm (*Helicoverp armigera*). However, data show that their incidence was lower under structures than in the open field, which could be due to the use of net enclosure in one of the structure at the farmer sites.

Although the incidence of the insect pests and mites was generally higher under structures, especially during the rainy season, in some cases this difference was not very pronounced during the dry months, at which time arthropod incidence between the two set-ups was comparable. Insects and mites, especially minute, soft-bodies species, are sensitive to water splashes, which can easily dislodge them from the plant. They are also sensitive to the higher temperatures, which may cause desiccation. The structures provided protections to these insects during the rainy season, thus resulting to their higher incidence at that time. However, in the absence of rain (dry months) their incidence was usually comparable between protected and unprotected circumstances.

Major diseases that were commonly found affecting vegetable crops inside structures and in the open field include leaf spotting, caused mainly by *Cercospora* spp., and affecting bitter melon and sweet pepper; downy mildew caused by *P. cubensis*, affecting mainly the cucurbits, including bitter melon, squash and cucumber. Bacterial wilt caused by *R. solanacearum* was also a major problem in some areas, affecting tomato and sweet pepper. In lettuce, *Sclerotium* wilt caused by *Sclerotium rolfsii* was the main problem.

The incidence of these diseases was generally higher in the open field than under protective structures (Table 8). This was because excessive moisture in the open field, especially during heavy rains in the form of surface water, is conducive to the motile bacterial-wilt pathogen *R. solanacearum*. Surface water run-off to other areas of the field also favours the dissemination of the water-borne inoculum to more of the area planted. Inside protective structures, moisture extremes are regulated and this is unfavourable to soil-borne pathogens such as *R. solanacearum*.

In case of downy mildew and *Cercospora* diseases, high moisture in the leaves of the plants favours fungal spore germination and infection of these airborne fungal diseases. Inside structures, drip or trickle irrigation was usually practised, such that the water was directly applied to the roots, minimising application of water to the foliage of the plants. This also minimised the germination, penetration and infection of wind-borne inocula of fungi that might have landed on the foliage. Rain splashes are also not present inside structures, this being another way whereby inoculum from the soil can be introduced to the leaves or upper parts of the plant. Rain splashes can also transfer pathogen propagules such as fungal spores from leaf to leaf or from one plant to another.

In summary, moisture regulation inside protective structures is the main cause of lower disease incidence, and this could partly explain the longer life spans and higher yields of crops grown under protective structures.

The incidence of virus diseases inside or outside usually depends on whether or not conditions are favourable for the insect vectors of the viruses, so there are times when the incidence of virus diseases inside structures may be either lower or higher than outside. Sooty mould on the other hand is favoured inside structures, because this fungus is attracted to the honeydew secreted by insects such as aphids, which find the environment inside structures very mush to their benefit.

Potential of low-tunnel structures

Low tunnels can be used for low-growing crops such as muskmelon, cabbage, lettuce and cauliflower where yield increases can be achieved, especially when the tunnels are covered with fine netting (Figure 5). These structures have great potential because they are cheap to construct, can be removed during the dry season and the net covering allows water to penetrate, reducing the need to irrigate. For the abovementioned crops, the plastic covering was no better than the open

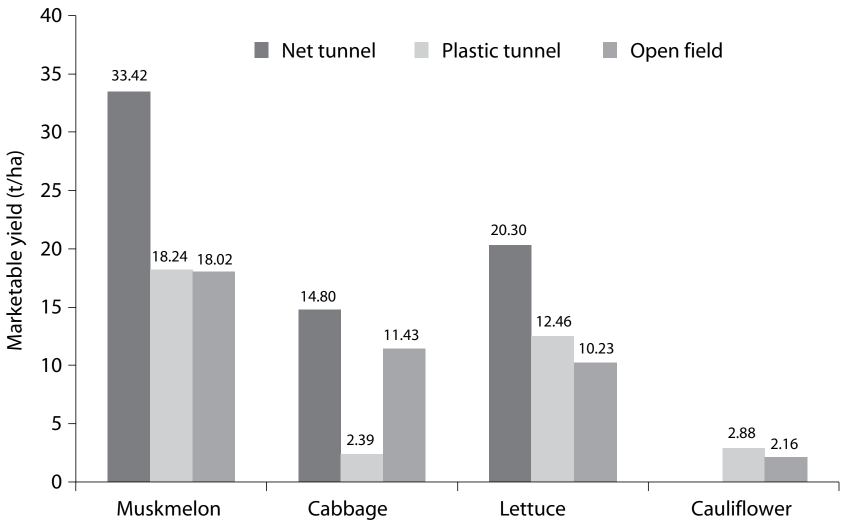

Figure 5. Yield data for muskmelon, cabbage, lettuce and cauliflower grown under low tunnels covered with plastic or net

Table 7. Major arthropod pest (insects and mites) attacking vegetables under protective structure

Crops	Pest incidence (%)		
Sweet pepper	Spider mite (*Tetranychus kanzawai*)	Broad mite (*Polyphagotarsonemus latus*)	
Under structure	23.50	31.40	
Open field	9.90	23.18	
String beans	Pod borer (*Maruca vitrata*)	Thrips (*Thrips tabacci*)	Leafhopper (*Empoasca* sp.)
Under structure	25.00	24.00	20.00
Open field	22.50	25.00	10.00
Bitter gourd	Aphids (*Aphis gossypii*)	Leaf folder (*Diaphania indica*)	
Under structure	38.50	13.50	
Open field	19.50	12.75	
Water melon	Broadmite (*Polyphagotarsonemus latus*)		
Under structure	25.00		
Open field	10.00		
Muskmelon	Leaf miner (*Liriomyza* sp.)		
Under structure	24.00		
Open field	25.10		
Tomato	Leaf miner (*Liriomyza* sp.)	Fruit worm (*Helicoverpa armigera*)	
Under structure	9.25	3.00	
Open field	14.50	18.00	

Table 8. Incidence of major diseases infecting vegetables grown under a protective structure

Crops/structure	Disease incidence (%)		
Bitter melon	*Cercospora* leaf spot (*Cercospora* spp.)	Downy mildew (*Pseudoperonospora cubensis*)	Virus
House-type structure	11.05	68.22	21.08
Open field	23.75	96.55	48.59
Sweet pepper	*Cercospora* leaf spot (*Cercospora* spp.)	Bacterial wilt (*Ralstonia solanacearum*)	Virus
House-type structure	10.75	0.10	4.16
Open Field	21.90	33.13	7.06
Tomato	Bacterial wilt (*R. solanacearum*)		
House-type structure	1.92		
Open field	30.58		
Squash	Downy mildew (*P. cubensis*)		
House-type structure	6.08		
Open field	42.40		
Cucumber	Downy mildew (*P. cubensis*)		
House-type structure	20.00		
Open field	100.00		
Lettuce	*Sclerotium* wilt (*Sclerotium rolfsii*)		
Plastic tunnel	0.61		
Net tunnel	9.68		
Open field	15.34		

field, which may have been due to high temperatures inside the tunnel.

Temperatures were higher under the tunnel covered with plastic than in net-covered tunnels and the open field (Figure 6) and this appeared detrimental to the growth of lettuce, which is a cool-season crop. Air temperatures under plastic tunnels were about 2°C higher than under net, and 5°C higher than in the open field. This observation is similar to the one reported by Baudoin and Nisen (1990) that tunnels covered with plastic increased the air and soil temperature by 2–10°C during daytime, much greater increases than those under house-type structure (Figure 7). It is clear that the use of net covering has potential for growing vegetables, since such tunnels are better ventilated than those with plastic roofing,

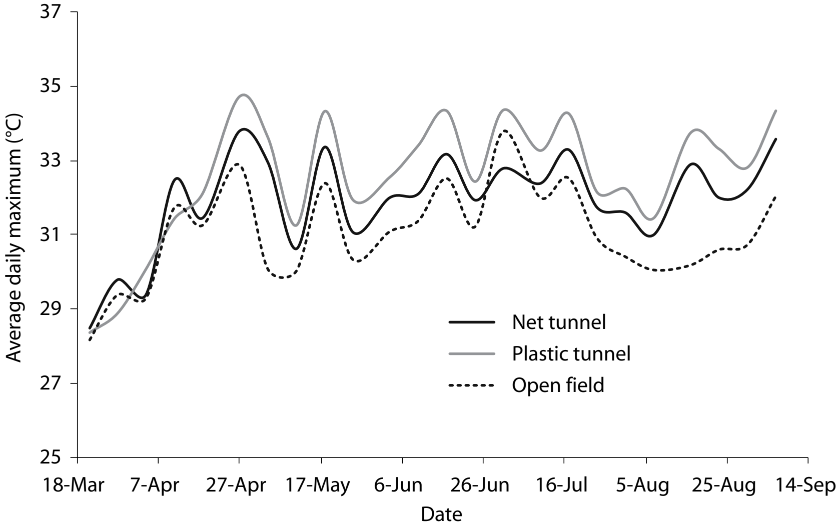

Figure 6. Average daily temperatures under tunnel-type structures and in the open field

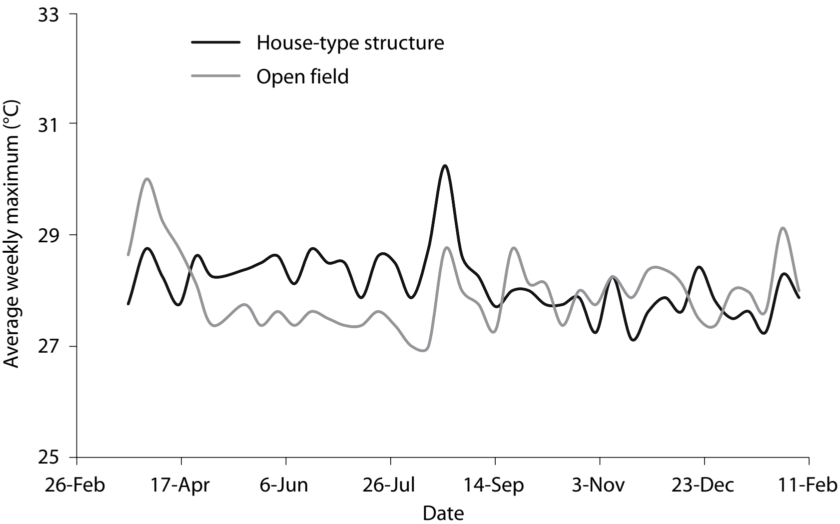

Figure 7. Average daily temperatures under house-type structures and in the open field

hence the lower temperatures inside. In times of heavy rain, the net also moderates the impact of the rainwater reaching the plant, but allows adequate penetration of light rain.

Conclusion

House-type structures made of bamboo are stronger than those made from coco lumber and are more suited to taller crops such as tomatoes, sweet pepper, bitter melon and beans. Low tunnels have great potential for low-growing crops such as lettuce, pechay and muskmelon, especially when roofed with fine netting rather than plastic. Generally, the crops grown under protective structures, regardless of the design and type of structure, have higher yields than those grown in open fields. Yields obtained, however, were found to be highly dependent on crop management, especially in relation to the choice of crop, irrigation management and pest control.

Protected cropping led to higher yields of vegetables in both wet and dry season. Disseminating this technology to other poor areas in Region VIII would help alleviate poverty and malnutrition, vegetables being a source of income and having a vital role in human nutrition and health.

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Preliminary research to develop a low-technology aeroponic system for producing clean seed potato in the Philippines

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Abstract

Potatoes are considered a high-value crop for the farmers in Mindanao, Philippines, but bacterial wilt is a major problem of potato production in this area. For the industry to survive, sustainable control measures need to be implemented. In addition, efficient systems need to be developed to produce large amounts of clean seed potato. To attain this, a scoping study was conducted to look at various options available for the development of a high-quality seed potato program in the southern Philippines, and recommendations were made to develop a soil-less, clean seed-potato production system based on aeroponics. To ensure effective seed production systems are developed for Mindanao farmers, current research at Mareeba, Australia, is looking at the development of cost-effective aeroponic structures, and at nutrition and insect-pest management in the aeroponically grown potatoes. Consideration is being given to developing a low-technology system capable of being established at village farm level, where there is minimal access to mainline electricity supplies, and it is difficult to obtain expensive inputs. Using farmer participatory research, integrated disease management and agronomic packages for sustainable production of potatoes in bacterial wilt–prone areas will be developed. The technology development will help provide opportunities for potato farmers to be self-sufficient in their seed requirements. It will also enable the private sector to produce seed potato in a cost-effective way, making the seed available to farmers at affordable prices. The low-cost production system, which is based on International Potato Centre and Vietnamese aeroponic technology, is likely to provide opportunities for potato farmers to have easy access to clean seed potato, which will help to expand and strengthen the potato industry in Philippines.

Introduction

Mindanao, the second largest island of the Philippines, consists of lands that are highly suitable for vegetable production. Having warm temperatures and regular rainfall, and being situated far enough south to escape the majority of typhoons that regularly destroy crops further north, make the island an ideal environment for intensive cropping. Bukidnon, one of the main potato-production zones in Mindanao, has an average annual temperature range of 18.5–26.6°C and average annual rainfall of 2,655 mm, uniformly distributed. This low variability climate allows farmers to produce four rotational crops on the same plot of land each year, typically potato, corn, cabbage and legumes, although there are many other crops grown in the region that may be added to the cropping sequence.

Potatoes are considered a high-value crop for Mindanao farmers, attracting prices of 25–80 pesos/kg ($US0.58–1.88), with the higher prices being attained

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around December when there is strong demand during Christmas festivities. In contrast, low-value crops, such as sweetpotato, sell for only around 5 pesos/kg ($US0.11).

Bacterial wilt disease caused by *Ralstonia solanacearum* has long been recognised as one of the major factors limiting potato production in Mindanao (Kloos and Fernandez 1985; Fernandez et al. 1986a; Tatoy et al. 1989; Young and Trevorrow 2007). It can infect potatoes through wounds as a result of cultivation or due to natural growth of root hairs (Kloos 1985). Kloos also indicated that excessive moisture, resulting in a proliferation of open lenticels, will facilitate bacterial entry of bacteria into the tuber. Tatoy et al. (1989) quoted that the high, uniformly distributed rainfall and non-flooding of the soils in Mindanao permit bacterial wilt to survive even if non-susceptible hosts are grown. It is also known to have a wide range of alternative hosts, including many other vegetable crops (particularly tomato, eggplant and other solanaceous crops) and can asymptomatically infect many of the common weeds, especially Solanaceae, found in the Mindanao agricultural systems. When present, bacteria can build up in the susceptible plants to create a year-round source of inoculum.

Hayward (1978) reported that race 1 of bacterial wilt occurs in virgin or uncultivated soils because of its wide host range. In the past, when bacterial wilt levels built up in cropping systems, farmers abandoned the land and, using slash-and-burn agriculture, move further into the forests. This can never be a sustainable solution, as the land is quickly infected, particularly when diseased planting material is used, and the new land thus also becomes unproductive. This whole process threatens soil health and global biodiversity and, if the problem of disease control and the increasing area of the regions' infected lands is not tackled, the future economic prosperity of the people. Where farmers have not had the option of moving into clean production areas, many have been forced to abandon potato cropping.

The research conducted in ACIAR project HORT/2007/066-3 'Enhanced profitability of selected value chains in Southern Philippines and Australia; Component 3—Integrated strategies for the management of bacterial wilt in solanaceous crops in Mindanao and Australia', found that Mindanao has a wide distribution of tropical strain Phylotype 1, Race 1, biovar 3, and cooler strain Pylotype II, race 3, biovar 2 of *R. solanacearum.* The studies also showed that there are significant differences in aggressiveness among isolates collected from different regions of Mindanao. While it is highly unlikely that farmers will be able to identify the type of bacterial wilt present on their land, it is essential they apply practices that will manage whichever strain is present. Due to the nature of the disease, individual management methods proved to provide poor control, but when used in unison by farmers the result was a 50% increase in marketable potato yields, and farmers were able to sustainably farm other solanaceous crops.

At three seed potato production sites in the Mindanao region (Miarayan, Kibangay and Imbayao), 18 potato varieties and two Northern Mindanao Integrated Agricultural Research Center (NOMIARC) lines have been evaluated (2008–12) for bacterial wilt tolerance. Two potato varieties, Igoata and Granola, and one NOMIARC line, NOM POB, showed comparative tolerance and had good yields. In the absence of true bacterial wilt–resistant varieties, use of clean planting material is an essential component of a bacterial wilt mitigation project.

Unfortunately, Mindanao farmers have minimal bulk seed multiplication infrastructure in place and they generally have to rely on their own or a neighbour's seed. The seed degeneration rate of certified seed, when it is available, has been observed to be very high, due to the certification schemes allowable tolerance level of 5% bacterial wilt in certified seed. There is a need for the scheme to reduce the tolerance level to 0% to align most seed schemes worldwide. Our studies showed that in the presence of bacterial wilt, potato yields can be as low as a few kilograms per hectare (Justo et al. 2013), so while there is some effort to ensure that the clean seed goes only to farmers who employ integrated management strategies, there are currently no set procedures to ensure that the resultant seed pieces are also free of the disease. Therefore, to look at the feasibility of developing clean seed production systems suitable for bacterial wilt prone lands, a scoping study was undertaken (Hughes and Trevorrow 2011) to review various options available for development of a quality seed potato program in the southern Philippines. Initial discussions were held with the Australian project personnel of ACIAR project HORT/2007/066 and with the Philippine project collaborators. A team made up of two Philippine and two Australian project members then visited Vietnam and the Philippines in November 2011. The aim of the Vietnam visit was for the team members to gain an understanding of the use of aeroponics in seed potato production (successfully developed by Professor Dr Nguyen Quant Thach at Hanoi University of Agriculture) and look at its suitability and/or adaptability to Philippine potato-production systems. The Philippines sector visit was to give the Australian team an opportunity for more in-depth examination of the current seed potato production systems and analyse how the observed practices might be integrated with different systems proposed as part of the scoping study. Taking this into consideration, pilot project activities are being negotiated with NOMIARC to develop effective high- and low-cost aeroponic units. The low-cost units, once developed, will be transferred to the field for testing with farmer cooperators. Demonstrations and hands-on training will be provided to collaborators, including Landcare and appropriate seed suppliers.

This paper discusses:

- the difference between the rate of seed production in the traditional and aeroponic systems
- the development of low-cost aeroponics production units
- the standardised practical application of the International Potato Center or CIP (now known as Bioversity International) and Vietnam aeroponic technology to provide the potato farmers easy access to clean seed potato so as to expand and strengthen the potato industry in the Philippines.

Results and discussion

Current seed availability and production in Mindanao

NOMIARC is currently the only source of clean seed potato in Mindanao (Figure 1). Virus tested in-vitro potatoes are used to produce minitubers, which are then sold to farmers at a subsidised price. Currently, this is 2.50 pesos/minituber ($US0.05). NOMIARC currently produces three crops of minitubers per year, generating a total of about 200,000–240,000. With more funding and staffing, the existing infrastructure could be maximised to produce 360,000 minitubers per year. In the southern Philippines, potato production occurs in Regions 9 (Zamboanga), 10 (Bukidnon province), 11 (Davao), 12 (Cotabato) and 13 (Caraga), and requests for seed are also received from Regions 6 (Kanlaon) and 7 (Cebu). Most of the seed potatoes produced by NOMIARC are distributed in Region 10. Conservative calculations indicate that, on an annual seed replenishment basis, NOMIARC is able to produce only 3% of Mindanao region's farmer seed requirement. If the current seed production system were increased to the maximum, which would require a nearly 80% increase in staff, production would still be in the vicinity of only 6% of the Bukidnon requirement (C. Lapoot, pers. comm. 2011).

Some seed potatoes are currently being imported into Mindanao potato-growing regions from the northern Philippines. There is concern that farmers may be importing more bacterial wilt onto their farms with this seed stock. In the past, market competition issues with the northern production zones had also made seed importation unreliable. The lack of availability of clean seed supplies means farmers have no option other than holding their own seed or buying from other farmers seed that is, in all likelihood, infected with bacterial wilt. NOMIARC staff believe that farmers may be re-using their own seed for up to five generations and it is likely it may often be longer than this. When re-using seed tubers, farmers are not utilising techniques of selecting disease-free seed designed to reduce seed degeneration rates.

Potential of aeroponic systems for potato seed production

Aeroponics and hydroponics are soil-less methods of potato production that eliminate the risk of bacterial wilt and other soil-borne disease infection. In simplified terms, aeroponics is a system of enclosing the potato plant roots in a dark chamber and supplying a solution of water and nutrients with a misting device (Ritter et al. 2001). In a comparison of hydroponic and aeroponic techniques, Ritter et al. (2001) found that the aeroponic plants grew longer and formed new shoots on lateral buds, with the secondary growth sometimes leading to formation of new stolons and additional tubers. They also found that, under aeroponics, the tuber yield—the number of tubers per plant—was around 100 as compared with 65 under hydroponic system, but the average tuber weight was lower over the whole crop. Viewing only Ritter's data produced during the main productive period rather than over the whole cycle, which includes a low-yielding tailing off period, the aeroponics still out-yielded the hydroponic system and the average tuber weight was equal to the hydroponics. CIP has also found that aeroponics offers the potential to improve production and

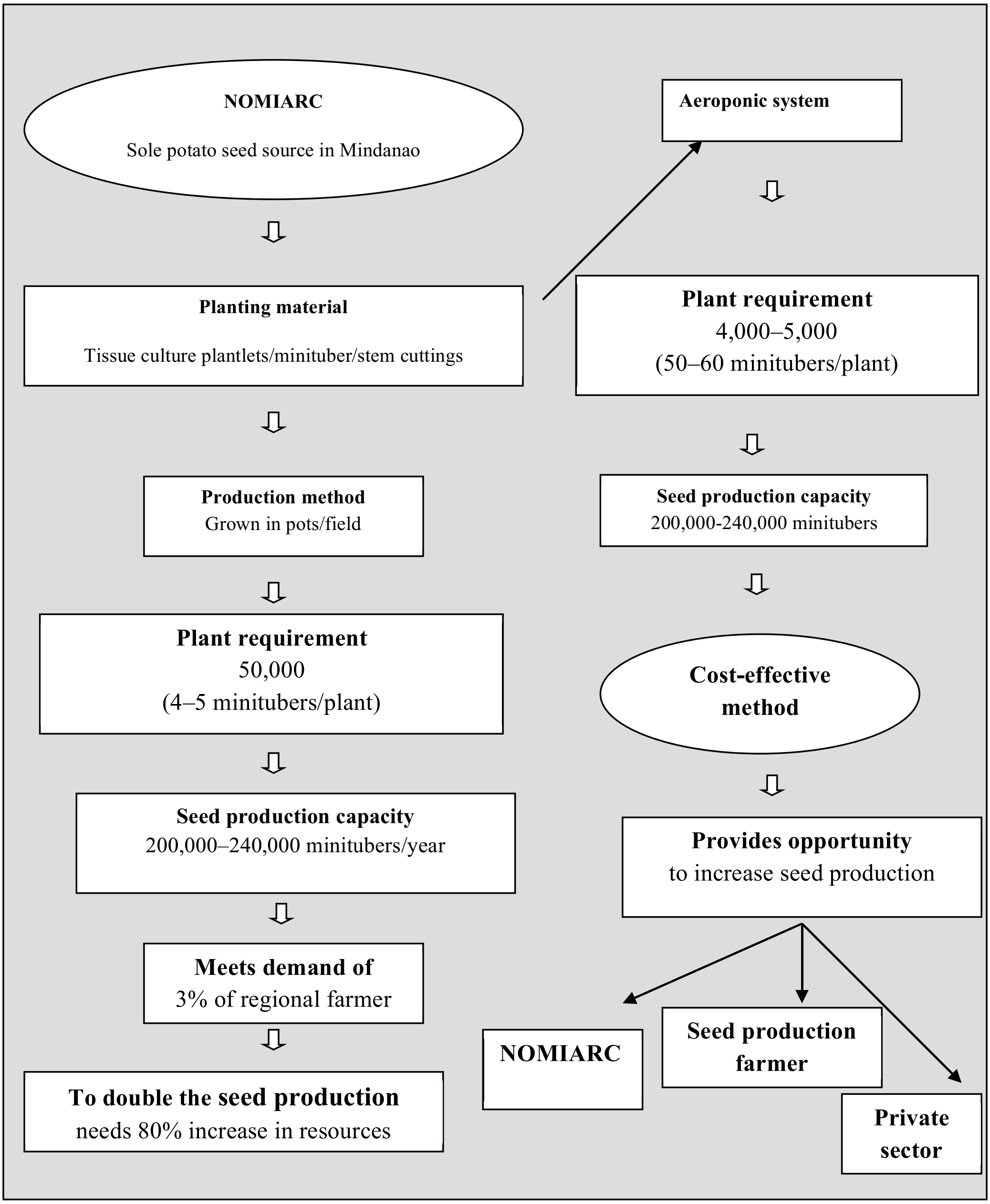

Figure 1. Current seed potato production system and potential to increase seed multiplication rapidly through aeroponic system (NOMIARC = Northern Mindanao Integrated Agricultural Research Center)

reduce costs compared with conventional methods or to other soil-less methods of hydroponics. Dr Truong Cong Tugen of the Vietnam Academy of Agricultural Sciences, Field Crops Research Institute, has been able to produce up to 733 tubers/m^2 using aeroponics. This system effectively exploits the vertical space of the greenhouse and the air-humidity balance to optimise the development of roots, tubers and foliage (Otazu 2010). Lung'aho et al. (2010) compared conventional and aeroponic technology for minituber production and reported producing 10 times more minitubers in the aeroponic system. They discussed a number of advantages of aeroponic production over conventional methods (Table 1), including less land requirement, less water and nutrient usage, sequential harvesting, reducing the number of field multiplications and easy transportability due to small-size tubers. These advantages will provide the best opportunity to seed potato growers and small landholders to produce high-quality seed. Further developing knowledge and skills in aeroponic technology will also help to resolve other issues such as production costs, labour requirements and disease management.

Ongoing research activities

Development of low-cost seed production technology through aeroponics

In developing an aeroponic seed potato production scheme for the southern Philippines, training of staff and practical hands-on experience to master the new technology are needed. Therefore aeroponic technology is being researched at the Centre for Tropical Agriculture, Mareeba, to deliver the potential outcomes to potato growers in Mindanao. A small, 2.0 × 1.5 m,

Table 1. Comparison of different systems for seed potato minituber production

Characteristic	Clonal multiplication	Minituber production system		
		Conventional stem cuttings	Conventional tissue culture	Aeroponics
Multiplication rate	1:6–10	1:3–5	1:6–10	1:50–100
Labour required	High	Modest	Modest	Modest
Land requirement	High	Medium	Low	Low
Cost investment	Relatively low	Modest	Modest	Initial investment is high
Energy dependence (sterilisation of substrate)	Not required	Required	Required	Not required
Sequential harvests	Not possible	Possible but not convenient	Possible but not convenient	Possible
Level of management skill required	Average	High	High	Very high
Water requirements	High	Modest	Modest	Low
Nutrient recirculation	Not possible	Not possible	Not possible	Possible
Risk of disease infection	Low	Modest	Modest	High
Transportability of pre-basic seed (field-grown seed; G1–G3 seed)	Costly due to bulkiness	Relatively cheap and convenient due to small size of tubers	Relatively cheap and convenient due to small size of tubers	Relatively cheap and convenient due to small size of tubers
Potential for reducing the number of field multiplications	Nil	Medium	Medium	High
Potential for automation	Nil	Medium	Medium	High
Environmental friendliness	No sterilisation of substrate (soil) required	Sterilisation of substrate required	Sterilisation of substrate required	No sterilisation of substrate required

aeroponic unit (Figures 2–7) has been constructed, and initial studies are being carried out to develop a low-cost aeroponic unit, to study varietal responses in seed production and nutritional requirements, and to solve insect pest issues.

The seed (minitubers 2–2.5 g) of two popular Australian varieties 'Sebago' and 'Nicola' were procured from Victorian Certified Seed Potato Australia. The minitubers were grown in sterilised sand in plastic tubes (67–120 mm) for 15 days. The roots were then washed with clean water and treated with the fungicide Mancozeb (0.25% for 15 minutes) before transplanting to the aeroponic unit (Figure 7). The timer was fixed to run the nutrient solution for 60 seconds after every 10 minutes. On hot days (≥ 28°C) it was adjusted to run 15 minutes on/off. The plants were securely staked and preventive fungicide/insecticide sprays were applied to avoid the incidence of insect pests. The pH (6.0–6.5) and electrical conductivity (2–2.5 mS/cm) of the nutrient solution were checked weekly and adjusted accordingly. Two commercially available nutrient solutions were evaluated:

- 'Flora' series ('FloraGro'–total N 2%, P_2O_5 1%, K_2O 6%, Mg 0.5%; Flora Micro N 5%, K_2O 1%, Ca 5%, B 100 ppm, Co 5.5 ppm, Cu 100 ppm, Fe 1,000 ppm, Mn 500 ppm, Mo 8 ppm, Zn 150 ppm and 'FloraBloom'–P_2O_5 5%, K_2O 4%. Mg 1.5%, S 1%)

Figure 2. Recycled iron structure utilised for the outer frame of the aeroponic box. Wood or bamboo could also be used and be cost-effective.

Figure 3. The aeroponic box is lined with 2-inch thick polystyrene to maintain optimal temperature and moisture conditions for development of roots and tuber formation.

Figure 4. Installation of nutrient tank and pump for recirculation of nutrient solution

Figure 5. The box is lined with black plastic film to prevent light penetration (essential for root growth) and to make it leak-proof for collection of nutrient solution.

Figure 6. The aeroponic unit ready for fixing curtains—an inner curtain to prevent the nebulised nutrient solution from escaping and outer black curtains to prevent light entering the box

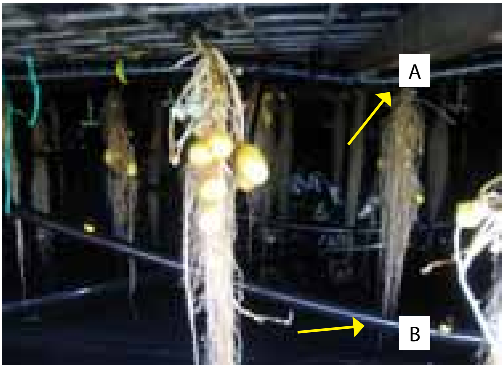

Figure 7. (A) Installation of nutrient feeding system—nebuliser fitted to the main pipe; (B) back-up irrigation system (run on gravity) to cover the risk of pump failure and power failure

- 'Plantastic' hydroponic solution A and B (total N 2.55%, P 0.38%, KNO_3 3.68%, Ca 2.6%, S 0.84%, Mg 0.65%, Fe 400 ppm, Mn 100 ppm, Bo 42 ppm, Zn 30 ppm, Cu 18 ppm Mo 6 ppm).

The FloraGro combined with FloraMicro and FloraBloom nutrition were found to be excellent for supporting plant growth and tuberisation in the aeroponic system. The Plantastic nutrient solution, supported good vegetative and root growth, but failed to produce potato tubers. This may be due to the application of the same nutrient concentration throughout the growing period, whereas in the Flora series the precise formula was used to mix FloraMicro, FloraGrow and FloraBloom as per manufacturer recommendations to make tailor-made nutrient mixes for each growth stage of the crop.

The varieties showed different responses in the aeroponic system with respect to plant growth and tuber production, which may be attributed to their genotypic and phenotypic characteristics and/or nutritional requirements. Tuber initiation in Nicola started 10 days earlier than in Sebago. The first harvest was made 50 days after transplanting (Figures 9–10). Evaluation of the commercially available chemicals and biological control agents for their ability to maintain healthy plants is continuing.

In the present study, the tubers of both varieties grown are being harvested in the 8–30 g weight range. Further data will be collected to determine the number of tubers/plant, evaluate the yield difference with respect to seed size under field conditions, and eventually standardise the tuber seed size for harvesting for direct commercial plantings. A cost–benefit

Figure 8. (A) Potato minitubers; (B) Planted in sterilised sand; (C) Transplanting of potato plants into the holes of the aeroponic unit (a sponge/clean cloth is wrapped around the neck of plant to hold it)

analysis for the aeroponic system will be conducted, to evaluate the effectiveness of the system over conventional methods for high-quality seed production.

The outcomes of the study will help farmers to:

- produce their own seed potatoes—only 600–800 plants from an area of less than 80 m^2 will provide enough seed tubers (40,000 approx) in 3–4 months for planting 1 ha
- provide rapid seed multiplication of desired varieties at low cost
- eliminate all stages of seed multiplication under field conditions
- allow access to high-quality seed at an affordable cost for commercial plantings
- avoid the risk of bacterial wilt contamination and further spread of the disease through seed.

A raw estimation has been made that to establish an 80 m^2 aeroponic facility in Philippines would cost 150,000 pesos, with an operating cost of 50,000 pesos per crop to grow 1,000 plants. These would produce more than 180,000 mintubers/year (3 crops/year), enough to provide clean planting material for 4.5 ha of land. This would give a profit of 130,000 pesos in the first year and around 300,000 pesos in second and subsequent years.

The aeroponic technique will be further tested and refined under Philippine conditions in the next phase of the project. Studies will be conducted to evaluate the best distribution and production systems for large-scale clean seed units (aeroponic units) at NOMIARC, and attempts will be made to skip all field multiplication of seed. The

Figure 9. Potato tuber growth after 40 days of transplanting into the aeroponic system: (left) variety Nicola; (right) Sebago

Figure 10. Seed potatoes, weight range 8–30 g, harvested from the aeroponic system: (left) variety Nicola; (right) Sebago

cost-effective, low-technology system will be developed and introduced to farmers so they can move into the clean seed production business and meet their own and regional seed demand. Every year, aeroponically grown seed will be used for commercial plantings covered by integrated pest management strategies. This will eliminate the risk of introduction and spread of seed and soil-borne diseases through latently infected planting material and will strengthen the clean seed program to build a sustainable potato industry in the Philippines. The technology developed in this project can be transferred directly to other tropical countries.

Future research

The authors are aware of the potential of aeroponic technology in high-quality seed potato production and its successful implementation for rapid multiplication, providing the ability to skip one generation of field multiplication in disease-prone countries. The preliminary studies on the development and cultural techniques for an aeroponic system have indicated that it can produce seed tubers of a size acceptable to Filipino farmers, making it possible for direct distribution of aeroponic seeds to farmers or certified seed growers. Adoption of this technology by small-scale seed producers in the cooler production areas will be tested across the Mindanao regions. Issues needing further refinement include: use of different planting materials; nutritional requirements; irrigation frequencies; harvesting times; seed storage; multiplication rates; development of agronomic packages for field planting; and insect pest management. The aeroponic process and technology also needs to be redesigned to be applicable to on-farm seed-production situations, since the government alone will never be able to produce the quantity of seed required by the potato industry. The development of a cost-effective aeroponic system may provide an opportunity for the private sector to multiply high-quality seed potatoes at faster rates and supply seeds to farmers at an affordable cost. In the Philippines, a major focus in the near future will be capacity building among local institutions to support the seed potato producers. The establishment of organised seed potato growers' associations is expected to provide a strong basis for technology uptake. The development and adoption of aeroponic technology is envisioned to lead to higher crop returns and incomes, reduced production costs, and lower field and postharvest losses, and to support the supply chain stakeholders to make potatoes available at affordable prices and improve food security and nutrition for the Philippine people.

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Phenotypic and genotypic relationships of *Ralstonia solanacearum* isolates from the northern and southern Philippines

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Abstract

The bacterial wilt pathogen was isolated from wilted white potato plants, soil and apparently healthy and symptomatic tubers from the northern and southern Philippines. The identity of the pathogen was confirmed as *Ralstonia solanacearum*, based on its colony morphology in TZC media biochemical tests, and by PCR-based detection using specific primers 750/760 and Nmult mix. Isolates are divided into Phylotypes I and II, which are well distributed in both southern and northern areas. No phenotypic differences were observed among isolates except for their aggressiveness on 'Yellow plum' tomato cultivar. All isolates were verified to be pathogenic to the Yellow plum tomato cultivar, but isolates from plants proved to be more aggressive than those from soil and tubers. DNA fingerprinting generated 6 and 25 RAPD and BOX clusters, respectively, indicating the diversity of the isolates.

Introduction

Economic losses due to bacterial wilt disease in the Philippines have long been a problem in vegetable production. The disease has affected major commodities including, but not limited to, white potato, tomato, pepper, eggplant and crucifers. The bacterium causing the disease, *Ralstonia solanacearum,* described as a 'species-complex', is widespread and is very prevalent in vegetable-growing regions in the country, e.g. in the highlands of Benguet and Bukidnon. These regions are considered 'food baskets' of the country because of their high production of vegetables due to favourable climatic conditions, ideal for planting. However, most crops grown in these areas, especially white potato, are vulnerable to *R. solanacearum*. The bacterial wilt disease is also a problem to many potato farmers because potato tubers that are used as planting materials are very susceptible to the bacterium and can harbour the pathogen without manifesting symptoms until planted. Thus, effective management strategies are warranted. Although a number of promising management strategies has been demonstrated, the threat presented by bacterial wilt disease in the Philippines remains a problem. It is also clear that a better understanding of the population structure of this highly diverse pathogen is needed in order to develop pathogen-specific or even site-specific management strategies. Genetic variability is also a very important aspect that can be explored to gather

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information about the pathogen. The study reported here aimed to isolate *R. solanacearum* from infected white potato plants, soil and apparently healthy and unhealthy potato tubers; confirm the identity of the isolates by their cultural characteristics in selective media, polymerase chain reaction (PCR)-based detection methods, and pathogenicity and aggressiveness tests on tomato; and analyse the genetic diversity and relatedness among isolates of *R. solanacearum* by random amplification of polymorphic DNAs (DNA) and using repetitive element (rep)–PCR.

Review of the literature

The causative agent of bacterial wilt disease was first reported in the Philippines by Reinking in 1918 as *Pseudomonas solanacearum*, and later by De Villa and Natural in 1998 (Tangonan 1999) as *R. solanacearum* causing rot. Potato is very popular in the Philippines and common in the highlands. It ranks first in terms of production in Benguet and Bukidnon, and serves as one of the major sources of income among farmers. Though crop rotation and removal of infected plants are practices, the bacterial wilt disease is still widespread and remains a growing concern in potato production.

The pathogen is considered highly variable, encompassing six biovars based on biochemical properties (Hayward et al. 1990) and five races based on host range (He et al. 1983). Race 1 is distributed in Asia, Australia and North America and has the highest number of host species, which include solanaceous crops; Race 2 is predominant in tropical areas of South America, the Caribbean, Brazil and the Philippines, where bananas, plantain and other *Musa* spp. are grown; and Race 3 is distributed worldwide except in the USA and Canada. Race 4 can be found only in Asia, while Race 5 is found only in China (Tahat and Sijam 2010). Biovar 2 of Race 3 is of quarantine importance in North America and has been listed as a 'Select Agent' plant pathogen under the Agricultural Bioterrorism Act of 2002 (Champoiseau and Momol 2008). However, the race and biovars classification system has been found 'unsatisfactory' and a new classification scheme has been described based on the variation in DNA sequence of the bacterium. As proposed by Fegan and Prior (2005), this pathogen is now further classified into phylotypes, based upon the phylogenetic analysis of the sequence generated from the 16S–23S internal transcribed spacer (ITS) region, endoglucanase and mutS gene. The Philippine isolates belong to Phylotype I (Asia) and consist of biovars 3, 4 and 5. Phylotype II includes strains belonging to biovars 1, 2 and 2T isolated from America. Phylotype III strains are those primarily from Africa and neighbouring islands and Phylotype IV are those isolated primarily from Indonesia. Phenotypic and genotypic variations have been studied in the Philippines (Natural et al. 2005) using a number of isolates from selected areas in the northern and southern parts of the country. In this study, however, more isolates were used to further characterise the pathogen and to determine both the phenotypic and genotypic variability by utilising DNA based-techniques to better understand the pathogens existence and movement in northern and southern regions, and to work towards appropriate disease management strategies.

Methodologies

Sample collection and laboratory isolation

Major potato-growing regions, as well as other vegetable-growing areas, were visited and surveyed to collect diseased and infected plants, tubers and soil. Collecting was more extensive in Benguet (northern Philippines) and Bukidnon (southern Philippines) as these areas were largely planted with solanaceous and high-value crops due to their geographic location and favourable climatic conditions for crop growth. Laboratory isolation was conducted at the Plant Pathology Laboratory, Institute of Plant Breeding, Crop Science Cluster, University of the Philippines Los Baños, Laguna. Different isolation methods were employed from different sources (plants, soil and tubers). For plants, wilted plant stem was immersed in distilled water and bacterial ooze was observed. A loopful of suspension was streaked onto TZC medium (10 g/L peptone, 5 g/L glucose, 1 g/L casein hydrolase, 18 g/L agar with tripheny tetrazolium chloride) and incubated for 48–72 hours at 32 °C. For tubers, a modified method was employed to isolate the bacterium from both symptomatic and asymptomatic tubers. A piece of potato was taken from the tuber by punching with a sterile 1 mL pipette, mixed with 1 mL sterile distilled water and the suspension streaked on to the TZC medium. The punched hole was washed with sterile distilled water (approximately 1 mL) and the resulting suspension was streaked onto TZC medium. For soil, 10 g of soil sample was mixed into 90 mL of distilled water and vigorously mixed for 20 minutes. Standard dilution test followed and a 100 mL of suspension from each dilution was spread onto TZC medium [with added crystal violet (5 ppm), polymixin (100 ppm), thyrothricin (20 ppm), chloromycitin (5 ppm) and cycloheximide (5 ppm)]. Typical colonies of the bacterium were individually placed in 1 mL of sterile distilled water in sterile 1.5 microcentrifuge tube (3 sets) and stored in room temperature for further verification and characterisation.

Growth on selective media and pathogenicity test

Isolates were characterised based on appearance on selective media and TZC. Growth was monitored from 24–72 hours at an incubation temperature of 32°C. For the pathogenicity study, 4-week-old tomato (cv. 'Yellow plum') plants were used as test plants (5 plants/isolate) and were inoculated with bacterial solution (OD_{600} = 0.3) by soil drenching. Plants were kept in a greenhouse and observed daily for symptom appearance.

Molecular characterisation

To further verify that isolates were *R. solanacearum*, PCR-based methods were employed using two sets of primers—759/760 (Opina et al. 1997) and RALSF/RALSR (Kang et al. 2007)—with product sizes of 281 and 982 base pairs, respectively. The former was from the ITS region sequence and the latter from the Cytochrome c1 peptide sequences of *R. solanacearum*. Alongside detection, isolates were ascertained into phylotypes (Table 1). Thus, a multiplex PCR analysis was performed to detect and, at the same time, characterise the isolates. Templates used for detection were either from bacterial suspension or extracted DNA. Extraction of DNA was accomplished following, with slight modification, the method described by Chen and Kuo (1993).

PCR assay was performed in a PC-960 cooled thermal cycler (Corbett Research), with 30 cycles of 94°C of denaturation for 30 seconds, 59°C of annealing for 90 seconds and another 90 seconds of extension at 72°C (Table 2). One cycle at 94°C of initial denaturation for 4 minutes and another at 72°C for final extension of 20 minutes were added before and after the actual 30 cycles, respectively. Following PCR amplification, 7 µL of the PCR product was analysed by gel electrophoresis on 1.2% w/v agarose gel (Pronadisa) in 0.5× Tris-acetate EDTA (TAE) buffer at 110 V for 1 hour. The gel was stained with GelRed™ (Biotium) for at least 30 minutes and viewed under ultraviolet light (UV) using the GelDoc-XR+ documentation system (Bio-Rad Laboratories, USA). Identity of the isolates was confirmed based on the size of the product against the standard DNA marker (1 kb plus ladder, Invitrogen, USA).

DNA fingerprinting and cluster analysis

RAPD primer OPA-07, (GAAACG GGTG) was used for amplification. A total of 25 µL reaction mixture consisting of 1× buffer, 1.5 mM MgCl2, 0.2 mM dNTPs, 0.67 µM of primer OPA-07, 1 unit of *Taq* polymerase (Invitrogen), and 1 µL volume of bacterial DNA solution as DNA template was assayed. The assay was performed under the following thermal cycling conditions: initial denaturation of 94°C for 5 minutes, followed by 30 cycles of denaturation at 94°C for 1 minute, annealing of 37°C for 1 minute and extension of 72°C for 2 minutes, and a final extension of 72°C for 5 minutes. DNA fingerprinting of *R. solanacearum* by rep-PCR was carried out using the following set of primer: BOX, BOXA1R (5′-CTA CGG CAA GGC GAC GCT

Table 1. Primers used, their sequences and expected product sizes

Primer name	Sequences	Expected product size (bp)	For detection of
759 760	GTCGCCGTCAACTCACTTTCC GTCGCCGTCAGCAATGCGGAATCG	281	*Ralstonia solanacearum*
RALSF RASLR	GCTCAAGGCATTCGTGTGGC GTTCATAGATCCAGGCCATC	932	*R. solanacearum*
Nmult:21:1F	CGTTGATGAGGCGCGCAATTT	144	Phylotype I
Nmult:21:2F	AAGTTATGGACGGTGGAAGTC	372	Phylotype II
Nmult:22: InF	ATTGCCAAGACGAGAGAAGTA	91	Phylotype III
Nmult:23:AF	ATTACSAGAGCAATCGAA	213	Phylotype IV
Nmult:22:RR	TCGCTTGACCCTATAACGAGTA	–	

Table 2. PCR reaction master mix components and concentrations

Item/description	RALSF/RALSR	759/760
Buffer concentration	1×	1×
$MgCl_2$ concentration	2 mM	1 mM
dNTPs concentration	0.2 mM	0.2 mM
Nmult primer mix	1×	1×
Forward primer	0.2 µM	0.2 µM
Reverse primer	0.2 µM	0.2 µM
DMSO	1%	1%
Taq polymerase added	0.6 U	0.6U
cDNA template	1 µL	1 µL

GAC G-3′) (Versalovic et al. 1994). PCR was done in a 15-µL reaction volume containing DEPC water, 1× Gitschier buffer, 0.16 mg/mL bovine serum albumin, 10% DMSO, 2.5 mM each dNTPs, 2 pmol of each primer, 0.05 unit of *Taq* polymerase, and 100 ng of template DNA. PCR conditions were as follows: initial denaturation at 94°C for 7 minutes, followed by 35 cycles of denaturation at 94°C for 1 minute, primer annealing at 53°C for 1 minute, and extension at 65°C for 8 minutes, with a final extension step at 65°C for 15 minutes. PCR assay was done in PC-960 (Corbett Research, Australia) for RAPD and MyCycler (BioRad Laboratories Inc., Singapore) for BOX–PCR. RAPD and BOX products were separated in a 1.5% agarose gel in 0.5× TAE buffer at 80 V for 70 minutes. Only reproducible bands were scored using a binomial system of scoring (1 = present, 0 = absent). NTSYS software was used to calculate Jaccard's (1908) similarity coefficients. These coefficients were used to construct a dendrogram by the unweighted pair-group method of arithmetic average (UPGMA).

Results and discussion

Field collection and symptomatology

The most frequent external symptoms observed on infected plants in the field are wilting, yellowing of the foliage and, sometimes, downward bending of leaves. When checked internally, the most frequent symptom was progressive discolouration of vascular tissues. On tubers, discolouration and decay, especially in the vascular ring area, and bacterial slime oozing from the infected area were observed. A total of 383 *R. solanacearum* isolates was collected from the northern and southern Philippines. Most isolates were from the soil (177) and plants (137), but there were also isolates from tubers (69). The number of isolates was highest in Dalwangan (Malaybalay, Bukidnon) followed by Buguias (Benguet) and Talakag (Bukidnon). One possible reason why most of the isolates were obtained from these sites could be the presence of susceptible hosts, such as white potato, which are continuously grown there. Aside from white potato, other solanaceous crops such as tomato and pepper are also grown, even though these crops are commonly found in the lowland as well. The first and last sites were located in the southern region, while the second site was in the northern part of the country. The rest of the isolates were evenly distributed in other locations where white potato and other solanaceous vegetables are grown.

Colony morphology and characteristics

Growth was visible as early as 36 hours after streaking, and appeared as white to creamy-white colonies with pinkish to reddish centres that are fluidal or mucoidal and opaque. These characteristics usually indicate that the bacterium is virulent. Mucoid substances are produced by the accumulation of an exopolysaccharide (EPS) that causes colonies to exhibit irregularity of their surfaces (Smith 1920). Whorls at the centre of the colony were often observed as a characteristic of the bacterium.

Simultaneous detection and phylotype identification of *R. solanacearum*

Isolates generated the expected 281 bp fragment defined by the 759/760 primer pair. A second fragment can be seen at either 144 bp or 372 bp fragment indicating its phylotype (Figure 2). The former confirms the identity of Phylotype I and the latter, Phylotype II. Phylotype I includes strains belonging to biovars 3, 4 and 5, and strains that are isolated primarily from Asia (Fegan and Prior 2005).

Figure 1. Growth of *Ralstonia solanacearum* in selective media, TZCA, after 48-hour incubation at 32°C

Interestingly, results of the phylotyping indicate the presence of Phylotype II, which is primarily isolated from America.

Out of 383 isolates, 190 were Phylotype I, which is almost 50% of the total, and the remaining 193 isolates were Phylotype II. Most of the Phylotype II isolates were observed in areas of low temperature and high elevation. Most of these Phylotype II isolates were collected in the northern region (Benguet) where elevation is slightly higher than the southern region (Bukidnon). However, Phylotype II isolates were still present in Bukidnon, especially in the elevated areas such as Miarayaon, Talakag, Bukidnon. Phylotype I isolates were common in the two regions, but those from northern region were isolated from the soil. The phylotyping scheme therefore helps us indicate the existence of specific *R. solanacearum* isolates in a particular area and provide information that may serve to guide policy on the movement of planting materials that may harbour the pathogen from elevated areas to the lowlands.

Absence of cytochrome c1 signal peptide sequence in some *R. solanacearum* Philippine isolates

Preliminary tests performed using the *R. solanacearum* specific primer (RALSF/RALSR) developed by Kang et al. (2007) using the cytochrome c1 signal peptide sequences revealed that it cannot amplify the expected product size of 932 bp in some Philippine *R. solanacearum* isolates. This was further verified when primer pair 759/760 with a smaller product size of 281 bp was included in the master mix. PCR analysis consistently revealed that RALSF/RALSR is less sensitive in detecting some of the isolates that were used. It was notable, however, that the 932 bp product size was only amplified on Phylotype I isolates. It appears that it fails to amplify those that belong to Phylotype II (Figure 3). This result holds true for both Benguet and Bukidnon isolates.

Detection in symptomatic and asymptomatic potato tubers and their variations in phylotypes

Apparently healthy or symptomless potato tubers were collected and used in the isolation of *R. solanacearum*. Phylotype analysis of the different

Figure 2. Agarose gel electrophoresis of PCR products from assay using primer pair 759/760 and Nmult primer mix. Lane M, molecular marker 1 kb plus ladder (Invitrogen, USA), lane NC, negative check (water), lane 1–14, *Ralstonia solanacearum* isolates. The 372 bp fragment indicates Phylotype II and 144 bp fragment indicates Phylotype I. The 281 bp fragment is universal to *R. solanacearum*.

Figure 3. Amplified PCR product using primers RALSF/RALSR resolved in 1.2% agarose gel stained in GelRed. Lane M, molecular weight marker (1 kb-plus ladder), lane 1, PCR negative check (water), lanes 2 to 6, *Ralstonia solanacearum* Phylotype II without RALSF/RALSR amplification. Lanes 7–8, *R. solanacearum* from other crops, lanes 9–15, Phylotype I with RALSF/RALSR amplification. Box highlighted in red emphasises the absence of 932 bp of select *R. solanacearum* isolates.

isolates showed the existence of phylotypes I and II. Variation in phylotypes was associated with the geographic origin of the isolates. Phylotype I was observed mainly among the isolates collected in Bukidnon, while Phylotype II was observed among the isolates collected from highlands in Benguet and Bukidnon. Interestingly, apparently healthy tubers harbour *R. solanacearum*, as indicated by the results of the PCR analysis with the presence of the two phylotypes. It was observed that most isolates from Mindanao belong to Phylotype I. According to Cellier and Prior (2010), this phylotype encompasses a majority of lowland or tropical strains with a wide host range. Phylotype II, into which all the isolates from Benguet were classified, encompassed highland and cold-tolerant strains of potato brown rot. This explains the distinct variation in phylotypes in terms of their geographic origin. Potato-growing areas in Benguet were at higher elevation and temperatures in the area are relatively lower than those in Bukidnon.

Reaction of *R. solanacearum* isolates to Yellow plum tomato cultivar

Typical wilting symptoms of bacterial infection were observed after inoculation on Yellow plum tomato cultivar (Figure 4). Most of the isolates were observed to induce infection 2–3 days after inoculation. The most aggressive isolates were those that were isolated from plants. Initial wilting of leaves was observed 2 days after inoculation (DAI). It was also observed that isolates from Benguet were more aggressive than isolates from Bukidnon. The former induced symptoms 2 DAI and the latter at 3 DAI on tomato test plants. The soil isolates came second to plant isolates in terms of aggressiveness. There was no difference in the degree of aggressiveness observed in soil isolates from different collection sites. Tubers yielded the least aggressive isolates, but tuber isolates from Bukidnon were more aggressive than those from Benguet.

Genomic DNA fingerprints using RAPD and BOX primers

RAPD–PCR analysis revealed six distinct groupings/clusters of *R. solanacearum* isolates based on binary scoring of reproducible bands with sizes that ranged from 340 to 1200 bp (Figure 5A). Application of RAPD analysis in *R. solanacearum* populations has been useful in detecting both phenotypic (Horita and Tsuchiya 1999) and genotypic diversity (Deepa et al. 2003; Grover et al. 2006). The R2 and R6 are the largest clusters (Figure 6) with 30 isolates each. R1 has 28 isolates that are more aggressive and were mostly isolated from elevated regions (Buguias and Talakag) and, with the exception of isolates S414-5, A49, WP233, 178T-1 and S90-2, belong to Phylotype II. Most isolates were also from plant tissues, with few from tubers and soil. S90-2, isolated from soil in Casisang, Malaybalay and Bukidnon, is grouped in this cluster, but is further separated into another unique subcluster. The second cluster, R2, has isolates that are mostly Phylotype I; exceptions being isolates 54T-2 and WP150. Most isolates were collected from Bukidnon, with the exception of an isolate from Benguet (54T-2). Isolates belonging to this cluster are those that are moderately aggressive (3–6 DAI). There were no trends observed in

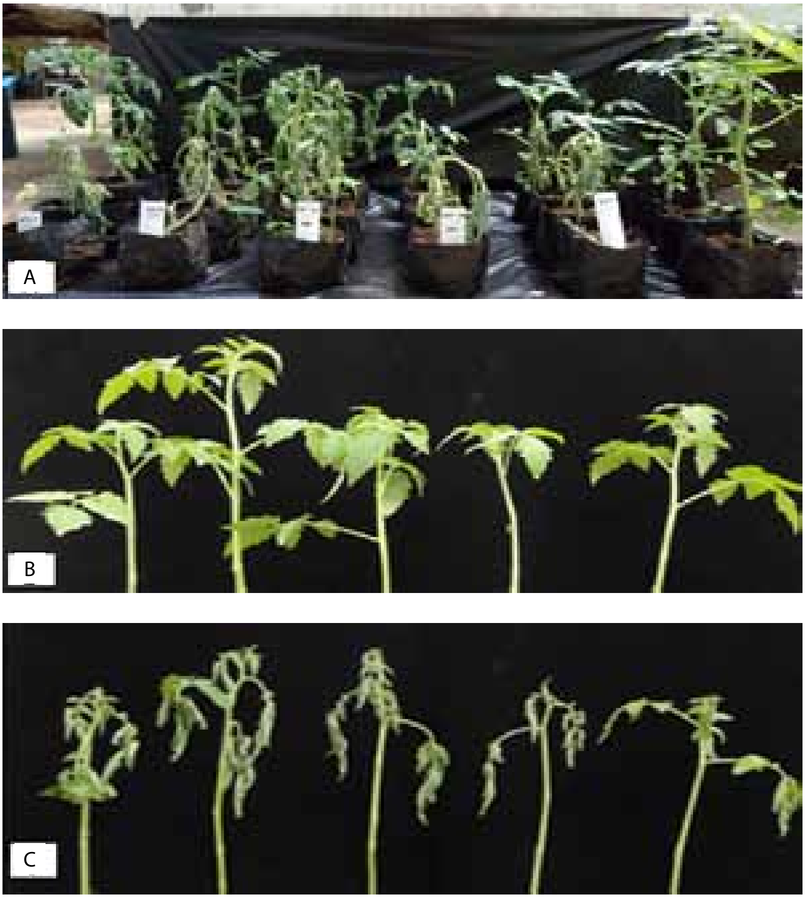

Figure 4. Reaction of tomato cultivar 'Yellow plum' to different *Ralstonia solanacearum* Philippine isolates (A), and comparison with healthy/uninoculated (B) and wilted/inoculated (C) tomato plants

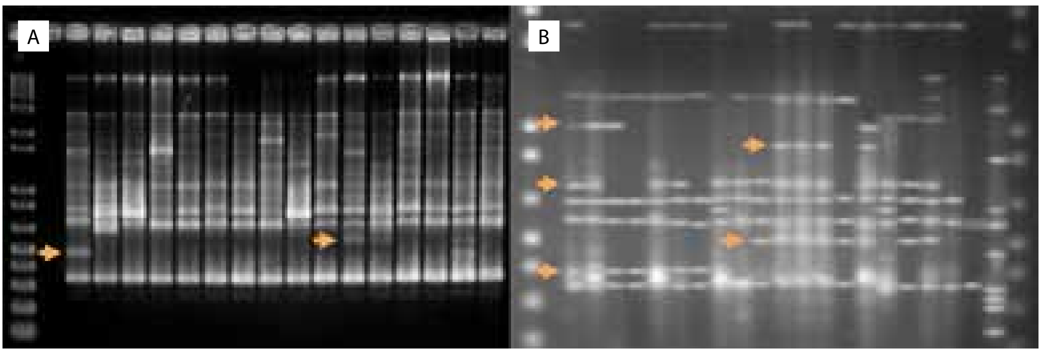

Figure 5. Banding patterns of *Ralstonia solanacearum* isolates generated using RAPD OPA-07 (A) and BOX (B) primers resolved in 1.5% agarose gel

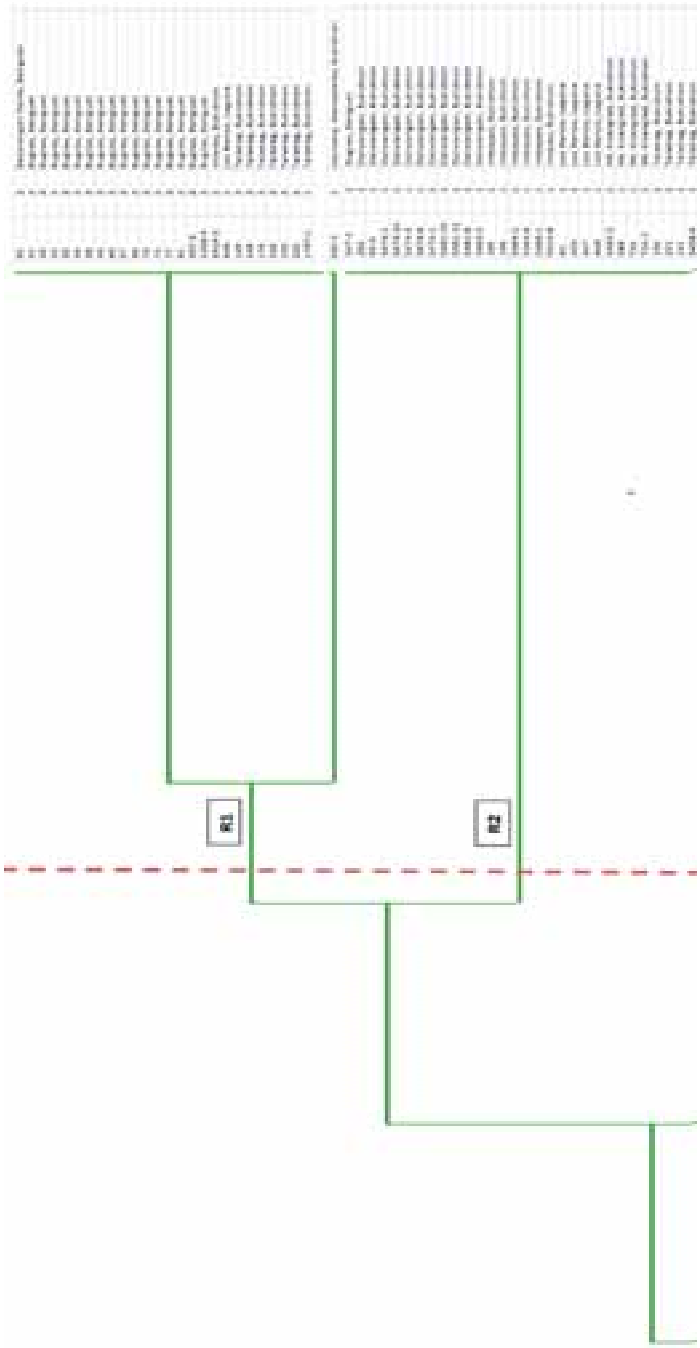

Figure 6. (a) Dendrogram derived by by unweighted pair group method, arithmetic mean (UPGMA) showing the similarity relationships among *Ralstonia solanacearum* isolates generated by RAPD-PCR analysis (cluster group 1)

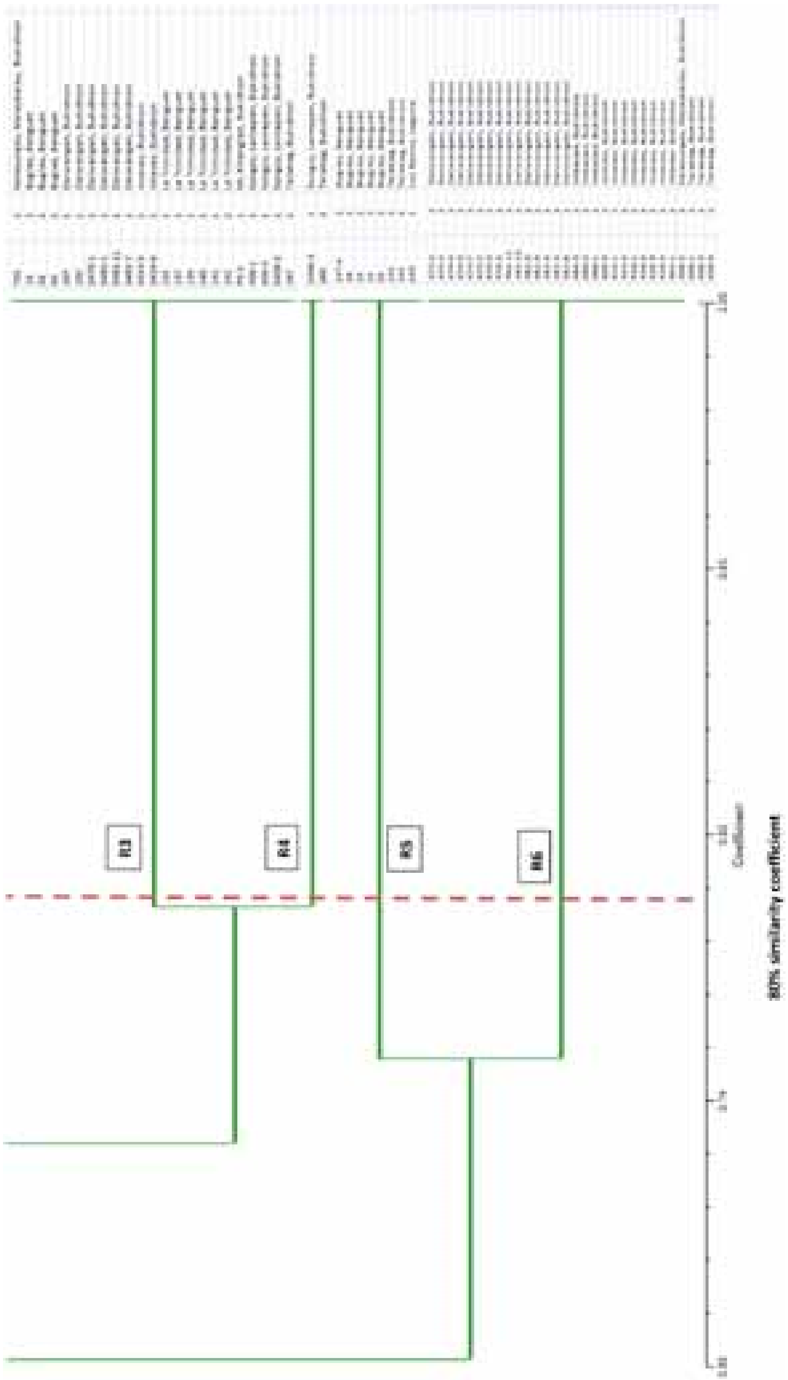

Figure 6. (b) Dendrogram derived by unweighted pair group method, arithmetic mean (UPGMA) showing the similarity relationships among *Ralstonia solanacearum* isolates generated by RAPD-PCR analysis (cluster grouping 2)

clusters R3, R4 and R5 (Figure 6B) since isolates were distributed in these clusters regardless of source and aggressiveness. However, cluster R6 was very distinct since it includes isolates from Bukidnon that are moderately aggressive and were all isolated from the soil. These are isolates from Dalwangan, Imbayao, Intavas and Talakag and one (1) isolate from Kalasungay. All isolates are Phylotype I. RAPD analysis is very useful for detecting polymorphism (Hilton and Penn 1988) and not just in *R. solanacearum* (e.g. Parent et al. 1996; Khoodoo et al. 2002).

Twenty-five BOX clusters (Figure 7) were defined from the *R. solanacearum* isolates by amplification using the BOX primer. Out of these 25 clusters, 5 were large. Fragments amplified from both Benguet and Mindanao isolates using BOX primers were observed to be mostly small-size fragments in the range 200–2,000 bp. The 350 and 600 bp fragments were common to many isolates. The largest cluster, B1, consists of isolates solely from Benguet, isolated from white potato plants and ascertained to belong to Phylotype II. These isolates are also aggressive on tomato cultivar Yellow plum and induced infection 2–3 DAI. A second large group is B5, which comprises Phylotype II isolates collected from soil with high disease incidence in Benguet. They are also (2–3 DAI) to moderately aggressive (4–9 DAI) isolates.

B13 is also a large cluster, comprising Phylotype I isolates from Bukidnon. They were isolated mainly from soil planted with white potato and tomato. This cluster was further divided into numerous subclusters, one of which was associated with soil from Songco, Lantapan, planted with tomato. Another large cluster is B17, which includes aggressive to

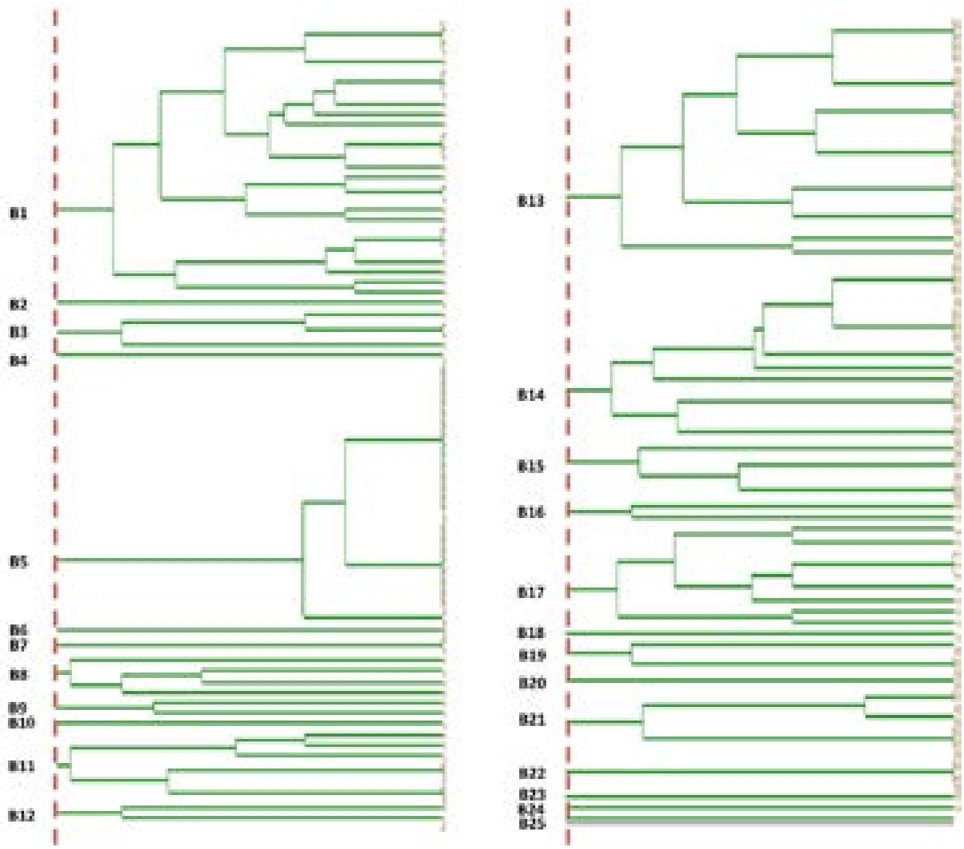

Figure 7. Unique BOX clusters identified from the *Ralstonia solanacearum* isolates obtained from Bukidnon and Benguet.

moderately aggressive isolates collected from white potato in Bukidnon. Another unique cluster, B21, consists of Phylotype I isolates from soil planted with tomato and pepper. Of the two primers (RAPD and BOX) used for DNA fingerprinting of the isolates, the BOX primer was more discriminating than the RAPD primer. More clusters/groups were defined by the BOX primer. Cruz et al. (2002) reported that BOX had a higher discriminating capacity because it showed an increase in the number of polymorphic bands.

Conclusion

This study successfully isolated *R. solanacearum* from wilted white potato plants, soils and apparently healthy and unhealthy potato tubers, and showed that these isolates are pathogenic to Yellow plum tomato cultivar with a variable degree of aggressiveness. Cultural characterisation identified the bacterium, but PCR-based detection using specific primers 759/760 and Nmult primer mix, further verified the identity of the bacterium and classified these into *R. solanacearum* phylotypes I and II. The presence of *R. solanacearum* Phylotype II is interesting, since this phylotype has previously been isolated primarily from North America. Furthermore, genomic fingerprinting using RAPD and BOX–PCR showed genetic diversity of *R. solanacearum* in the northern and southern Philippines. The study also showed the accuracy and reliability of using PCR in detecting the bacterium in healthy tubers. This technique can therefore be used to make sure that only *R. solanacearum*-free white potato planting materials are disseminated to farmers.

Acknowledgments

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Soil amendments for bacterial wilt management in solanaceous vegetables

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Abstract

Soil amendment with broccoli, radish and wild sunflower (*Tithonia diversifolia)* were evaluated for bacterial wilt (*Ralstonia solanacearum)* suppression in potato. Plant biomass was incorporated into the soil at 5 kg/m^2 during soil cultivation and allowed to decompose. Wild sunflower soil amendments reduced *R. solanacearum* populations in two cropping seasons of potato; thus the incidence of bacterial wilt was less compared with broccoli and radish amendment. The high amount of organic matter from wild sunflower decomposition promoted microbial growth acting as an antagonist to soil pathogens such as *R. solanacearum.* Wild sunflower also contains a phytotherapeutic agent, sesquiterpene lactone 1, that has antimicrobial activity. Yield consequently increased due to the lower bacterial wilt incidence in wild-sunflower-amended plots both at the research station and in farmer field trials. The higher number of tubers per plant and weight of marketable tubers harvested from plants with wild sunflower amendments could be attributed to the higher soil pH and increased organic matter and nutrient elements phosphorus and potassium added to the soil upon decomposition of wild sunflower biomass.

Introduction

Bacterial wilt, a disease caused by the soil-borne bacterium *Ralstonia solanacearum,* infects solanaceous vegetables such as potato, tomato, eggplant and pepper. There are two predominant strains detected: Phylotype I race 1 biovar 3 (tropical climate strain) and Phylotype II race 3 biovar 2 (cooler temperate strain). Infected plants wilt and eventually die. Bacterial wilt causes as much as 30–60% losses in vegetable crops. The disease spreads through planting infected seeds, irrigation water, run-off from hilly areas, farm implements, and movement of people and animals from farm to farm. In Mindanao, bacterial wilt spread rapidly through the introduction of infected planting materials brought by farmers moving from the northern Philippines and from unreliable seed sources. Farmers' practice of continuous planting solanaceous crops in the same area also intensifies the disease problem.

There are no pesticides that can control bacterial wilt. The use of methyl bromide, a soil fumigant, has been banned due to its environmental hazard. A safer and effective method to reduce bacterial wilt through biofumigation using brassica crops has been introduced into the Philippines through an earlier project of the Australian Centre for International Agricultural Research (ACIAR) in 2001. All brassica crops, including radish, broccoli, cauliflower, cabbage, pechay and Chinese mustard, contain isothiocyanates (ITCs), the vapour of which, released from the roots of the plant by hydrolysis, suppresses soil-borne diseases such as bacterial wilt (Akiew and Trevorrow 1999). The process is called biofumigation. However, the amounts of ITCs vary within the brassica group. Broccoli, cauliflower, radish and Chinese mustard have large amount of ITCs and are thus most effective in bacterial wilt

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suppression. The amount of biomass incorporated into the soil that produced the maximum bacterial wilt suppression was found to be 5 kg/m^2 (Justo et al. 2006; Kirkegaard 2007). Unlike the Australian technology of biofumigation that specifically grows brassica crops as green manure, in the Philippines the leftovers from brassica crops from harvest are utilised. Biofumigation requires a large amount of biomass to be effective, but such is not always available in the farmer's field, so alternatives to brassica crops are needed for soil amendment. These were not available to farmers who had large areas planted to potatoes. Hence, plants grown in abundance in the areas such as wild sunflower *Tithonia diversifolia* were evaluated as non-brassica treatments. Thus, the study reported here was conducted to assess the efficiency of wild sunflower as a soil amendment for bacterial wilt management in potato and its effect on yield and yield parameters such as size and number of tubers.

Literature review

Bacterial wilt infection is systemic in the vascular system, producing a wilt of part or all of the plant. Other symptoms that may occur with or without wilting include browning of vascular tissue, bacterial exude from cut vessels, stunting and chlorosis of plants. Young (2008) attributed crop losses due to bacterial wilt to several factors, such as the presence of both tropical and temperate strains that can cause the disease in varying environments. The bacteria also persist in the soil for up to 7 years in solanaceous crops and have many alternate host crops and weeds. Mono-cropping potatoes, or rotation with other susceptible hosts such as tomato, eggplant and pepper, increases inoculum in the soil, thus raising the incidence of bacterial wilt in the area.

The results of surveys and characterisation of bacterial wilt of potato conducted in the Philippine highlands showed two strains: Phylotype I race 1 biovar 3 (tropical climate strain) and Phylotype II race 3 biovar 2 (cooler temperate strain) (de la Cueva et al. 2012). French (1994) considered that over 90% of cases of bacterial wilt were caused by Race 3 biovar 2, primarily a tuber-borne disease. He added that potato is the most common host, but at high temperatures and at high inoculum levels it can infect tomato and, rarely, a few other crops and specific weeds. However, with the introduction of potatoes into the highland tropical areas, Race 1 biovar 3 established. Race 1 biovar 3 has a wider host range of solanaceous crops, as well as many weeds and native plants (French 1994).

Management of soil-borne diseases such as bacterial wilt in potatoes poses great challenges. The underlying objective of integrated pest management (IPM) is the minimum application of broad-spectrum pesticides, so reducing environmental contamination and the disruption of natural enemies, and delaying the development of pesticide resistance. Implementation of IPM is founded on monitoring for the occurrence of noxious organisms and the concomitant level of risk of economic injury. Monitoring microscopic bacteria in the soil is difficult and expensive. Monitoring for symptoms such as wilting is an easier and more practical way of detecting the incidence of bacterial wilt in the soil. However, expression of the symptoms for bacterial wilt indicates that losses have already occurred and that control measures are late.

Soil-borne diseases were easily controlled by broad-spectrum soil fumigants such as metam sodium but due to environmental hazards they were eventually banned. Studies on soil bioremediation started to address soil-borne pests and diseases. The ITCs naturally occurring in brassica crops are the same toxic compounds generated by metam sodium when in contact with moist soil (Turner and Corden 1963). Isothiocyanates are hydrolysis products resulting from the action of myrosinase on glucosinolates, a class of sulfur compounds occurring as secondary products in the plant families Tovaraceae, Resedaceae, Capparaceae, Moringaceae and Brassicaceae (Fenwick et al. 1983; Brown and Morra 1997; Rossa et al. 1997).

Matthiessen and Kirkegaard (2006) presented a summary of pest suppression by different brassica species, such as on plant parasitic nematodes (*Meloidogyne chitwoodi* and *M. javanica*), fungal pathogens (*Sclerotinia minor, Aphonomyces euteiches, Rhizoctonia solani, Pyrenochaeta lycopersici, Verticillium dahliae* and *Didymella bryoniae*), bacteria (*Ralstonia solanacearum* and *Streptomyces scabeie),* insects *(Inopus rubriceps)* and various weed species.

Kirkegaard (2007) identified two mechanisms of suppression by brassica green manure. The first mechanism was a short-term suppression (over 2–3 days) related to the release of ITCs from the brassica tissues. The optimal approach developed involved: the use of brassica tissues with high concentrations of toxic ITCs, such as mustard, radish and broccoli;

incorporating 5 kg/m^2 of fresh tissue into the soil; adequate maceration of tissues at a cellular level to release ITCs; adequate water to facilitate hydrolysis of ITCs; rapid and thorough incorporation for complete mixing of ITCs through the soil; watering or covering to retain the volatile ITCs in the soil; and targeting light-textured soils with low organic matter to reduce inactivation of the ITCs. The second mechanism was a suppression related to the effects of organic matter that occurred over a period of 3–4 weeks. In the Philippines, showed little evidence a 50–60% suppression of bacterial wilt and root knot nematodes was associated to ITCs, as there was no strict adherence to the optimal protocols for ITC-related suppression. Kirkegaard (2007) further confirmed that addition of nitrogenous compounds to the soil could generate the same pattern of suppression as the green manures. Evidence suggests that this relates to the mobilisation of specific antagonistic indigenous bacterial populations as a result of the nitrogenous components of the amendments.

Materials and methods

Trials were conducted at the research station of the Northern Mindanao Integrated Agriculture and Research Center (NOMIARC), Dalwangan, Malaybalay City, for two cropping seasons, August–November 2009 and 2010, and at three farmers' fields in Kibangay, Miarayon and Imbayao, all in Bukidnon province. At NOMIARC, three biofumigation treatments (radish, broccoli and wild sunflower) plus a control (without bacterial wilt suppressant) were assigned to 7 m × 4 m plots following a randomised complete block design with five replicates. An aggressive isolate of *R. solanacearum* was inoculated at the study site at NOMIARC to ensure even distribution of the disease agent, whereas in the farmers' fields the effect of treatments on incidence of the bacterium was observed under natural field conditions. After the bacterium had established for 5–7 days, initial bacterial colony counts were taken from a 10 mL stock solution (1:100,000 concentration). The initial population count was 3.25 colony-forming units (cfu)/g of soil. After soil incorporation, bacterial colony counts were made to determine the effect of ITCs and sunflower on the population of wilt bacteria.

One hundred grams of composite soil samples was collected from each treatment plot for initial bacterial wilt colony count before biofumigation. Ninety millilitres of distilled water was added to 10 g of well-pulverised soil and mixed well. Ten millilitres from a stock solution was diluted to 1:100,000 concentration and 100 μL of each dilution was plated on TZC media (casamino acid 1.0 g/L, peptone 10 g/L, glucose 5.0 g/L, agar 17.0 g/L, tetrazolium chloride (5 mL of a 1% solution per L), cyclohexamide 100 mg/L) and plates were incubated at 30ºC for 48 hours. Plant biomass was shredded and incorporated into the plots at a rate of 5 kg/m^2. The plots were watered after incorporation. Foundation seeds of the potato cultivar 'Granola' were planted at a distance of 40 cm between hills and 1.5 m between rows, 2 weeks after biofumigation. Soil samples for bacterial wilt colony counts were taken at 15 and 30 days after planting, and at harvest. The recommended amount of fertiliser, 120–190–190 kg NPK/ha, was applied uniformly to all the plots. Weeding, watering and pesticide application were done when necessary.

The plants were observed regularly for signs of bacterial wilt. At the onset of infection, weekly counts of infected plants were recorded until 10 weeks after planting. All tubers harvested from 280 sample plants per plot were sorted, classified into marketable and non-marketable, and weighed. Data were summarised and analysed statistically.

At Kibangay, the treatments were wild sunflower, broccoli and control, while at Miarayon and Imbayao, the treatments were wild sunflower, cabbage and control. The treatment plots were laid out following the randomised complete design with five replicates. The farmers' experimental areas were assumed to have the lowest bacterial wilt incidence. Soil samples (100 g/plot) were taken to determine the wilt bacteria population. Foundation seeds were planted on each 1-metre bed plot, using double-row spacing at 6 plants/m^2. Vermicast (5 tonnes/ha) and commercial fertiliser (120–190–190 kg NPK/ha) were applied. Pesticide application and hand weeding were done when necessary. At harvest, all tubers were classified into marketable and unmarketable, and weighed.

Results and discussion

At NOMIARC, biofumigation using radish, broccoli and wild sunflower was evaluated for bacterial wilt suppression in potato for two cropping seasons. Tables 1 and 2 show that the *R. solanacearum* population was significantly suppressed by soil incorporation of brassica crops (radish and broccoli) and wild sunflower, compared with the control where population increased. Radish and broccoli were among the brassica crops with high ITCs that were responsible for the suppression of both bacterial wilt and root-knot nematode. Suppression observed from wild-sunflower-amended plots was the most effective among the treatment plots. Kirkegaard (2007) attributed suppression in wild-sunflower-amended plots to the addition of high organic matter that mobilised the growth of specific antagonistic indigenous bacterial populations. These antagonistic bacterial populations rapidly increased and masked the action of plant pathogen populations in the soil. Wild sunflower ethyl acetate extract contains sesquiterpene lactone 1, which has been shown to have phytotherapeutic properties against some bacterial infections (Obafemi et al. 2006): sesquiterpene lactone 1 inhibited activity of five Gram-positive and two Gram-negative organisms and the fungus *Candida albicans*.

Suppression of the *R. solanacearum* population caused a corresponding decrease in bacterial wilt infection (Figure 1 and Table 2). Fifteen days after soil amendment, plant tissues have decomposed, and the mechanism of suppression by wild sunflower amendment has been exerted. Figure 1 indicates that soil amendment suppressed bacterial wilt infection as early as 15 and 30 days after amendment and continuously kept the population low compared with that in the untreated plot.

Bacterial wilt incidence was lower in wild-sunflower-amended soil than with radish and broccoli incorporation. Nevertheless, bacterial wilt infection caused a general decline in the yield of potatoes (Table 3) during the first trial. The decline was markedly greater in control plots. The average yield of potatoes in Bukidnon is 10.8–15 tonnes/ha. Although the bacterial wilt incidence was lower during the second trial, yields from all treatment plots were almost nil during this cropping season due to high incidence of potato leaf blight caused by *Phytophthora infestans.* The weather during the

Table 1. *Ralstonia solanacearum* population (colony-forming units (cfu)/g of soil) before and after biomass incorporation of radish, broccoli and sunflower; Northern Mindanao Integrated Agricultural Research Center, Bukidnon, August–November 2009

Treatments	*Ralstonia solanacearum* population (cfu/g of soil)		Reduction in population (%)	Nematode population		
	before incorporation	at harvest		Initial	At harvest	Reduction (%)
Broccoli	26,605	12, 665b	52.4	230	139b	39.56
Radish	26,605	10,625c	60.06	218	126c	42.2
Wild sunflower	26,605	7,210d	72.9	252	113d	55.16
Control	26,605	41,925a	57.58 ↑	324	416a	28.39 ↑
CV (%)		11.44			10.18	
F-test		*			*	

Means followed by the same letter are not significantly different at 5% level DMRT.

Table 2. Bacterial wilt incidence in potatoes grown in soil amended with broccoli, radish and wild sunflower; Northern Mindanao Integrated Agricultural Research Center, Bukidnon, August–November 2009 and July–November 2010)

Treatment	Bacterial wilt incidence (%)	
	August–November 2009 10 weeks after planting	July–November 2010 10 weeks after planting
Broccoli	23.53bc	5.89
Radish	23.86b	6.02
Wild sunflower	13.49c	3.71
Control	24.75a	6.10

CV 11.03 ns
Means followed by the same letter are not significantly different at 5% level DMRT.

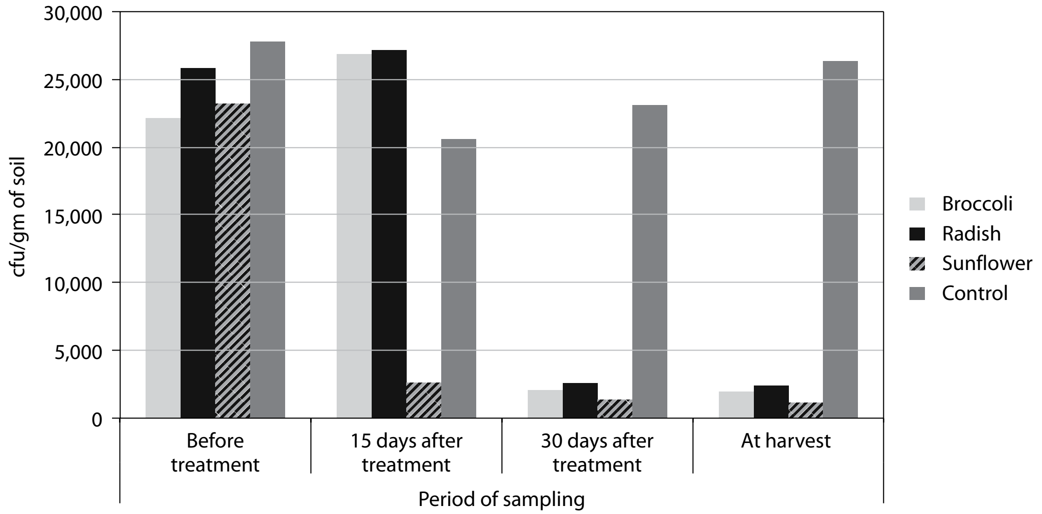

Figure 1. *Ralstonia solanacearum* population (colony-forming units (cfu)/g of soil) before and after radish, broccoli and wild sunflower amendment; Northern Mindanao Integrated Agricultural Research Center, Bukidnon, July–November 2010)

Table 3. Yield of potatoes, cv. Granola, grown in soil amended with broccoli, radish and wild sunflower; Northern Mindanao Integrated Agricultural Research Center, Bukidnon, August–November 2009 and July–November 2010

Treatment	Yield (tonnes/ha)					
	August–November 2009			July–November 2010		
	Marketable	Non-Marketable	No. of infected tubers	Marketable	Non-marketable	No. of infected tubers
Broccoli	3.95c	0.95b	136	0.002	0.001	0.001
Radish	4.47b	0.85c	131	0.003	0.002	0.002
Wild sunflower	6.62a	0.82cd	110	0.004	0.001	0.001
Control	2.98d	1.80a	188	0.003	0.002	0.002
CV %	13.41	12.74	10.54			
F-test	*	*	*			

Means followed by the same letter are not significantly different at 5% level DMRT.

July–November 2010 cropping period was very favourable for late blight infection, even if periodic fungicide applications were made.

Soil samples were collected at the time of harvest and analysed to determine the effect of soil amendment on soil nutrients (nitrogen, phosphorus and potassium), pH and organic matter. The results are summarised in Table 4. Soil at NOMIARC was acidic (pH 4.7–4.9). Soil amendment slightly increased the soil pH from 4.7 to 4.9. Potatoes need a soil pH of 4.8–6.5. Increased yield in wild-sunflower-amended soil could be due to increased potassium and phosphorus from wild sunflower decomposition. Potassium and phosphorus are nutrients needed for the development of tubers.

At the three potato-growing areas of Kibangay, Miarayon and Imbayao, the farmer collaborators were, respectively, Paul Cabaledas, Erol Nabe and Gabriel Banadao. Their sites were selected for least incidence of bacterial wilt and for not having been grown to potatoes for several cropping seasons. This study also aimed to produce clean seed potato for farmer distribution. Biofumigation was introduced to the farmers during a workshop conducted before planning the study. Farmer Cabaledas incorporated broccoli from harvest in his farm, while farmers Nabe and Banadao harvested cabbage and used the waste for biofumigation. These crops were commonly produced in their barangays or villages. Wild sunflower growing abundantly along the road, field borders and peripheries can easily supply the large biomass needed for their respective areas. The foundation seeds of potato cultivar Granola were planted in plots and amended with broccoli/cabbage and wild sunflower.

Bacterial wilt incidence was either very low or absent (Miarayon and Imbayao) in the treated plots in the three potato pilot areas (Table 5). The same was observed in Kibangay for soils incorporated with wild sunflower. The control plots demonstrated 2–8% incidence of bacterial wilt across the three test farms.

In Kibangay and Miarayon, higher numbers of tubers per plant were harvested in the wild-sunflower-amended plots. Overall, significantly higher yields were obtained from the wild-sunflower-amended soils than from the cabbage- or broccoli-amended plots and the untreated plots (Table 5). Wild sunflower soil amendment improves soil condition by increasing soil pH and organic matter, phosphorus and potassium in the soil.

Summary and conclusions

Soil amendments using broccoli, radish and wild sunflower for biofumigation suppressed bacterial wilt in the soil and increased the yield of potatoes. Wild sunflower was found to be most effective in bacterial wilt suppression, due to its organic matter increasing the antagonistic activity of the microbial population and the phytotherapeutic effect on some bacterial infections. Wild sunflower, upon decomposition, also improves soil conditions by increasing soil pH, organic matter, and the nutrient elements

Table 4. Soil analysis of samples taken from plots with broccoli, radish and wild-sunflower amendments; Northern Mindanao Integrated Agricultural Research Center, Bukidnon

Treatment	Nutrient elements and soil pH				
	pH	Organic matter %	Nitrogen (N) %	Phosphorus (P) (Bray) ppm	Potassium (K) c mol(+)/kg soil
Broccoli	4.8	4.52	0.24	12.5	0.76
Radish	4.9	4.62	0.24	19.5	0.57
Wild sunflower	4.9	4.57	0.22	24.0	0.92
Control	4.7	5.04	0.24	15.8	0.97

Table 5. Bacterial wilt incidence, yield and yield parameters of potatoes grown in soil with broccoli/cabbage and wild sunflower amendments at Miarayon, Imbayao and Kibangay, Bukidnon, Philippines; July–November 2011

Location	Parameters	Wild sunflower	Cabbage/ broccoli	Control	CV (%)	F-test
Miarayon	Bacterial wilt incidence (%)	0b	0b	2a	0.0	**
	No. of tubers/plant	6.81a	6.2a	5.67b	8.5	**
	Average weight of tubers (g)	27a	23b	30a	17.4	**
	Total yield (t/ha)	11.79a	8.77c	10.65b	10.6	*
Imbayao	Bacterial wilt incidence (%)	0b	0b	8a		**
	No. of tubers/plant	4.9b	5.6a	4.7b	16.1	**
	Average weight of tubers (g)	42b	33a	37a	15.5	**
	Total yield (t/ha)	12.6b	10.96a	10.56a	23.5	**
Kibangay	Bacterial wilt incidence (%)	0b	5a	7a	16.9	**
	No. of tubers/plant	7.2b	6.3a	6.0a	3.8	**
	Average weight of tubers (g)	50b	31a	31a	6.7	**
	Total yield (t/ha)	20.42b	10.90a	11.20a	16.7	**

Means followed by the same letters are not significantly different at 5% level DMRT.

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	No. of tubers/plant	4.9b	5.6a	4.7b	16.1	**
	Average weight of tubers (g)	42b	33a	37a	15.5	**
	Total yield (t/ha)	12.6b	10.96a	10.56a	23.5	**
Kibangay	Bacterial wilt incidence (%)	0b	5a	7a	16.9	**
	No. of tubers/plant	7.2b	6.3a	6.0a	3.8	**
	Average weight of tubers (g)	50b	31a	31a	6.7	**
	Total yield (t/ha)	20.42b	10.90a	11.20a	16.7	**

Means followed by the same letters are not significantly different at 5% level DMRT.

potassium and phosphorus, thus increasing the yield of potatoes. Soil amendments using brassica and wild sunflower are an environment-friendly, best-bet approach for sound integrated disease management strategies in potato.

Further studies on the effect of soil amendment using wild sunflower should be conducted using different potato varieties and other solanaceous crops such as tomato, pepper and eggplant, which also are hosts of bacterial wilt. There is a need also to test the effect of wild sunflower amendments on other soil-borne pests and diseases. Further analysis and identification of the mechanism of control by wild sunflower needs investigation.

Early and late blight decreased yields of potatoes and tomatoes in Mindanao due to weather conditions favourable to their outbreak. There is a need to evaluate other options in controlling leaf blight, such as the use of tolerant varieties.

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Commercial potato varieties and lines tolerant to bacterial wilt, *Ralstonia solanacearum*

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Abstract

The increasing demand for commercial potato varieties tolerant to bacterial wilt is the main concern of the government in catering to the seed needs of potato farmers. Varietal evaluations for bacterial wilt tolerance were conducted in pot trials under greenhouse conditions at the Northern Mindanao Integrated Agricultural Research Center (NOMIARC) bacterial wilt nursery and at three selected farm sites—Kibangay, Imbayao and Miarayon—all in the province of Bukidnon. Pot trials revealed that bacterial wilt infections were significantly different between the 18 varieties and 4 lines of potato. At 10^4 *Ralstonia solanacearum* colony counts*,* the highest infection was observed in cultivar Columbos and the lowest in the line NOMPO D. The most severe infection was observed in Sheepody variety, whereas the least infection was seen in the variety Granola and the line NOMPO E. At the bacterial wilt nursery, the top 10 varieties/lines that showed significant tolerance to bacterial wilt were NOMPO E, Granola, Atlantic, Igorota, NOMPO B, NOMPO D, Asterix, NOMPO A, Catani and Kennebec. The highest number of healthy tubers was harvested from Granola. The results of trials conducted at three farm sites revealed that bacterial wilt incidence varies with location. In Kibangay, the most severe bacterial wilt infection was found in Ranyag variety. Raja variety showed the lowest percentage infection. while the highest yield was obtained from line NOMPO B. In Imbayao, on the other hand, Igorota was the most severely infected. Ranyag showed the least infection and gave the highest yield. In Miarayon, the highest infection was observed in Asterix, while line NOMPO A gave the highest yield. The release to farmers of the tolerant varieties identified in this study should significantly increase their incomes and reduce their production costs.

Introduction

Potatoes, together with rice, maize and wheat, are one of the world's most important staple foods. More than a billion people worldwide eat potatoes, and global total crop production exceeds 300 million tonnes. The yields of potatoes in developing countries are increasing, but at a declining rate (FAO 2008). This decline is mainly the result of the use of poor-quality seed by farmers. Farmers use tubers from the previous season's harvest as seed, which favours a build-up of tissue-borne pathogens and leads to significant loss of yield and tuber quality (Chiipanthenga et al. 2012).

Potato farmers in Mindanao were experiencing yield losses primarily because of the impacts of the soil-borne diseases. Bacterial wilt caused by *Ralstonia solanacearum* can cause losses of up to

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75% in potato crops. Disease severity increases if *R. solanacearum* is found in association with root nematodes. Nematode infestation changes the physiology of the plants, increasing susceptibility to bacterial wilt (Stansbury et al. 2001). Bacterial wilt infection can spread throughout the potato or other vegetable growing areas. One of the most important steps a farmer can take is to prevent the disease. Bacterial wilt spreads through planting of infected tubers (Champoiseau et al. 2009), use of infected sources of water for irrigation and erosion during heavy rains (Kaur and Mukerji 2004. Development of resistant cultivars could therefore play an important role in managing the disease (Muthoni et al. 2012). In regions where the disease is prevalent, crop rotation with non-host plants, intercropping, weed control, planting in uninfected fields, selection of appropriate planting time, deep ploughing of crop residues and satisfactory soil drainage or early- and late-season irrigation management are recommended cultural management practices to prevent the spread of the disease (Champoiseau 2008). Continuous cropping of solanaceous crops in the same area also contributes to high severity of bacterial wilt infection. There are no pesticides available to control bacterial wilt but, through integrated management approaches, the disease can be reduced or suppressed, if not totally eradicated. Clean seed, proper crop rotation, biofumigation, resistant varieties and sanitation are among the recommended strategies for bacterial wilt management.

Currently, the supply of seed potato tolerant to bacterial wilt infection cannot meet the increasing demand for disease-free planting materials. Hence, this study was conducted to evaluate the 18 commercial varieties and 4 lines of potato accessions at the Northern Mindanao Integrated Agricultural Research Center (NOMIARC) plant tissue laboratory for tolerance to bacterial wilt infection, adaptability to local conditions and yield performance. The identified tolerant varieties/lines will serve as an option to Granola, the first introduced and most widely grown variety of the potato in the Philippines with high tolerance to bacterial wilt infection. Specifically, the study aimed to:

- identify potato varieties tolerant to bacterial wilt infection under screenhouse and bacterial wilt nursery conditions
- evaluate potato varieties tolerant to bacterial wilt infection under field conditions and identify varieties with good yield.

Literature review

A major limiting factor in profitable potato production is disease, which can be seed and/or soil borne. Vegetative propagation of potatoes and cutting prior to planting increases the chances for transmission of many yield-limiting diseases caused by fungi, bacteria, viruses and nematodes. Total control of many of these diseases is often impossible, and a combination of control strategies is necessary.

Ralstonia solanacearum is considered to be a 'species complex', due to significant variation within the group. It was historically subdivided into five races, based loosely on host range, and five biovars, based on ability to acidify a panel of 5–8 carbohydrate substrates, but this old classification system has proved to be unsatisfactory (Champoiseau et al. 2009).

The host resistance to the pathogen is limited, so bacterial wilt is very difficult to control. The disease generally occurs in lowlands in tropical or subtropical areas, but one subgroup of *R. solanacearum* called Race 3 biovar 2 (R3bv2) attacks plants at higher altitudes or in temperate zones. R3bv2 is an extremely destructive potato pathogen that disrupts seed-potato production and causes serious quarantine-related losses (Champoiseau et al. 2009).

The virulence of R3bv2 usually decreases when temperatures exceed 35°C. The disease is most severe at temperatures in the range 24–35°C and is seldom found in temperate climates where the mean temperature for any winter month falls below 10°C. The main pathway for spread is by latently infected seed potatoes and other vegetative propagating materials (Stansbury et al. 2001).

Infected seed tubers are the main means of dissemination of *R. solanacearum* (particularly Race 3 strains). In cool conditions, such as tropical elevations above 2,500 m, infected but symptomless plants may harbour the bacterium and transmit it to progeny tubers as latent infection, leading to severe disease outbreaks when grown at warmer locations. The pathogen can survive in soil (mostly on plant debris) and in the root system and rhizosphere of many hosts (weeds, other host crops, potato volunteers) (Martin and French 1985).

Practices such as cleaning and sanitising field and handling equipment, planting seed tubers produced under strict certification procedures, and application of sanitary cultural practices will prevent movement of the pathogen from infested to pathogen-free fields and avoid its inadvertent introduction. Host removal and destruction is required, along with disinfection, as well as several years of non-host production in infected fields or associated growing areas before any quarantine ban can be lifted (Champoiseau 2008).

There are many methods to produce healthy seed. The method selected should be adapted to the local environment. In highland environments, high-quality seed tubers for evaluation trials can be obtained from healthy plants identified in the field during a previous growing season (positive selection). Seed can also be produced in net houses by using high-tech systems such as hydroponics and aeroponics, or by multiplying plants derived from health-tested in-vitro cultures or pre-basic tubers (CIP 2007).

Most potato growers in developing countries do not use good-quality seed, because of its high cost or lack of availability. As a result, there is a strong need for cost-effective methods to produce high-quality seed that can be accessed by small farmers at an affordable price. The conventional way of producing quality pre-basic potato seed is to multiply clean in-vitro material in the greenhouse. This method usually produces yields of 5–10 minitubers per plant (Otazú 2010).

The effectiveness of integrated control strategies involving the use of resistant varieties, crop rotation and other cultural measures has been monitored by measuring disease incidence in a subsequent crop (French et al. 1995).

Materials and methods

The Tissue Culture Laboratory of NOMIARC has a collection of 18 commercial varieties (Alchip, Alpha, Asterix, ASN, Astra, Atlantic, Catani, CIP 30.5, Columbos, Franze, Granola, Igorota, IP, Kennebec, Nooksack, Raja, Raniag and Sheepody) and 4 lines (NOMPO A, NOMPO B, NOMPO D, and NOMPO E). The varieties were mass-multiplied through in-vitro plantlets used for the establishment of the mother plant nurseries for production of rooted stem cuttings. The NOMPO lines were derived from the breeding program of NOMIARC.

Varieties/lines were established in a screenhouse to evaluate performance under controlled conditions subject to inoculation of *R. solanacearum*, and in the bacterial wilt nursery for the evaluation of varieties under natural conditions with high levels of bacterial wilt.

Screenhouse evaluation

Ten 2-week-old rooted stem cuttings per variety were planted in sterile media (coir dust + soil, 1:1 ratio) in 155-cm diameter, sterilised, polyethylene plastic pots. Varieties were laid out in a completely randomised design replicated five times. Five sample plants were used as data plants. Each pot was inoculated with a 10^4 bacterial colony count or 10 mL of the most aggressive isolate of pure *R. solanacearum* through drenching the inoculums evenly on the pot. Expression of bacterial wilt incidence and its severity, and of other foliar diseases, were monitored and recorded weekly until 11 weeks after planting or when all plants had died. The recommended amount of fertiliser was applied. Water and fungicide were applied as necessary. All tubers per pot were counted, sorted and weighed at harvest. Two croppings were conducted in the screenhouse. Data were summarised and analysed statistically at the 5% level of significance.

Bacterial wilt nursery evaluation

A 308 m^2 area (22 m × 14 m) of the NOMIARC bacterial wilt nursery was thoroughly prepared. Ten pieces of foundation seeds (G0) per variety/line were planted in 1 m × 4 m plots at a planting distance of 40 cm between hills and 1 m between rows. Treatment or variety/line was arranged in a randomised complete block design with three replicates. Inorganic fertiliser was applied at the recommended rate of 120–240–240 kg NPK/ha and 5 tonnes (t) of organic fertiliser per hectare (ha). Watering and fungicide were applied as necessary. Signs of bacterial wilt and other foliar diseases were monitored weekly. The number of bacterial-wilt-infected plants per plot was recorded weekly until 11 weeks after planting or until all plants had died. At harvest, all tubers per plot were sorted, counted and weighed. Data were summarised and analysed statistically at the 5% level of significance.

On-farm evaluation

Potato varieties tolerant to bacterial wilt infection under natural conditions and with good yield were evaluated through on-farm establishment of the 18 varieties and 4 lines of potato. This was done at three project sites: Barangay Miarayon, Talakag; Kibangay, Lantapan; and Imbayao, Malaybalay City, Bukidnon. Foundation seeds were planted in 1-m beds, double rows with three replicates arranged in a randomised complete block design. Ten sample plants per variety served as data plants. Fertiliser was applied as follows: a basal application of vermicast at a rate of 5 t/ha and 240–240–240 kg/ha N, P_2O_5 and K_2O split applications. Pesticides were applied as necessary.

Recommended cultural practices for potato production were followed. At 5 weeks after emergence, regular monitoring for symptom expression of bacterial wilt and leaf blight on 10 plants per plot was done for 11 consecutive weeks or until all plants had died. At harvest, tubers from 10 plants per plot were sorted, counted and weighed. All data were summarised and analysed statistically.

Results and discussion

Screenhouse evaluation for bacterial wilt tolerance

Statistical analysis revealed significant differences between the 18 commercial varieties and 4 NOMIARC lines for bacterial wilt incidence and severity from the two croppings (Figure 1). Columbos had the highest level of infection (75%) and NOMPO D the lowest (17%). The most severe infection was observed in Sheepody (35.6%) and the least in NOMPO E (18.4%) and Granola (18.5%). The findings here may help to register lines NOMPO D and E as varieties.

The highest number of infected tubers (35) was collected from the Raja variety and the lowest (1) from Granola. Furthermore, the highest number (108) and weight (1.04 kg/plant) of healthy tubers were obtained from Granola (Table 1). Columbos gave the lowest number of healthy tubers (7) and yield (0.17 kg/plant). Granola variety, a table potato, was classified as highly tolerant to bacterial wilt infection, giving high yields in both controlled and open-field conditions.

Selection of best-bet varieties under screenhouse conditions

Based on the evaluation conducted on the different varieties/lines in the screenhouse, six promising varieties and four lines of potato were selected as

Table 1. Number of infected, and number and average weight of healthy tubers, of 18 varieties and 4 lines of potato for two greenhouse croppings at the Northern Mindanao Integrated Agricultural Research Center, Dalwangan, Malaybalay City, August 2009 – May 2010

Varieties	No. of infected tubers	No. of healthy tubers	Average weight of healthy tubers (kg/plant)
Alchip	12^{fg}	17^{o}	0.27
Alpha	20^{de}	12^{q}	0.05
Asterix	5^{f}	15^{p}	0.20
ASN	20e	25^{m}	0.14
Astra	11^{g}	34^{k}	0.13
Atlantic	21^{de}	63^{e}	0.47
Catani	33^{b}	75^{d}	0.29
CIP 30.5	8^{hi}	21^{n}	0.17
Columbos	3^{jk}	7^{r}	0.17
Franze	29^{hi}	82^{b}	0.55
Granola	1^{k}	108^{a}	1.04
Igorota	6^{ij}	37^{jk}	0.40
IP	14^{ef}	41^{i}	0.41
Kennebec	5^{j}	17^{o}	0.18
Nooksack	20^{de}	28^{l}	0.71
Raja	35^{a}	48^{g}	0.75
Ranyag	7^{i}	42^{h}	0.77
Sheepody	15^{e}	38^{j}	0.62
NOMPO A	22^{d}	50^{f}	0.58
NOMPO B	8^{jk}	74^{de}	0.64
NOMPO D	13^{f}	50^{f}	0.75
NOMPO E	9^{h}	80^{c}	1.22
F-test	*	*	NS
CV (%)	10.12	9.3	11.32

Means followed by a common letter are not significantly different at 5% level of Duncan's multiple range test.

the varieties tolerant to bacterial wilt infection. This selection was based on the degree of infection each variety expressed when inoculated with *R. solanacearum*. The evaluation was conducted over two cropping seasons, and selections were classified as either tolerant or moderately tolerant. The tolerant varieties/lines were NOMPO E, Granola, Atlantic, Igorota, NOMPO B and NOM PO D, while the moderately tolerant varieties/lines were Asterix, NOMPO A, Catani and Kennebec.

Bacterial wilt evaluation at the bacterial wilt nursery

Figure 2 shows the mean colony counts of the *R. solanacearum* population in the bacterial wilt nursery before incorporation, 30 days after planting and at harvest. Before incorporation, the population count of *R. solanacearum* was 1.29×10^5 colony-forming units (cfu)/g of soil, while at 30 days after planting the population had fallen to 1.25×10^5 cfu/g. On the other hand, at harvest the colony count had increased to 1.28×10^5 cfu/g of soil, or by 2.8%. Results varied due to environmental factors affecting the population of *R. solanacearum* in the area, with relative humidity ranging from 22 to 88%, average daily rainfall from 3.4 to 4.7 mm and minimum air temperature in the range 27.8–31.5°C, which favours the growth of bacteria in the soil, thus causing bacterial wilt infection to potato plants.

Statistical analysis revealed that variety ASN had the highest percentage severity (85%) and incidence (100%) of bacterial wilt infection. It is judged to be highly susceptible (Table 2). It was followed by Nooksack (78.17; 90%) and IP (70.25; 90%). They are judged to be susceptible to bacterial wilt infection. Low severity was expressed in line NOMPO E with 22.16% infection. Together with Raja, it also had the lowest incidence of 20%. These two varieties were considered tolerant to bacterial wilt infection. The moderately tolerant varieties were: Granola, NOMPO A, NOMPO B, NOMPO D, Granola, Astra, Alpha and Asterix.

Among the varieties evaluated, statistical analysis showed that Catani had the highest number of infected tubers (33) from the two croppings conducted (Table 3). The variety with the lowest number of infected tubers (1) and highest number of healthy tubers (80) and weight per plant (1.04 kg) was Granola, followed by Catani (76 pieces; 0.29 kg/plant). Columbos produced the lowest number (7) and weight (0.17 kg) of healthy tubers per plant.

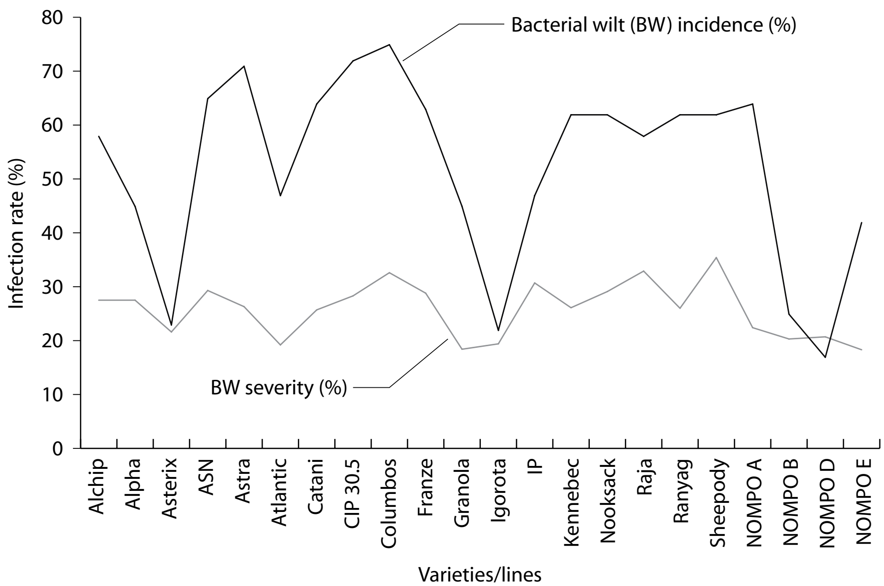

Figure 1. Mean percentage bacterial wilt incidence and severity in 18 varieties and 4 lines of potato for two greenhouse croppings at the Northern Mindanao Integrated Agricultural Research Center, Dalwangan, Malaybalay City, August 2009 – May 2010

Adaptability trials at three potato-growing areas of Bukidnon

Evaluation of the test varieties/lines was also conducted in the farmers' field at the three potato-growing areas in Bukidnon—Imbayao, Miarayon and Kibangay. At Imbayao, Malaybalay City, all the materials evaluated grew vigorously. However, the crop was infected with bacterial wilt at 45 days after planting. Bacterial wilt incidence ranged from 30% with Ranyag and NOMPO B to 80% with variety Igorota. Ranyag, NOMPO B and ASN with tuber

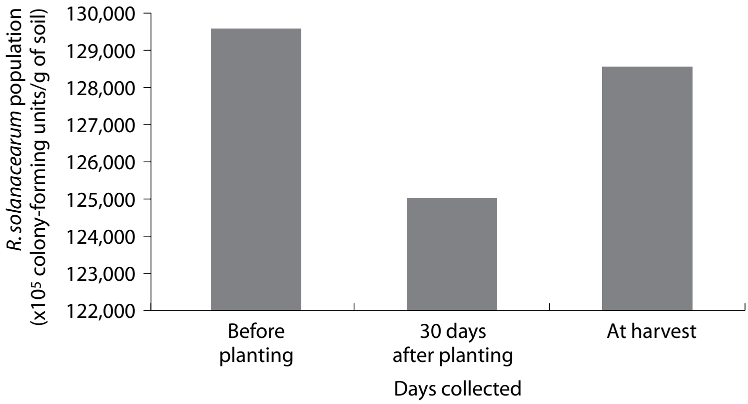

Figure 2. *Ralstonia solanacearum* population in the soil before planting, 30 days after planting, and at harvest, at the bacterial wilt nursery at the Northern Mindanao Integrated Agricultural Research Center, Dalwangan, Malaybalay City, August–November 2010 and January–April 2011

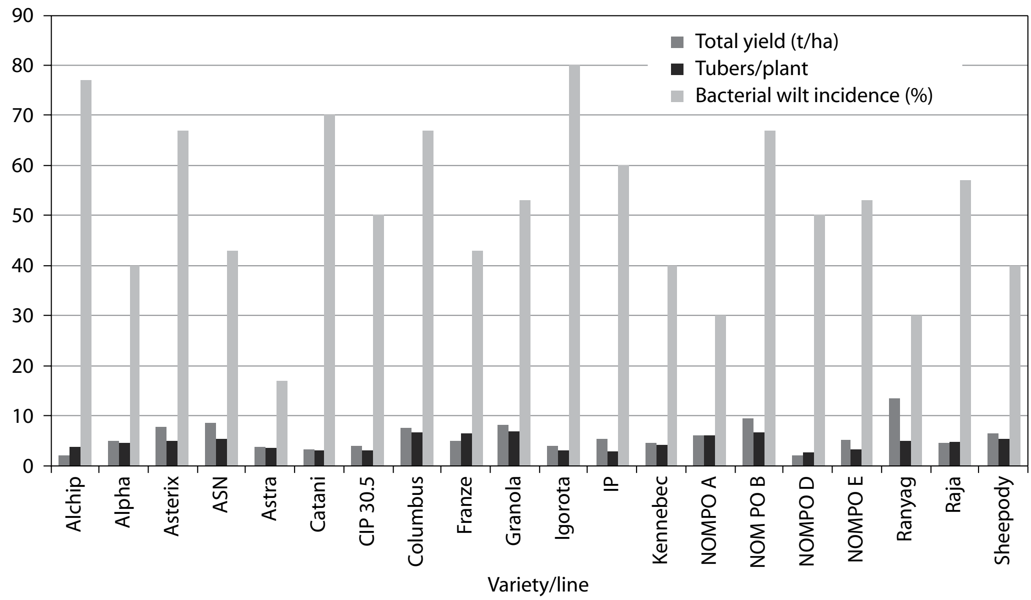

Figure 3. Adaptability trial of newly introduced potato varieties in Imbayao, Malaybalay City (1,200 masl), September–December 2010

Table 2. Mean percentage bacterial wilt incidence and severity in 18 varieties and 4 lines of potato evaluated in the bacterial wilt nursery in two croppings at the Northern Mindanao Integrated Agricultural Research Center, Dalwangan, Malaybalay City, June–August 2010

Varieties	Bacterial wilt severity (%)	Bacterial wilt incidence (%)	Tolerance levels to *Ralstonia solanacearum*
Alchip	33.15[i]	63[f]	Moderately susceptible
Alpha	15.02[m]	36[m]	Moderately tolerant
Asterix	22.13[l]	46[l]	Moderately tolerant
ASN	85.01[a]	100[a]	Highly susceptible
Astra	22.13[l]	33[n]	Moderately tolerant
Atlantic	25.33[kl]	60[g]	Moderately susceptible
Catani	26.22[k]	66[e]	Moderately susceptible
CIP30.5	74.15[c]	76[d]	Moderately susceptible
Columbos	64.87[ef]	59[h]	Moderately susceptible
Franze	60.13[f]	53[j]	Moderately susceptible
Granola	30.00[j]	30[o]	Moderately tolerant
Igorota	50.12[g]	54[i]	Moderately susceptible
IP	70.25[d]	90[b]	Susceptible
Kennebec	60.12[f]	50[k]	Moderately susceptible
Nooksack	78.17[b]	90[b]	Susceptible
Raja	25.12[kl]	20[o]	Tolerant
Raniag	65.11[e]	50[k]	Moderately susceptible
Sheepody	33.21[i]	36[m]	Moderately tolerant
NOMPO A	35.20[h]	30[o]	Moderately tolerant
NOMPO B	32.16[j]	30[o]	Moderately tolerant
NOMPO D	55.10[g]	86[c]	Moderately susceptible
NOMPO E	22.16[l]	20[p]	Tolerant
F-test	*	*	
CV (%)	19.12	20.41	

Means followed by the same letter are not significantly different at 5% level of Duncan's multiple range test.

yields of 13.49, 9.39 and 8.68 t/ha, respectively, out-yielded Granola (8.12 t/ha) (Figure 3). Furthermore, varieties such as Asterix, Columbus and Sheepody were significantly better than Franze and Alpha in terms of yield obtained. These varieties are promising cultivars for commercial production.

At Miarayon, Talakag, Bukidnon, bacterial wilt incidence was low compared with that in Imbayao (Figure 4). Bacterial wilt infection was monitored late in the growing season at 75 days after planting. At the study area, varieties Granola, Franze and Catani were not infected with bacterial wilt. The highest bacterial wilt infection was exhibited by Asterix, with 26% infection. There were nine varieties that out-yielded Granola and Alpha. One of them was line NOMPO A with 17.93 t/ha, compared with Granola with 12.28 t/ha and Alpha with 12.03 t/ha.

At Kibangay, Ranyag variety exhibited the most severe bacterial wilt incidence (88%), followed by Igorota (86%) and Columbos (73%) (Figure 5). The lowest infection rate of 16% was observed in Raja variety. Three varieties and one line significantly out-yielded the variety Granola at this site: NOMPO B, Igorota, Columbus and Alpha with 18.04, 17.89, 13.33 and 12.89 t/ha, respectively. Tubers per plant, at 14, were also highest in NOMPO B.

The correlations between location, varieties and yield parameters are showed in Table 4. Bacterial wilt incidence was highly influenced by location (0.664**), and markedly affected the yields (0.358**), tubers per plant (0.341**) and average tuber weight (0.365**). Imbayao had higher bacterial wilt incidence than Kibangay and Miarayon. Generally, varieties with higher average tuber weight and higher number of tubers per plant had higher yields. The total yield is not affected by location (–0.627**) but yield increased with higher tuber number (0.738**). The tubers per plant is negatively

Table 3. Mean number of infected tubers, healthy tubers and weight of healthy tubers of the 18 varieties and 4 lines of potato evaluated in two croppings at the bacterial wilt nursery at the Northern Mindanao Integrated Agricultural Research Center, Dalwangan, Malaybalay City, June–August 2010

Varieties	No. of infected tubers	No. of healthy tubers	Weight of healthy tubers (kg/plant)
Alchip	13^{h}	18^{g}	0.28
Alpha	20^{d}	13^{s}	0.05
Asterix	6^{n}	16^{k}	0.20
ASN	20^{d}	26^{o}	0.14
Astra	11^{i}	35^{m}	0.13
Atlantic	22^{c}	64^{e}	0.47
Catani	33^{a}	76^{b}	0.29
CIP30.5	9^{k}	22^{f}	0.17
Columbos	3^{o}	7^{t}	0.17
Franze	30^{b}	68^{c}	0.56
Granola	1^{f}	80^{a}	1.04
Igorota	6^{n}	38^{j}	0.41
IP	15^{g}	42^{k}	0.41
Kennebec	3^{o}	18^{g}	0.18
Nooksack	10^{j}	29^{n}	0.72
Raja	18^{e}	48^{i}	0.38
Raniag	8^{l}	43^{j}	0.77
Shepody	16^{f}	38^{l}	0.87
NOMPO A	11^{i}	50^{g}	0.29
NOMPO B	8^{l}	62^{f}	0.64
NOMPO D	7^{m}	51^{h}	0.38
NOMPO E	9^{k}	67^{d}	1.22
F-test	*	*	NS
CV	11.08	10.20	11.33

Means followed by the same letter are not significantly different at 5% level of Duncan's multiple range test.

correlated with location (–0.627**) but positively correlated with total yield (0.738**). This means that higher yield was obtained with varieties that produced many tubers per plant but the number of tubers per plant was not dependent on location.

Summary and conclusions

Among the 18 varieties and 4 lines of potato evaluated in the screenhouse and bacterial wilt nursery at NOMIARC, Dalwangan, Malaybalay City, for tolerance to bacterial wilt, the tolerant varieties and lines were Granola, Atlantic, Igorota, NOMPO E, NOMPO B and NOMPO D. Asterix, Catani, Kennebec and NOMPO A were moderately tolerant to bacterial wilt. The highest yields and numbers of healthy tubers were obtained from Granola and NOMPO E.

Yield performance and tolerance to bacterial wilt of the 18 varieties and 4 lines varied by location. The population and distribution of *Ralstonia solanacearum* at the three farm sites differed, thus so did bacterial wilt incidence among the varieties and lines evaluated. Nevertheless, bacterial wilt incidence was highly influenced by location, and markedly affected the yields, tubers per plant and average weight. The tubers per plant was negatively correlated with location but positively correlated with total yield. This means that higher yields were obtained with varieties that produced more tubers per plant, but the number of tubers per plant was not dependent on location.

Acknowledgment

The authors wish to thank ACIAR and PCAARRD for granting funds for the project.

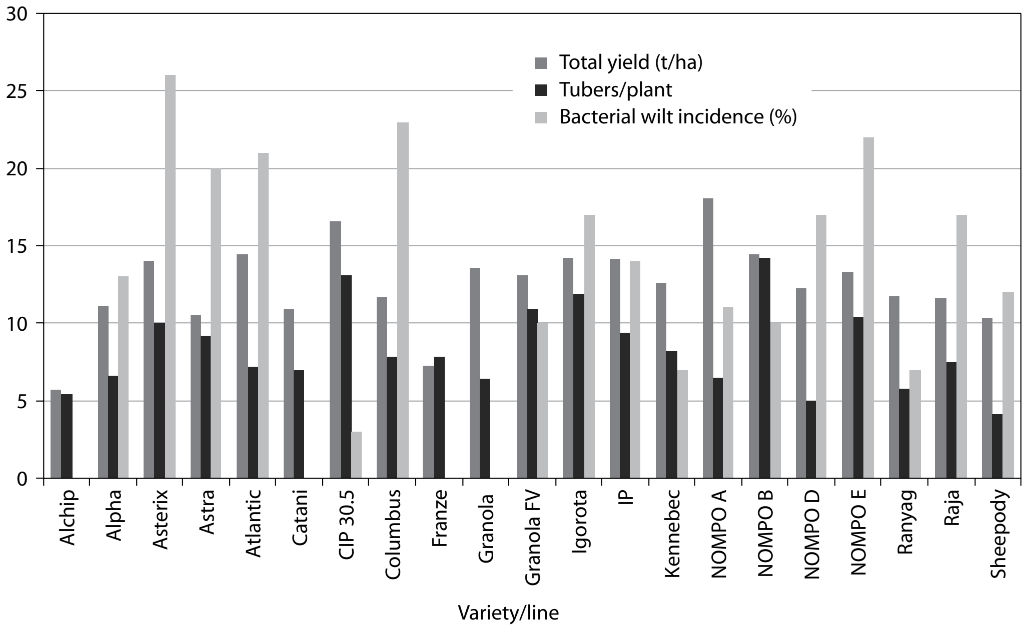

Figure 4. Adaptability trial of newly introduced potato varieties in Miarayon, Talakag, Bukidnon (1,400 masl), October 2010 – January 2011

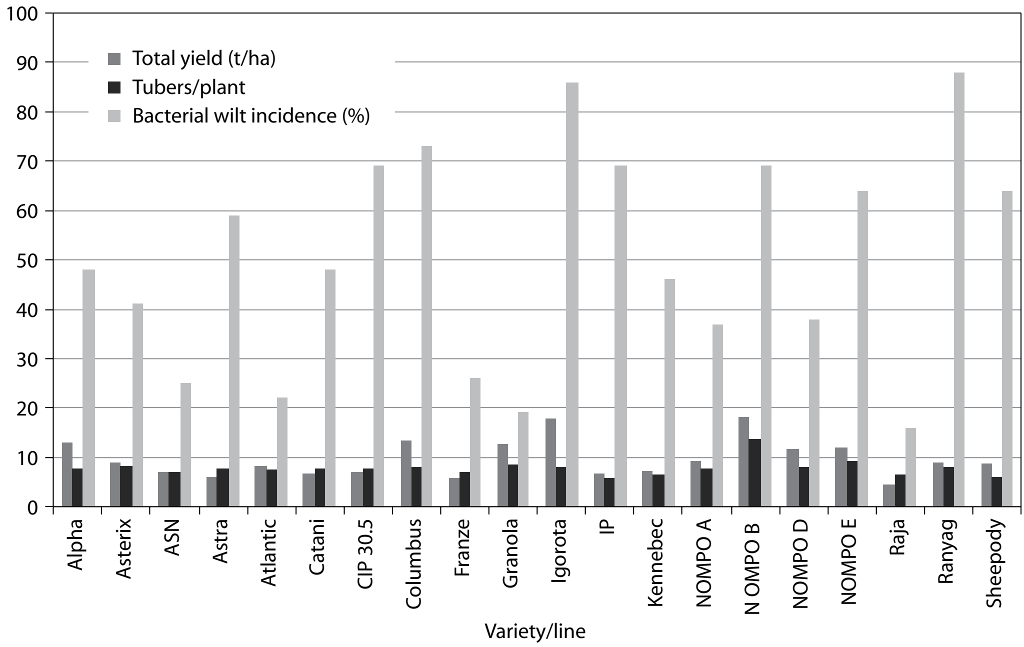

Figure 5. Adaptability trial of newly introduced potato varieties in Kibangay, Lantapan, Bukidnon (1,200 masl), October 2010 – February 2011

Table 4. Pearson correlation coefficient between different factors in the adaptability trial of potato varieties across locations

	Location	Varieties	Bacterial wilt incidence (%)	Total yield (t/ha)	Tubers/ plant	Mean tuber weight (g)
Location	1	0	0.664(**)	–0.637(**)	–0.627(**)	–0.027
Varieties	0	1	0.02	0.217	0.156	–0.04
Bacterial wilt incidence (%)	0.664(**)	0.02	1	–0.358(**)	–0.341(**)	0.365(**)
Total yield (t/ha)	–0.637(**)	0.217	–0.358(**)	1	0.738(**)	0.219
Tubers/plant (no.)	–0.627(**)	0.156	–0.341(**)	0.738(**)	1	0.193
Average tuber weight (g)	–0.027	–0.04	0.365(**)	0.219	0.193	1

** Correlation is significant at the 0.01 level (2-tailed) variety

Appendix

Table A1. Number of infected and healthy tubers and weight of healthy tubers from 18 varieties and 4 lines evaluated in the bacterial wilt nursery at NOMIARC, Dalwangan, Malaybalay City, August–November 2010 and January–April 2011

Varieties	No. of infected tubers		No. of healthy tubers		Weight of healthy tubers (kg)	
	1st crop	2nd crop	1st crop	2nd crop	1st crop	2nd crop
Alchip	0	25^{f}	25^{h}	10^{p}	0.53	0.02
Alpha	0	40^{c}	8^{m}	17^{n}	0.08	0.01
Asterix	0	11^{m}	8^{m}	23^{m}	0.08	0.32
ASN	5	35^{d}	41^{ef}	10^{p}	0.25	0.02
Astra	0	22^{g}	57^{b}	12^{o}	0.2	0.05
Atlantic	3	40^{c}	52^{c}	75^{f}	0.53	0.40
Catani	0	66^{a}	91^{a}	60^{hi}	0.13	0.45
CIP 30.5	2	15^{jk}	18^{jf}	25^{m}	0.08	0.25
Columbos	0	6^{n}	4^{n}	10^{p}	0.08	0.25
Franze	5	54^{b}	50^{cd}	85^{e}	0.13	0.98
Granola	0	1^{o}	56^{bc}	104^{a}	0.98	1.1
Igorota	0	12^{lm}	11^{lm}	64^{h}	0.03	0.78
IP	9	20^{h}	44^{e}	39^{k}	0.07	0.75
Kennebec	–	5^{no}	–	35^{l}	–	0.35
Nooksack	–	20^{h}	–	57^{j}	–	1.43
Raja	–	35^{d}	–	96^{cd}	–	0.75
Raniag	5	10^{m}	12^{l}	73^{fg}	0.58	0.95
Sheepody	0	31^{e}	17^{jk}	59^{hi}	0.58	1.15
NOMPO A	–	22^{g}	–	100^{ab}	–	0.58
NOMPO B	0	16^{j}	24^{hi}	99^{bc}	0.25	1.02
NOMPO D	–	13l	–	101^{b}	–	0.75
NOMPO E	0	18^{j}	36^{g}	97^{c}	0.33	2.1

Table A2. Adaptability trial of newly introduced potato varieties in Imbayao, Malaybalay City (1,200 masl), 28 September–27 December 2010

Varieties	Total yield t/ha	Tubers/plant	Mean tuber weight (g)	Bacterial wilt incidence (%)
Alchip	2.04^{m}	3.83^{c}	14.84^{d}	77.00^{a}
Alpha	4.98^{hi}	4.67^{b}	33.06^{c}	40.00^{bc}
Asterix	7.66^{cde}	5.03^{ab}	39.09^{bc}	67.00^{a}
ASN	8.68^{bc}	5.46^{a}	39.24^{bc}	43.00^{b}
Astra	3.79^{kl}	3.43^{c}	36.17^{c}	17.00^{d}
Catani	3.41^{lk}	3.00^{cd}	35.06^{c}	70.00^{a}
CIP 30.5	3.87^{kl}	3.02^{cd}	30.87^{c}	50.00^{b}
Columbus	7.50^{de}	6.58^{a}	51.74^{b}	67.00^{a}
Franze	4.96^{hi}	6.46^{a}	26.36^{c}	43.00^{b}
Granola	8.12^{cd}	6.80^{a}	43.91^{b}	53.00^{b}
Igorota	4.01^{jkl}	3.17^{cd}	15.70^{d}	80.00^{a}
IP	5.4gh	2.80^{d}	84.72^{a}	60.00^{b}
Kennebec	4.66^{hij}	4.13^{bc}	31.21^{bc}	40.00^{bc}
NOMPO A	6.00^{fg}	6.07^{a}	28.46^{c}	30.00^{c}
NOMPO B	9.39^{b}	6.75^{a}	52.61^{b}	67.00^{a}
NOMPO D	1.97^{m}	2.67^{d}	42.09^{b}	50.00^{b}
NOMPO E	5.20^{ghi}	3.29^{cd}	49.45^{b}	53.00^{b}
Ranyag	13.49^{a}	5.00^{ab}	82.93^{a}	30.00^{c}
Raja	4.49^{ij}	4.78^{b}	33.79^{c}	57.00^{b}
Sheepody	6.49^{f}	5.50^{a}	40.93^{bd}	40.00^{bc}
F-test	**	**	**	**
CV %	10.9	17.3	18.6	16.4

Means followed by same letter were not significant at 5% level of Duncan's multiple range test

Table A3. Adaptability trial of newly introduced potato varieties in Miarayon, Talakag, Bukidnon (1,400 masl), October 6, 20010 to January 6, 2011

Variety	Bacterial wilt incidence (%)	Tubers/plant (piece)	Average tuber weight (g)	Total yield (t/ha)
Alchip	0.00^{c}	5.4^{c}	32^{d}	5.69^{e}
Alpha	13.00^{b}	6.6	51^{b}	11.07^{cd}
Asterix	26.00^{a}	10.0^{b}	42^{c}	14.03^{b}
Astra	20.00^{a}	9.2^{bc}	34^{d}	10.51^{d}
Atlantic	21.00^{a}	7.2	64^{ab}	14.43^{b}
Catani	0.00^{c}	7.0	47^{c}	10.88^{d}
CIP 30.5	3.00^{c}	13.1^{a}	39	16.55^{ab}
Columbus	23.00^{a}	7.8^{c}	46^{c}	11.69^{c}
Franze	0.00^{c}	7.8^{c}	30^{d}	7.29^{de}
Granola	0.00^{c}	6.4	57^{b}	13.55^{bc}
Granola FV	10.00^{b}	10.9^{b}	37^{cd}	13.11^{c}
Igorota	17.00^{ab}	11.9^{a}	43^{c}	14.22^{b}
IP	14.00^{b}	9.4^{b}	45^{c}	14.14^{b}
Kennebec	7.00^{bc}	8.2^{c}	48^{c}	12.60^{c}
NOMPO A	11.00^{b}	6.5	83^{a}	18.07^{a}

Continued ...

Table A3. (continued)

Variety	Bacterial wilt incidence (%)	Tubers/plant (piece)	Average tuber weight (g)	Total yield (t/ha)
NOMPO B	10.00^{b}	14.2^{a}	31^{d}	14.42^{b}
NOMPO D	17.00^{ab}	5.0^{cd}	72^{a}	12.25^{c}
NOMPO E	22.00^{a}	10.4^{b}	39^{cd}	13.27^{bc}
Ranyag	7.00^{bc}	5.8^{c}	58^{b}	11.75^{c}
Raja	17.00^{ab}	7.5^{c}	46^{c}	11.62^{c}
Sheepody	12.00^{b}	4.1	76^{a}	10.35^{d}
C.V. %	10.3	13.9	21.5	15.4
F-test	**	**	**	**

Means followed by same letter were not significant at 5% level Duncan's multiple range test

Table A4. Adaptability trial of newly introduced potato varieties in Kibangay, Lantapan, Bukidnon (1,200 masl) 21 October 2010 – 4 February 2011

Variety	Bacterial wilt incidence (%)	Tubers/plant	Mean tuber weight (g)	Total yield (t/ha)
Alpha	48.00^{bc}	7.63^{b}	174.69	12.89^{b}
Asterix	41.00^{c}	8.09^{b}	138.2	9.01^{c}
ASN	25.00^{d}	6.89^{bc}	175.50^{d}	6.93^{d}
Astra	59.00^{b}	7.69^{b}	106.00^{e}	6.10^{d}
Atlantic	22.00^{d}	7.37^{b}	159.67^{d}	8.23^{c}
Catani	48.00^{bc}	7.63^{b}	124.52^{de}	6.69^{d}
CIP 30.5	69.00^{b}	7.79^{b}	221.00^{c}	6.91^{d}
Columbus	73.00^{a}	7.97^{b}	342.67^{b}	13.33^{b}
Franze	26.00^{d}	6.92^{bc}	125.33^{e}	5.74^{de}
Granola	19.00^{e}	8.53	416.00^{a}	12.57^{b}
Igorota	86.00^{a}	7.96^{b}	225.69^{c}	17.89^{a}
IP	69.00^{b}	5.68^{c}	298.67^{bc}	6.61^{d}
Kennebec	46.00^{bc}	6.36^{c}	168.27^{d}	7.29^{cd}
NOMPO A	37.00^{c}	7.80^{b}	188.35^{d}	9.26^{c}
N OMPO B	69.00^{b}	13.60^{a}	306.00^{b}	18.04^{a}
NOMPO D	38.00^{c}	7.87^{b}	175.36^{d}	11.74^{bc}
NOMPO E	64.00^{b}	9.20^{b}	217.64^{c}	11.89^{bc}
Raja	16.00^{f}	6.47^{c}	106.00^{e}	4.46^{e}
Ranyag	88.00^{a}	7.91^{b}	151.67^{d}	8.98^{c}
Sheepody	64.00^{b}	6.03^{c}	268.38^{c}	8.81^{c}
C.V. %	21.9	13.4	12.1	14.1
F- test	**	**	**	**

Means followed by same letter were not significant at 5% level Duncan's multiple range test

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Experiences with the Catholic Relief Services' clustering process for agroenterprise development and some suggestions for improvement[a]

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Abstract

An evaluation of the Catholic Relief Services' (CRS) eight-step clustering approach to agroenterprise development was a key focus of the Australian Centre for International Agricultural Research (ACIAR) – Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD) horticulture project on 'Enhancing the profitability of selected vegetable value chains in the southern Philippines'. The CRS approach encourages farmers to form small, collaborative marketing groups (clusters) and to facilitate the sustainable development of these clusters. The research, which used participative action learning and action research processes, identified that an enhanced clustering approach should incorporate processes that overcome issues such as: input financing arrangements to replace loans from informal moneylenders and traders; risks associated with production failures and pest and disease problems; maintaining relationships with buyers; and building group resilience and independence so that donor agencies have an exit strategy. The research findings suggest that to enhance the sustainability of the clusters the CRS eight-step process should be applied to three phases: (i) establishment, (ii) building resilience and (iii) implementing an exit strategy.

Introduction

An integral part of the Australian Centre for International Agricultural Research (ACIAR) Project HORT/2007/066 Component 4, 'Analysis of selected value chains in the southern Philippines', was to analyse the performance of the Catholic Relief Services' (CRS) eight-step clustering approach to agroenterprise development, to ascertain its potential for

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[a] The paper draws heavily on the following papers: Murray-Prior R.B., Batt P.J., Concepcion S.B., Montiflor M.O., Axalan J., Lamban R.J.G., Real R.R., Israel F.T., Bacus R.G. and Apara D.I. 2011. Towards a sustainable approach to clustering small-scale farmers to market their agricultural produce. Pp. 136–145 in 'Building capabilities for sustainable global business: balancing corporate success and social good', Proceedings of the 12th International Conference of the Society for Global Business and Economic Development, Singapore, 21–23 July 2011. Accessible at <http://sbus.montclair.edu/sgbed>.
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facilitating the development of collaborative marketing groups (clusters) and to suggest improvements to the process. Initially, CRS was to facilitate the cluster marketing groups, and the role of the University of the Philippines Mindanao (UPMin) and Curtin University (Western Australia) was to evaluate their effectiveness. In the wake of the global financial crisis, a lack of external funds forced CRS to re-evaluate its development activities in the Philippines, particularly agriculture and, more specifically, this project. Unable to find a suitable agency to undertake the role of CRS, the University of the Philippines Strategic Research and Management Foundation (UPSTREAM) assumed the role of facilitating the development of the cluster marketing groups using the CRS process.

The CRS clustering approach to agroenterprise development

The CRS clustering approach to agroenterprise development is referred to as the 'eight-step clustering approach' (CRS-Philippines 2007) (Figure 1). It begins by identifying the project site, building partnerships with farmers and other stakeholders, such as local businesses, local government and non-government organisations (NGOs), forming a working group and providing a project and cluster orientation to smallholder farmers. Step 2 is a participatory process in which the farmers identify the community's resources, products, and production and marketing practices during basic marketing training. The group then decides what product or products will be the focus of their activities. Step 3 involves training farmers to undertake a market chain study and to conduct market visits in which they develop an understanding of the chains for their selected products and negotiate trading terms with potential buyers.

Step 4 is the cluster formation phase, in which interested farmers form the cluster, select leaders and settle on a basic cluster agreement and objectives. Step 5, or cluster plan formulation, involves the development of a planting and harvest calendar for the products of the cluster and deciding on the test-marketing plan. The test-marketing activities in Step 6 involve at least four trial product deliveries. After each delivery, cluster members hold meetings to assess performance and adjust the plan to enable improvements. Once the group and facilitators judge the test markets successful, Step 7 follows, which involves planning and conducting a scaling up process. Scaling up involves producing more products or additional products to supply existing markets or more diversified markets. Cluster members and facilitators appraise readiness for scaling up against criteria that assess cluster willingness, level of product supply, market performance, management performance and their financial needs. The final step of cluster strengthening involves undertaking activities

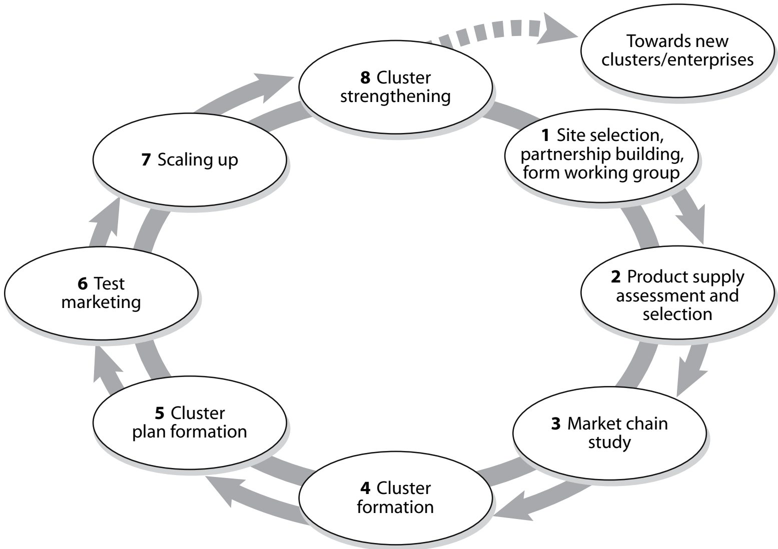

Figure 1. Eight-step process of the clustering approach to agroenterprise development: an action learning process (Source: CRS-Philippines 2007)

that expand cluster capacity and networks with other clusters and businesses. The objective is to improve cluster maturity.

While this process has been extensively employed in facilitating the development of clusters, the evidence to date suggests that very few of these cluster marketing groups have survived once funding has been withdrawn. Murray-Prior (2007) suggests that collaborative marketing groups will survive only where they offer some comparative advantage. In other instances, it is apparent that many NGOs are reluctant to let their more successful groups go, for future funding is contingent upon their ability to demonstrate success. Inadvertently, this may often result in the cluster becoming dependent upon the NGO. With limited budgets, if the clustering process is to be replicable, there must be a process by which formal linkages with the more mature groups can be severed, to enable them, with minimum intervention, to make their own decisions and to become self-sustaining. In turn, that enables resources to be redirected towards the formation of new cluster groups, greatly increasing the reach and the impact of the project.

This paper explores some suggested improvements to the CRS eight-step plan for agroenterprise development that will lead to more sustainable and successful cluster marketing groups.

Methodology

The methodology used to investigate the application of the CRS clustering approach involves an integrated participatory action learning and action research process with over 29 cluster marketing groups (CMGs) in Mindanao, the southern Philippines. The UPMin, through the UPSTREAM Foundation, facilitated the establishment of several CMGs in Davao, Bukidnon and South Cotabato using the CRS eight-step process. At the same time, research officers from UPMin were involved in an action research process that documented each cluster group's activities and investigated issues as they arose (Figure 2). Surveys were conducted of farm household resources, production activities and the relationships among farmers, wholesalers and traders, farmers and the cluster, clusters and traders, and wholesalers and institutional markets. Case study reports were prepared for each cluster and on selected farmers within the clusters. Findings from these investigations, discussions between the researchers and field officers, and evidence from the literature and experiences of the researchers, field officers and farmers, were used to identify and evaluate changes to the clustering process and activities.

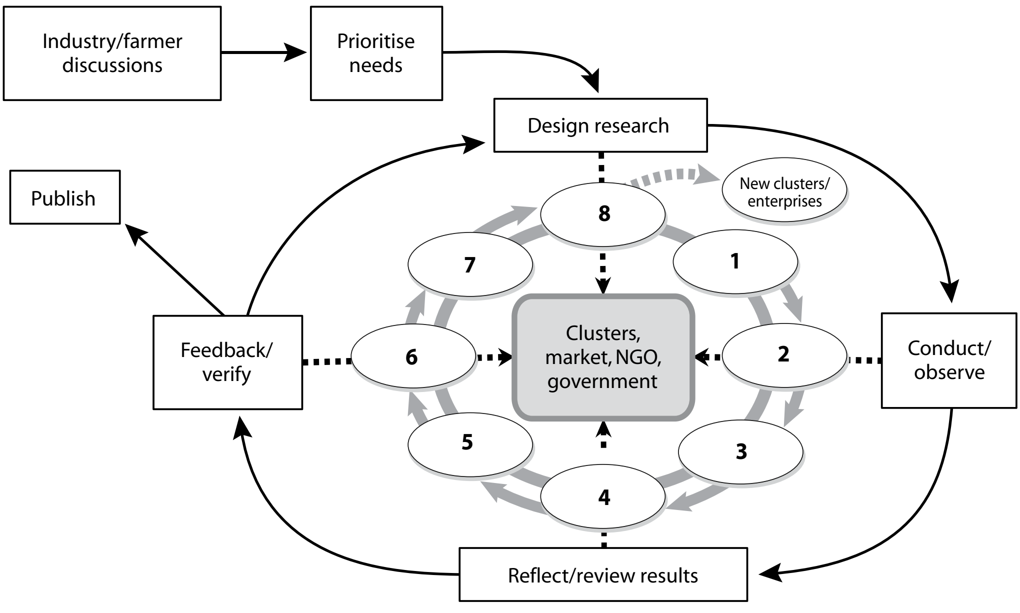

Figure 2. Participatory action research process integrated with action learning process for marketing clusters

Because of the quantity of data involved in this action research/action learning study, which occurred over 4 years with 29 cluster groups, it is not possible to present the results supporting the discussions. Therefore, the paper summarises data, discussions and conclusions presented in previous papers published by the research team. It also follows the qualitative research approach in presenting the results and discussion together, which is the norm for action research.

Issues to be addressed by an enhanced clustering process

This combined participative action learning and action research process identified the need for an enhanced clustering process to incorporate processes that would overcome some of the major issues such as: input financing arrangements to replace loans from informal moneylenders and traders; the risks associated with production failures; maintaining relationships with buyers; and building group resilience and independence so that donor agencies have an exit strategy.

What to do about the input financing problem

Smallholder farmers in the Philippines and elsewhere have limited or no access to the formal lending sector. Thus, they have to rely on informal moneylenders, including local traders, landlords, commodity wholesalers and other village moneylenders (Robinson 2001; Llanto 2007). These loans are often at rates well above those charged by commercial microfinance institutions because such markets sometimes have characteristics of monopolistic competition (Robinson 2001). When smallholder farmers market their produce through a CMG, such as those created using the CRS clustering process, these arrangements often bypass the traditional marketing system. Consequently, the farmers may be unable to access loans from local traders and commodity wholesalers. These lenders often lend money for inputs in the expectation that they will be able to buy the product at prices that are advantageous to them. They may also threaten smallholders with not lending money or refusing to buy their product if they sell through a cluster. This appears to be a common occurrence (Llanto 2007).

Llanto (2007) and Campaigne and Rausch (2010) suggest that lending to farmers who are connected to an integrated supply chain is more feasible. Some of the cluster groups from Bukidnon and South Cotabato have accessed finance through microfinance institutions, partly because they were organised groups. However, their outcomes have been mixed (Axalan et al. 2010; Real et al. 2010). When production fails due to weather or disease problems, farmers who have formal loans from microfinance institutions face additional burdens, which can affect both the viability of the cluster and its marketing arrangements. In Bukidnon, squash, sweet pepper and bitter gourd clusters were unable to meet their contractual obligations due to disease- and weather -elated problems (Real et al. 2010). Since the microfinance institution provided the loans because the farmers were members of a CMG, some clusters had farmers who withdrew because they expected that they would be liable to repay the loans of other cluster members. On the other hand, members of a sweet pepper cluster in South Cotabato who received loans from a microfinance institution had fewer problems, partly because they did not have the same level of production failures, but also because of the way in which their loans were structured (Axalan et al. 2010). Other clusters in the Davao City area do not have access to microfinance and must therefore self-finance or obtain some funding from informal moneylenders.

In light of the literature on microfinance, some lessons can be drawn from these examples. Microfinance loans can increase the risk to farmers because they lead to greater investment in inputs, which the microfinance institution may not recover if production problems occur or if market prices are inordinately low. Often farmers involved in new cluster marketing groups are involved in learning about and implementing many new and interrelated behaviours. Adopting new behaviours and crops is inherently risky. In this case, farmers are adopting new marketing arrangements, often growing new or expanded areas of crops, and are learning to cooperate to produce, market and deliver their crop to a focal buyer at some particular time.

If farmers in the early stages of clustering are provided with loans, the combination of these risks can leave farmers and clusters in a perilous financial position, as happened to the clusters in Bukidnon. In one case, the loan was linked to a particular crop and marketing arrangement (Real et al. 2010). The microfinance institution lent the money on the expectation that the crop would be sold through a particular agent who would deduct loan repayments and pay the farmers the remaining money. When the group could not meet the quantity and quality requirement due to a viral infection, the agent rejected the clusters' product and hence repayments were not made. Since the repayments were linked to a particular crop and repayment arrangement, some farmers did not feel obligated to repay the loan.

Some of the loans made to clusters in Bukidnon were based on overoptimistic assumptions about yields and prices (Real et al. 2010). Since farmers are learning and adopting many new skills and behaviours in the early stages of clustering, the likelihood of crop failure is high. Vegetable prices in the Philippines are extremely volatile because of seasonal variations in production, with the frequency and potency of typhoons (Batt et al. 2011) adding an additional complication. Budgeting for loans must be conservative to allow for the high level of production and price risk, and to decrease the risk of over indebtedness.

Furthermore, such loans should be made only for the purchase of physical inputs such as seed, fertiliser and pesticides. In Bukidnon particularly, it was evident that the value of the loan extended was much greater than the crop needs, which resulted in funds being redirected towards the purchase of household goods. Ideally, farmers should finance part of the crop from their own resources. Hermes and Lensink (2007) suggest that credit rationing can increase the likelihood of loan repayment, which is consistent with this view. Additionally, there is some evidence that loans are necessary only for crops that are more expensive to grow and not for all crops, at least in the initial trial stages. As farmers gain experience with crops and cluster marketing, and as the clusters seek to expand production and scale up, loans may become more necessary.

A comparison of the lending strategies followed by microfinance institutions in Bukidnon and South Cotabato and their successes and failures supports some of the principles underlying the Grameen Bank and the Association for Social Advancement (Llanto 2007). These include compulsory savings or capital build-up, progressively larger loans based on demonstrated competence, and financial education for loan recipients in budgeting, saving and managing debt (Llanto 2007; Cohen 2010).

Finally, donor agencies need to be careful when promoting and supporting loans to cluster marketing groups, because the action can lead to the impression that the loans are a gift. Farmers are used to charitable institutions providing gifts, and even where the loan is provided by a microfinance institution, if it is linked to the support that a donor agency provides for the cluster marketing group, it can be perceived as a handout. Experience with the loans made to some of the farmers in Bukidnon suggests this was a contributing factor to problems associated with repayment by some farmers.

Risks associated with production failures

Vegetable farming in the Philippines can be a risky business, with production quantity and quality varying widely due to climatic conditions and pest and disease outbreaks (Batt et al. 2011). Dry periods can lead to poor crop emergence and growth, while wet periods can dramatically affect seedling survival, flowering, product quality and yield. Wet weather also intensifies fungal diseases, which can increase costs of control and severely reduce yields. Similarly, poor seed selection results in disease outbreaks (as occurred for the bitter gourd cluster), while pest and disease outbreaks can occur as a result of climatic conditions, poor rotations or poor crop hygiene. These variations in yield and quality not only reduce farmers' returns, but also make it more difficult for clusters to be consistent suppliers to institutional markets.

One strategy adopted by farmers to manage the risk is to adopt lower-input production systems that require lower financial outlays and reduce yield variability. Many clusters are in relatively remote areas, so imported fertilisers and pesticides are expensive and difficult to obtain. Accordingly, farmers have been investigating the use of organic and 'natural farming' (Jensen et al. 2006) systems. These systems use local inputs, such as organic fertilisers, composts and homemade pesticides. Further investigation is needed to see what effects these systems have on levels and variability of yield and quality.

Another strategy is for the cluster to commit only a portion of its expected yield to the focal buyer, particularly if this is an institutional buyer who wants consistent supply. A common figure is 60% of a conservative estimate of yield, although this varies depending on the crop and the number of buyers. This strategy has additional advantages, in that farmers are then free to sell their surplus product to other buyers, particularly if there is a spike in prices. They can also maintain their relationships with traditional buyers who provide other services such as credit. It also spreads their risk if one of their buyers defaults or refuses to accept product for whatever reason.

Maintaining relationships with buyers

Modern value chains, because they require consistent quantity and quality of supply and processes for ensuring food safety, have generally developed in advanced economies and are therefore more suited to medium- to large-scale farmers. Smallholder farmers in the Philippines have little understanding of these markets because they have traditionally dealt only with local traders, and rarely visit the wet markets where most of their product is sold. The clustering process tries to overcome this deficiency by training farmers to conduct their own market chain studies, including talking to buyers at different stages of the chain and in different markets. Farmers are also taught negotiating skills, which improves their confidence and ability to negotiate prices, volume and quality with institutional and other buyers. Nevertheless, smallholder farmers generally take some time to develop their knowledge of market operations and requirements, and this can create misunderstandings and conflict between the cluster and buyers—especially institutional buyers. Conversely, institutional buyers often come from cities and have little understanding of the constraints faced by smallholder farmers, which exacerbates misunderstandings and conflicts between the two groups. This combination has led to numerous breakdowns in the relationship between buyers and clusters.

One strategy to reduce the effect of this issue is the conduct of series of test-marketing activities (CRS Step 6). After each trial, the cluster evaluates the performance of the trial product deliveries in terms of the quantity and quality of the product that was delivered versus what was planned. However, there can still be misunderstandings between the cluster and its buyer, and sometimes the donor agency has to facilitate a discussion about the causes of the misunderstanding. Sometimes the problem is with the farmers, but equally the problem can be with the buyer who can try to take advantage of the farmers, possibly because that is what they have been used to doing.

This is a learning process for both sides and it appears that in some cases it requires a couple of years, including periods where the cluster sells to other buyers, before a sustainable relationship is achieved. In other situations, a sustainable relationship may not be possible due to a whole range of reasons. The donor agency that is facilitating this process needs to have patience and to act as an honest broker by not taking sides, and by attempting to identify the root causes of the problem. It is important for farmers to be involved in discussions and negotiations with the institutional buyers, as this is the only way in which understanding and mutual respect can be gained and sustained. Supermarket buyers of vegetables from Davao and Bukidnon clusters have been taken to the smallholder farms where the vegetables they are buying are grown, to give them an appreciation of some of the difficulties faced by the farmers in getting a quality product to market.

Enhancements to the CRS clustering process

Cooperatives and cooperative marketing arrangements have a poor record in the Philippines. Many of these cooperatives were set up for political reasons such as agricultural development, pacification of revolutionary activities and distribution of subsidised inputs. Most cooperatives failed when government removed institutional supports. Outside support can enhance the chances of success of smallholder cooperatives (Murray-Prior 2007), but it can encourage dependency, which means the cooperatives are not sustainable once external support is withdrawn (Shigetomi 2006). If cluster marketing is to be a successful alternative, processes are required that develop resilience in the groups so that they can survive with minimal external support. This also implies building in an exit strategy as a component of the clustering approach.

There are two key factors that are important to the success of cluster marketing arrangements: 1. a comparative advantage over alternative marketing structures; and 2. trust in cluster management and between cluster members (Murray-Prior 2007). The clustering approach addresses the first of these issues through its focus on developing a marketing plan and its test-marketing activities. The group is unlikely to form unless the cluster farmers see a comparative advantage for cluster marketing over their existing marketing arrangements. The second issue is addressed in a number of ways (CRS-Philippines 2007). First, the process is participatory and transparent, and considerable effort is devoted to activities that involve cluster members, market chain investigations, development of the production plans, and keeping records on deliveries and payments that are accessible to all members. Members develop a cluster agreement, develop cluster enterprise plans and business policies and systems, and review test-marketing activities. Second, clusters conduct regular meetings, and members elect the leadership team. Third, clusters are normally restricted to 15 or fewer members so that trust can be maintained through group pressure. As well, the clusters and their leaders receive training in group processes and leadership. Evidence from the trust measures collected by the research officers (e.g. Montiflor et al. 2010) indicate that cluster members currently have high levels of trust in their cluster.

While comparative advantage and trust are essential to the successful operations of CMGs they are not sufficient; nor do they guarantee success in the long run. A three-phase clustering framework is proposed that builds on and enhances the processes outlined in the CRS eight-step process. It incorporates three phases: Phase 1—Establishment; Phase 2—Building resilience; and Phase 3—Implement an exit strategy (Figure 3). Each of these phases is a type of participatory action learning cycle and contains a series of steps that may be repeated depending on the maturity of the group.

Phase 1—Establishment

The establishment phase follows the first six steps of the CRS process (CRS–Philippines 2007) with minor modifications and takes 1–2 years. In step 1 (site selection, partnership building and formation of working group), greater emphasis needs to be put on investigating input-financing arrangements, both the existing informal lending arrangements and potential microfinance lenders if farmers are not involved with them already. More orientation is required on saving, loans and financing alternatives in addition to the orientation on marketing that is currently provided.

In step 2 (product supply assessment and product selection), potential crops and products should be ranked but not selected. Product selection would then be re-evaluated following the market research (CRS step 3). This step should be expanded to include an investigation of input requirements for particular crops selected following the market research, potential sources and costs of those inputs, and the ability of farmers to finance these inputs. Financial institutions may help with the latter.

In step 4 (cluster formation), the eight-step process of orientation on marketing basics and clustering needs to be broadened to include production issues, sources of inputs and the financial implications of particular crops. Step 5 (cluster plan formulation) would then proceed according to the eight-step process. The test-marketing activities (CRS step 6) would go through a number of stages including: (i) assessment of cluster commitment and capability of members; (ii) identification of information and training needs and conduct of trainings to overcome deficiencies; (iii) evaluation of buyers and establishment of a good working relationship; and (iv) refinement of agroenterprise plans.

Phase 2—Building resilience

The focus of Phase 2 is essentially cluster strengthening and capacity building—an expansion of the CRS step 8, known as cluster strengthening. Groups

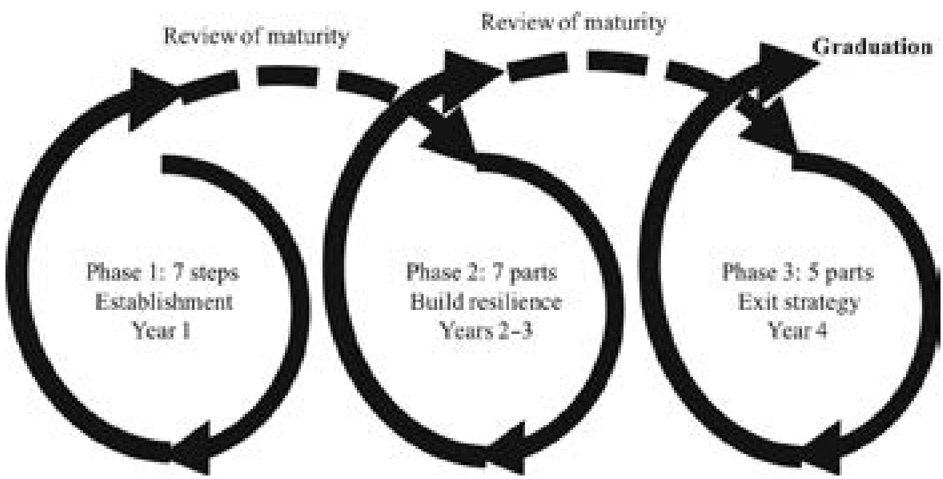

Figure 3. Three phases in enhanced clustering process

will often go through periods of decline in activity, often caused by production or marketing problems. A lack of capacity and immaturity in the cluster can sometimes cause marketing problems, but buyers not paying or not complying with their agreements can also be a cause. Problems like these can cause the cluster to collapse, but if the donor agency is able to support the cluster in developing strategies to deal with these problems, the clusters develop confidence in their own abilities and are in a better position to deal with future issues without assistance. One example of this from our research occurred with the Ned cluster, which delivered product to a buyer who did not pay them. The group negotiated with their microfinance agency to obtain a loan and then investigated and found new markets for their products (Axalan et al. 2010). Their ability to overcome this problem led to greater commitment.

Kaganzai et al. (2009) argue that this 'repair and maintenance' support from donor agencies may be necessary in the scaling-up phase of collaborative marketing groups. In fact, one or two of these difficult periods can be part of the process of developing resilience. Clusters have overcome production problems by establishing links with seed companies to provide better quality seed and changed production practices with the assistance of local government advisers. Clusters have overcome marketing problems by identifying new buyers and markets and subsequently diversified their markets. In this phase, the role of the donor agency is to provide assistance when the cluster is struggling, to help enhance cluster networks and to build cluster capacity. They provide less direct assistance, and the group is encouraged to draw on its own resources. The steps in this phase include: (i) revisiting the product supply assessment step and reassessing training support needs; (ii) undertaking a further market chain study with a view to reassessing the cluster's performance in meeting market needs, identifying additional markets and selecting focal market chains; (iii) review cluster membership and structure; (iv) identifying information, training and support needs which are addressed through training and capacity-building activities; (v) formulating cluster and operational plans; and (vi) conducting and reviewing marketing activities.

Phase 3—Implementing an exit strategy

Sustainability of cluster marketing arrangements is problematic, as many such groups have failed after the donor agency withdraws. Some reasons for this problem include: donor agencies taking control of marketing and hence replacing the market intermediary; donor agencies providing too many gifts and creating a 'handout mentality'; competition between donor agencies; donor agencies focusing on 'favourite' groups that have a 'reputation' for success; and the failure of donor agencies to develop exit strategies. Markelova and Mwangi (2010) call for donor agencies to develop viable exit strategies from the onset of their project, so as to lessen dependency issues. The CRS clustering process already includes criteria for assessing cluster maturity (see CRS–Philippines 2007, p. 140), so the focus here is on how to incorporate these into a process for implementing an exit strategy for the donor agency. The specific steps in this phase could include: (i) a workshop to assess maturity for graduation or exit of the donor agency; (ii) training in business planning and the development of business plans; (iii) strengthening links with support institutions; (iv) formulating a business plan for the cluster's afterlife; (v) participatory evaluation of the clustering process, the donor agency involvement in the process and the donor agency performance; and (iv) organising a graduation activity. It must be made clear to the farmers from the beginning of the establishment phase that the donor agency will provide support for only a finite period and that the CMG will need to build its resilience and become self-sustaining. Identifying this phase in the process helps to emphasise this reality to the cluster members and to the donor agency staff.

Conclusions

Development activities of many donor agencies fail because they do not focus on an exit strategy from the initial planning stages. This paper outlines an expansion of the CRS eight-step plan for agroenterprise development to cover each of three phases: (i) establishment; (ii) building resilience; and (iii) implementing an exit strategy, so that the focus will be on the cluster marketing group becoming self-sustaining. It also addresses access to finance from the formal lending sector, but this can increase risks for farmers, so the donor agency must ensure that farmers do not get the perception that the loans are a gift. Building long-term relationships between cluster marketing groups and institutional buyers in the Philippines is a difficult process. A donor agency will have to invest considerable time and effort in facilitating this process and organising activities that build capacity and relationships between the smallholder farmers, institutional buyers and other government and non-government institutions, so that clusters can undertake these activities after the donor agency exits.

This is the first time the CRS eight-step plan has been investigated scientifically. The three-phase process also has the potential to become a process used widely in the Philippines and elsewhere, as a mechanism to facilitate rural development and improve smallholder farmer incomes. However, the sustainability of clusters under this process and under the existing CRS eight-step plan, and the factors that will increase long-term sustainability still need to be investigated.

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Impacts of clustering of vegetable farmers in the Philippines

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Abstract

This assessment was made as part of a systematic process of evaluating the impacts of clustering vegetable farmers in the southern Philippines. Program theory was used to map the impacts. The performance of cluster and non-cluster farmers was compared. Farmers' performance before and after clustering was also examined. The study found that, on average, cluster farmers had higher incomes than non-cluster farmers. Moreover, farmers increased their income by about 47% after clustering. Examining the returns on investment in the research project, it was found that the net present value (NPV) was 35.3 million pesos, the internal rate of return (IRR) 48.6% and the benefit:cost ratio (BCR) 2.47. When spillover effects were considered at a 5% adoption rate, the NPV, IRR and BCR increased to 106.9 million pesos, 81.5% and 3.8, respectively.

Introduction

One of the most vexing problems in developing countries is the persistence of poverty. In the Philippines, poverty levels remain high at about 26.5% (Virola 2011). In 2009, the number of people below the poverty line was recorded at 23.1 million, which translates to about 970,000 more impoverished Filipinos than there were in 2006. According to IFAD (2011, 2012), Mindanao includes the highest incidences of poverty and many of the poor people in Mindanao are smallholder farmers.

Smallholder farmers are faced with numerous constraints, including low productivity, poor-quality product and low returns for their produce. This, in turn, is due to a multitude of issues, including lack of technical know-how, use of low-yielding varieties, inefficient or non-optimal input use, poor farm management practices and poor postharvest practices. In addition, farmers also lack information about prices and markets, and face institutional and infrastructural constraints that translate into high transaction costs and inability to access markets, particularly high-value markets. Thus, farmers are being bypassed by the opportunities arising from globalisation and the fast-changing consumer demand.

Past development projects focused on either the production side or the marketing side. However, given the wide ranging and complex issues faced by farmers, a more holistic approach is needed to meet their needs. Moreover, as an understanding of what the market wants is important to be able to gain access to desired markets, an integrated approach looking at the entire supply chain is important. But the question is: How can this be done in practice? Most farmers in the Philippines are smallholder

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farmers with small-scale operations, have poor capitalisation and access to credit, may not immediately have the capacity to deliver the requirements of high-value markets and do not have the confidence to approach and negotiate with new high-value markets. Yet, understanding and accessing these markets could help hasten income improvements and thus alleviate poverty.

With this challenge in mind, a group of researchers under an Australian Centre for International Agricultural Research (ACIAR)-funded project, investigated a process that has the potential to enhance farmers' understanding of the value chain. This enhancement would allow them to identify opportunities and constraints along the chain and, at the same time, implement a range of actions and interventions to overcome constraints across the production and marketing spectrum that would enable them to take up opportunities to increase their incomes. This process involved is 'clustering'.

The power of clustering

Clustering is a form of collaborative marketing wherein a group of farmers organise to collectively market their produce. There are many forms of collaborative marketing, including cooperatives, grower associations and cluster-marketing groups.

Clustering is not a new approach. In fact, agro-based clustering is becoming one of the key approaches development practitioners are using to progress the agricultural sector (Galvez-Nogales 2010; Theus and Zeng 2012). In agro-clusters, producers in the same agricultural sectors get together to participate in value chains to gain market opportunities and overcome common challenges. Galvez-Nogales, an FAO marketing economist, analysed agro-based clusters in different regions. According to her, agro-based clustering is an efficient and sustainable way of linking farmers to global value chains. The approach has benefits in terms of diffusing innovations, using and creating farm services, and increasing access to markets and information.

The Catholic Relief Services (CRS) has also been applying the clustering process to farmers in Mindanao, in their case using an eight-step clustering process (CRS–Philippines 2007). The CRS eight-step clustering approach involves organising smallholder farmers into 'clusters' of 5–15 farmers to supply high-quality vegetables to market specifications and to the volume required by buyers. One of the characteristics of the CRS eight-step process is that it is market-driven. Farmers start with understanding market needs, then plan production and marketing with a view to responding to those needs. In the process, farmers produce the type of vegetables needed, to the quality specifications required and guided by the knowledge that they are producing what the market wants when it needs it. As a consequence, farmers know their targets and they are producing with the knowledge that markets are more likely to buy their products. It is also quite likely that they can obtain higher prices for their produce.

The project

In 2006, an ACIAR project in Mindanao, southern Philippines, began looking at ways smallholder farmers in that region could participate better in value chains. The aims of the project were:

- to improve the capacity of smallholder vegetable farmers to better fulfil the needs of traditional and institutional buyers
- to assist smallholder vegetable producers in Mindanao to adopt effective market linkage mechanisms via collaborative marketing arrangements and clusters
- to identify and propose potential interventions at the farmer and market intermediary level to improve the performance of value chains in the southern Philippines vegetable industry

The project involved the analysis of value chains forged from collaborative marketing arrangements of farmers. The CRS eight-step approach was used in the formation of clusters. The implementation of clustering under the CRS eight-step approach follows a sequential process that prepares farmers to link with different negotiated markets. The process is illustrated in Figure 1.

A total of 29 clusters comprising 360 farmers (228 males; 132 females) participated in the project from nine locations in the southern Philippines (South Cotabato (Lake Sebu, Tupi, Surallah and Koronadal City); Bukidnon (Malayabalay, Lantapan and Impasug-ong); Davao City (Calinan and Marilog)).

As part of the process, interventions and capacity-building activities were conducted with each cluster. Between 2008 to 2011, 69 activities were held, involving 14 different types of capacity-building activities. The total participant count was 1,242, comprising 755 males and 487 females. The

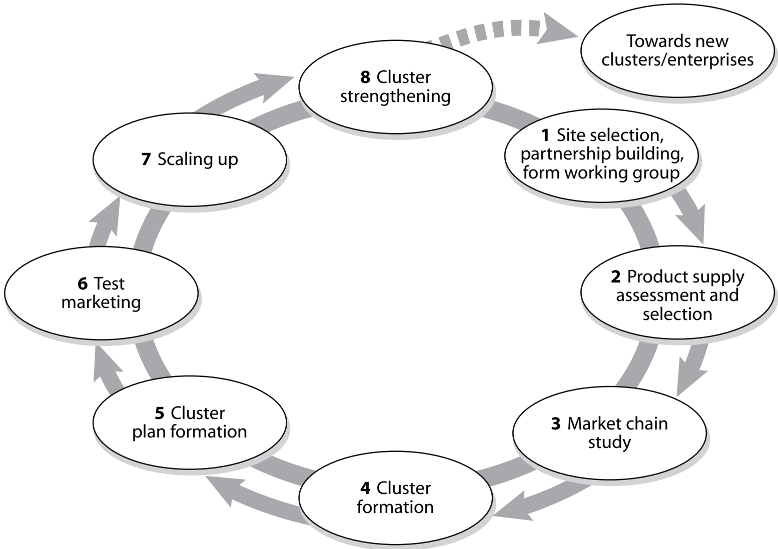

Figure 1. CRS eight-step clustering process for forming farmer clusters

interventions included market visits by farmers, postharvest training, transfer of technology (e.g. protected cropping structures) and provision of material support (i.e. seeds, sorting shed, plastic crates, weighing scales). Other capacity-building activities included pest and disease training; cluster enterprise planning; buyer interviews and negotiation; training in basic recording, basic economics and accounting, and leadership and financial management; and attendance at vegetable congresses. These activities are integral to the clustering process, as they are critical in improving production and postproduction practices for farmers to be able to meet the requirements of markets. For instance, the pest and disease training was meant to help farmers deal with pest and disease control, which helped them improve product quality and reduce farm losses, while the market visits allowed farmers to meet downstream buyers and to see, first hand, what the market requires.

Clearly, participants benefited from various activities geared towards assisting them, but crucial questions are: What has been the impact on farmers? Does clustering matter for smallholder vegetable farmers in Mindanao? If so, what is the impact of clustering? Is our research making a difference?

The aim of this paper is to examine the impact of clustering on vegetable smallholder farmers in Mindanao. Specifically, we examined whether clustering had an impact in terms of income, production and prices received by farmers. Are cluster farmers better off than non-cluster farmers? We also examined the economic impact of the research project and determined the returns on investment from the clustering research.

Methodology

To adequately answer the research question, the framework adopted for the research was participatory action learning. Both qualitative and quantitative approaches were used to measure the impacts. Data gathering was done using a combination of methods, including qualitative techniques (e.g. focus group discussions, interviews and researchers' observations) and quantitative techniques (e.g. survey and recording of actual input and output data).

To measure the impact of clustering, a quasi-experimental design was employed. The framework for the impact assessment is illustrated in Figure 2. The study compared cluster farms before and after clustering, as well as cluster and non-cluster farms. As baseline data for non-cluster farms were not available, matching of samples was done in the selection of non-cluster farms, whereby non-cluster farms chosen were from similar areas and operating under similar farming systems. Also, the range of non-cluster farm sizes was similar to that for cluster farms.

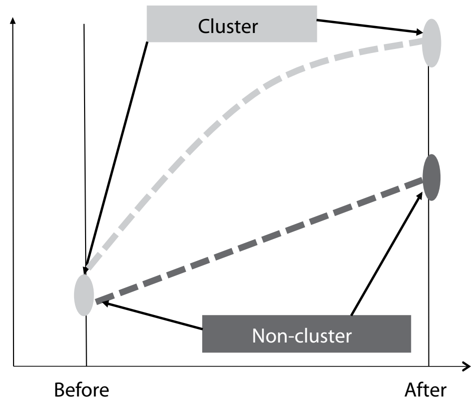

Figure 2. Framework for measuring impact of clustering

Structured interviews were conducted with 174 farmers from the three research sites. Baseline interviews were conducted with 48 farmers. These were used for the 'before clustering' scenario, while 61 cluster farmers were interviewed for the 'after clustering' scenario. Meanwhile, 65 farmers who did not belong to any cluster were interviewed as non-cluster farmers. The numbers of farmers interviewed are shown in Table 1.

To assess the impacts of clustering smallholder growers on marketing vegetable produce, economic analyses such as gross margin analysis and costs and returns analysis were conducted on both the cluster farm groups and the non-cluster groups, as well as on the cluster groups before and after clustering. To assess the economic impact of the research project, cost–benefit analysis was carried out. The net present value (NPV), internal rate of return (IRR) and benefit:cost ratio (BCR) were calculated at the farm-level for two scenarios —without adoption and with adoption. Further analyses were also made assuming spillover effects in the community for both situations with no adoption and with adoption. The results of the analyses are discussed later in the paper. Before going to the results section, we first discuss the program theory of the clustering approach—how project inputs were converted to outputs and outcomes, and how impacts were achieved in the project.

From inputs to outcomes: program theory of the eight-step clustering approach

The main aim of the clustering approach is to increase the net returns or incomes of smallholder farmers. How did the project get to that outcome?

The project employed a logic framework which supposes that inputs (resources) used in the activities (project interventions) result in outputs (production) that will lead to outcomes (improved incomes) with ultimate impact (poverty reduction). The underpinning theory of clustering vegetable growers is that bringing farmers together to build a critical mass and honing their skills and capacity in production and marketing will enable them to respond to market demand and requirements. This will allow them to participate in modern value chains and benefit from receiving better prices than what they would have received from their traditional markets. To follow the path from inputs to outputs, program theory was utilised.

As mentioned previously, the clustering approach follows a sequential process that builds farmers' capacity to link with different markets and the whole supply chain more effectively and efficiently. A critical component in the CRS eight-step clustering process is improving farm-to-market linkages. Improving marketing alliances allows smallholder farmers to link with institutional buyers, thus improving their access to institutional markets and other value chains. By having access to the institutional markets, smallholders receive higher prices for their produce, which results in higher vegetable sales and therefore increases household income. This in turn will help reduce poverty in the country, the ultimate developmental goal (Figure 3).

The program theory for the clustering approach was mapped to explore the path from inputs to

Table 1. Smallholder survey participants

Area	No. of cluster farmers	No. of non- cluster farmers	Total
Before	48	–	48
After	61	65	126
Total	109	65	174

outcomes (Figure 4). The key intervention activities in the eight-step clustering process involve: linking farmers with supply-chain partners including institutional markets; improving understanding of markets through market visits and market research (including walking the supply chain); training in production and farm management, alternative pest and disease control, postharvest practices, financial management and record keeping; provision of inputs and resources such as seed, plastic crates, weighing scales and fertilisers; and transfer of technology to farmers. These interventions result in improved market chain linkages, higher production and productivity, improved postharvest practices, decreased postharvest losses, higher product quality and better prices received for their produce. All these translate into higher incomes from vegetable production, thus contributing to household income. Having more secure markets also reduces the risks to farmers.

As illustrated in Figure 4, improving smallholders' knowledge on production will improve their ability to improve the quality of the produce, reduce loss and wastage and improve overall production. This process will lead to farmers obtaining higher market

Figure 3. Pathway to increased income and poverty reduction through clustering

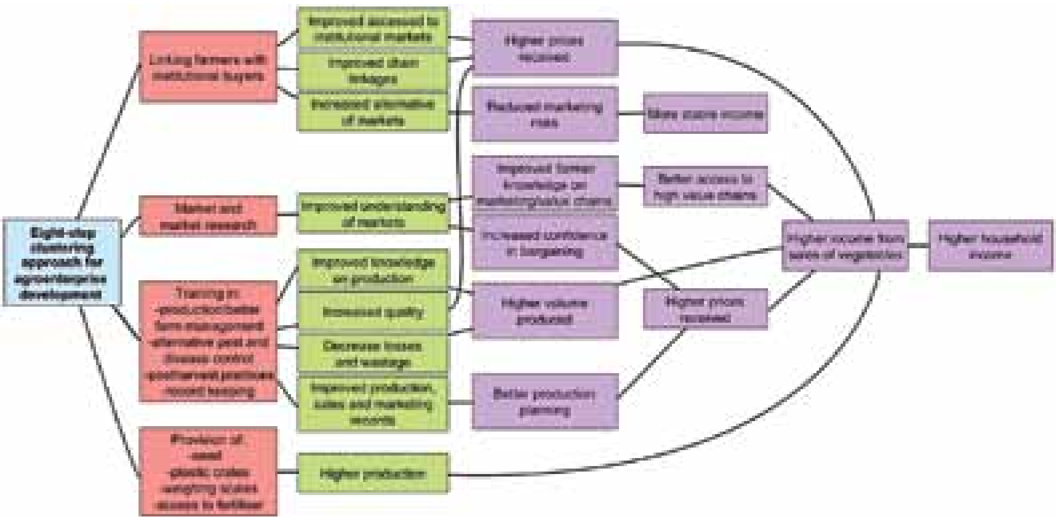

Figure 4. Program theory of the impact of clustering on smallholder farmers' incomes

prices for their produce. Similarly, leveraging the higher production level emanating from improved productivity and product consolidation with other cluster members, as well as their improved ability to plan farm production, cluster farmers are better able to cope with and meet market demand, producing what the market wants in a timely fashion. The end result of these interventions is higher returns and higher household income.

In the same manner, provision of some farm inputs such as seed, plastic crates, weighing scales and fertilisers will lead to increased production levels, lower wastage and higher volumes of marketable products, leading to higher returns on sales and, ultimately, improved incomes for smallholder households.

Results and discussion

The results of the impact analysis are presented below. The discussion focuses on the impact on returns from vegetable production, on volume of production, prices received and on household income. The return on investment in the research project is then presented.

Impacts of clustering

Impact on production

Results of the comparison of production levels of farms before and after clustering show that the volume of production increased in 9 of the 11 commodities (Figure 5). The most dramatic increase was in tomato production, which increased from 665 kg to over 4.3 tonnes (t), eggplant from 0.5 t to close to 3 t and chayote from 720 kg to 2.4 t. However, sword pepper declined, perhaps because farmers shifted to other crops that had relatively higher profitability.

The increase in production is reflected in the increase in the output value, with significant increases in the value of production of six commodities post clustering. The value of production of sweet pepper increased from 27,538 to 39,697 pesos; eggplant from 4,489 to 41,259 pesos; chayote from 2,880 to 28,078 pesos; and tomato from 8,720 to 41,686 pesos. As expected, the value of production of sword pepper declined in the post-clustering scenario in line with the fall in output (see Figure 6).

Comparing the performance of cluster and non-cluster farms, the results of the analysis showed that cluster farm production levels were higher than non-cluster farmers for all but one crop. Most produce showed significant differences in production levels, while marginal increases were shown on pechay and string beans. Again, the difference in tomato production between cluster (over 4.3 t) and non-cluster (1.6 t) was the most dramatic (Figure 7).

Comparing the value of production of cluster farmers and non-cluster farmers, cluster farmers had higher values of production for six of eight commodities (Figure 8).

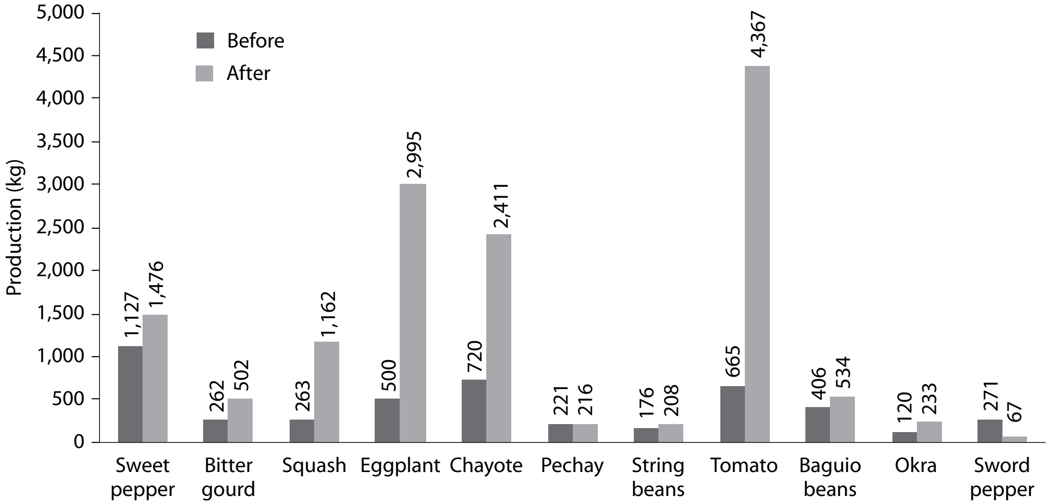

Figure 5. Volume of production before and after clustering

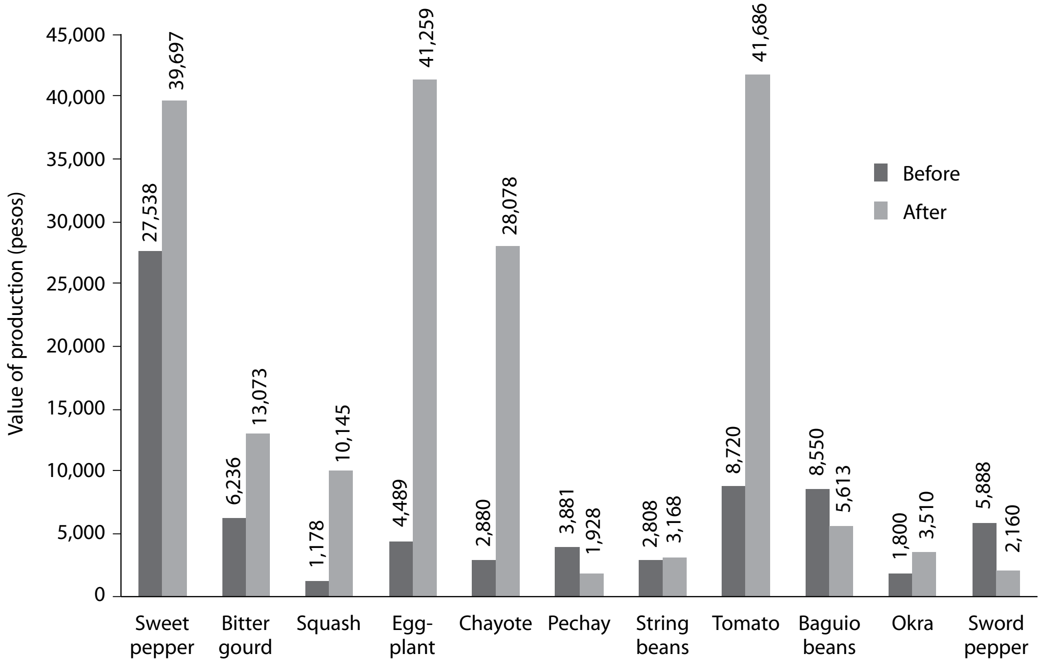

Figure 6. Value of vegetable production before and after clustering

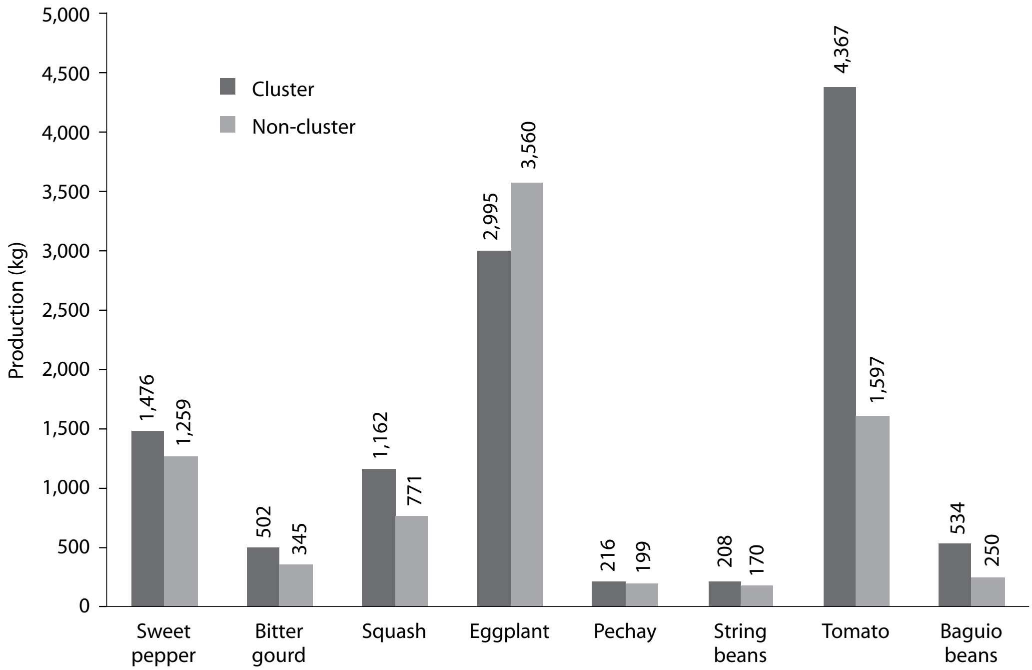

Figure 7. Vegetable production of cluster versus non-cluster farms

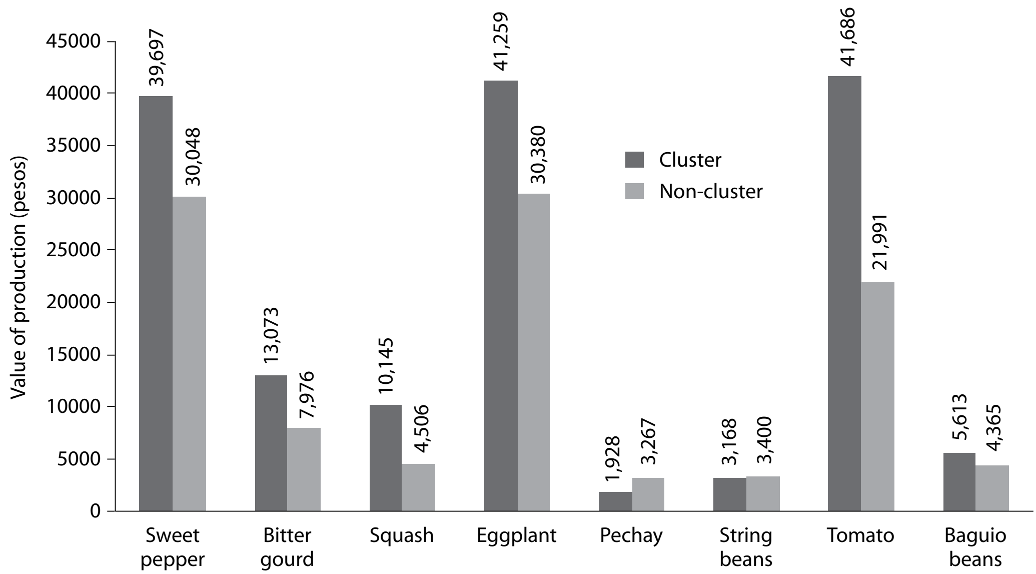

Figure 8. Value of vegetable production of cluster versus non-cluster farms

Impact on prices received by farmers

Clustering benefited farmers by gaining them access to institutional markets, allowing greater market certainty and higher prices for their produce. Figure 9 shows price comparisons for selected commodities in traditional and institutional markets. Institutional market prices were always higher by about 10–25 pesos/kg. Farmers who used to supply their produce only in traditional markets were able to benefit from the premium prices supermarkets pay to their suppliers. At the same time, farmers were still able to sell to traditional markets, particularly the products that did not meet the market specifications of institutional buyers.

Impact on net income of farmers

On average, the net income from vegetable production increased for most vegetables after clustering. Significant increases in net income were recorded for sweet pepper, eggplant, chayote and tomato after clustering (Figure 10). Once again, cluster farms performed better in terms of net incomes from their vegetable enterprise. Comparing cluster and non-cluster farms, the results showed that the net incomes of cluster farms growing eggplant, tomato, sweet pepper and squash were significantly higher than those of non-cluster farms. It is only in pechay production that the non-cluster farms performed better than cluster farms, but the net income from this activity was quite small (Figure 11).

Impact on household income

Looking at the overall household income, the results indicate that the monthly income increased by 47% among the participating cluster farmers: from 4,904 pesos/month before the project to 7,192 pesos/month after the project. Furthermore, the average household income of cluster farmers is higher by about 18% than that of non-cluster farmers (Figure 12). Therefore, clustering has indeed been beneficial to farmers in terms of its impact on household income.

Returns on project investment

Clearly, the clustering process has benefited farmers. These benefits came from a multitude of factors including improvements in production levels, improvements in postharvest production and better prices received. The next question is: What is the return on investment for the project?

Economic impact of the project

To answer this question, a cost–benefit analysis of the project was conducted. The project investment for this research was quite significant, with key

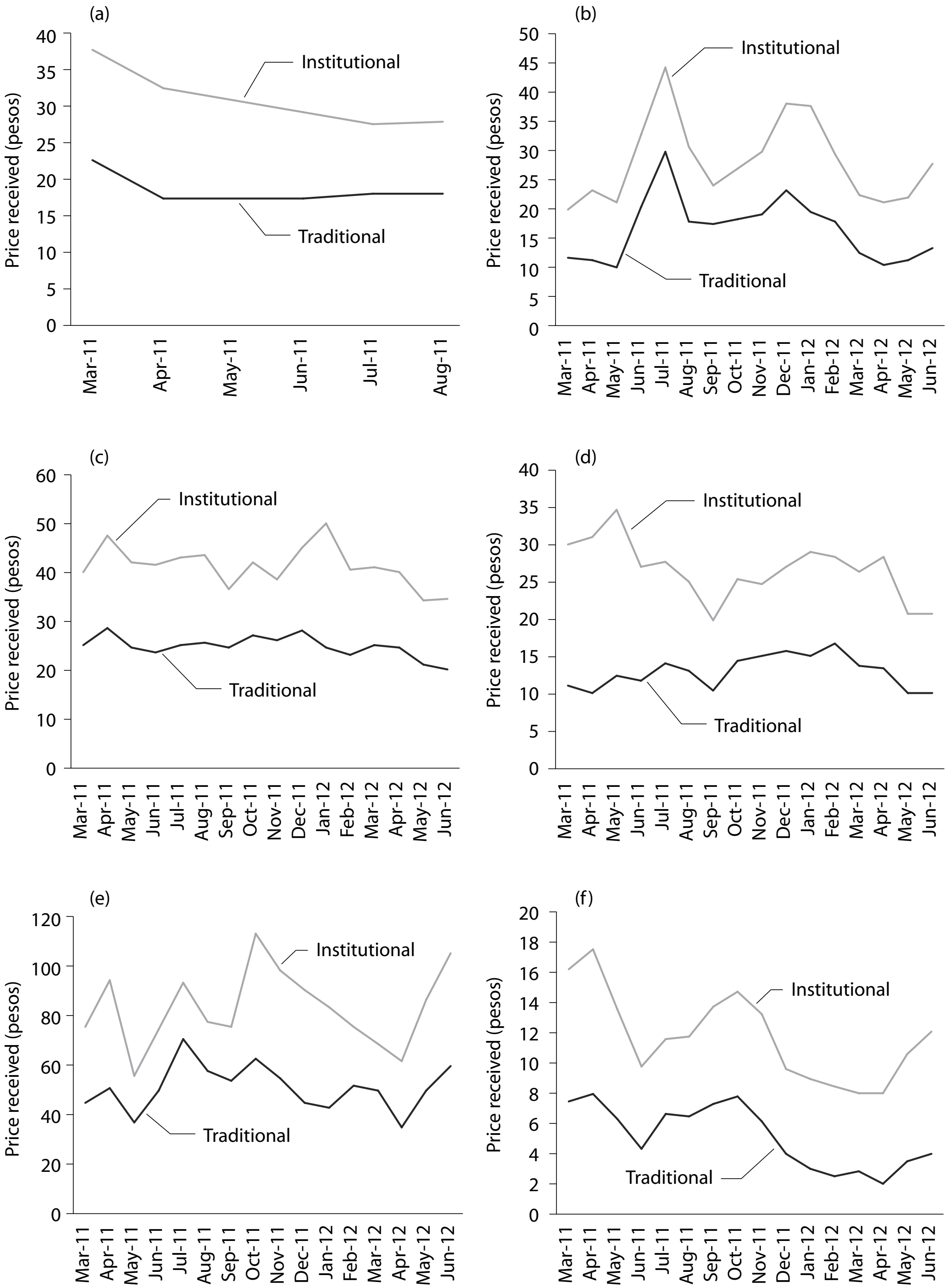

Figure 9. Price comparisons for vegetables sold in institutional and traditional markets: (a) carrot; (b) cabbage; (c) bitter gourd; (d) eggplant; (e) cauliflower; (f) squash

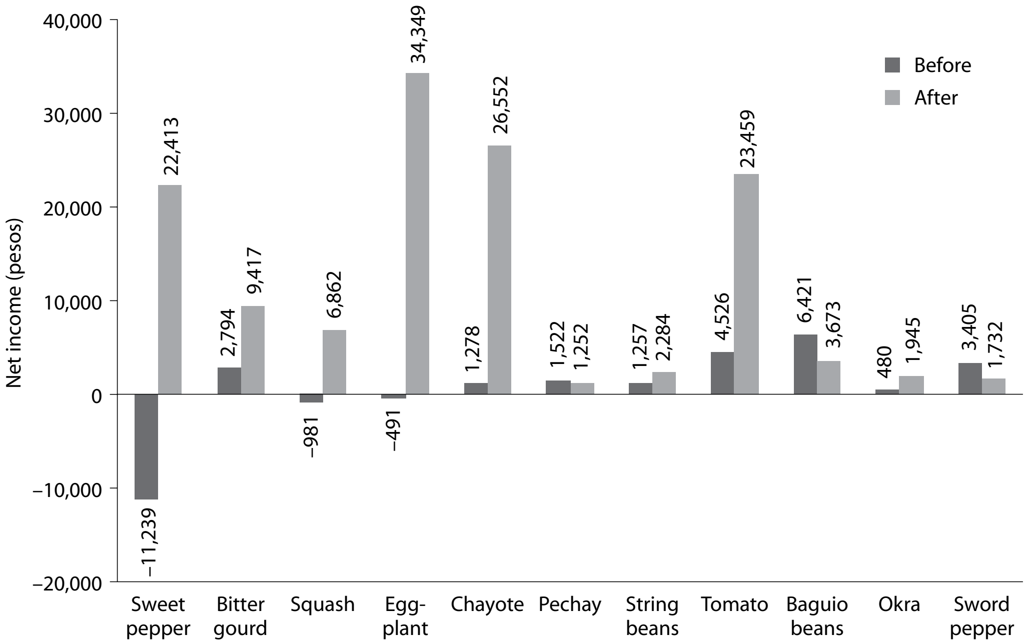

Figure 10. Net incomes from vegetables before and after clustering

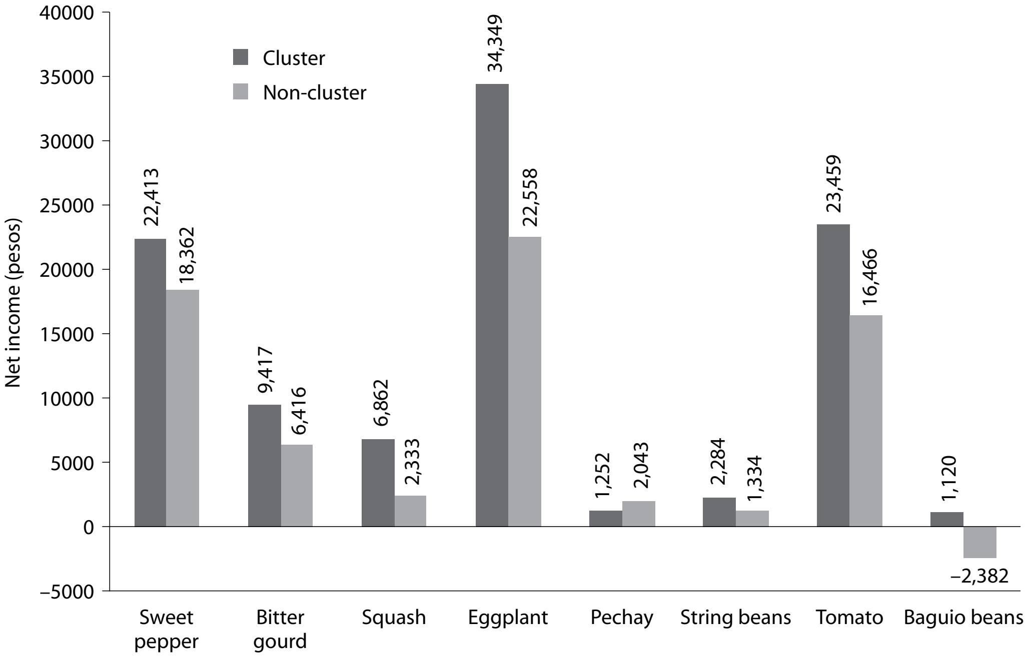

Figure 11. Net income from vegetables of cluster versus non-cluster farms

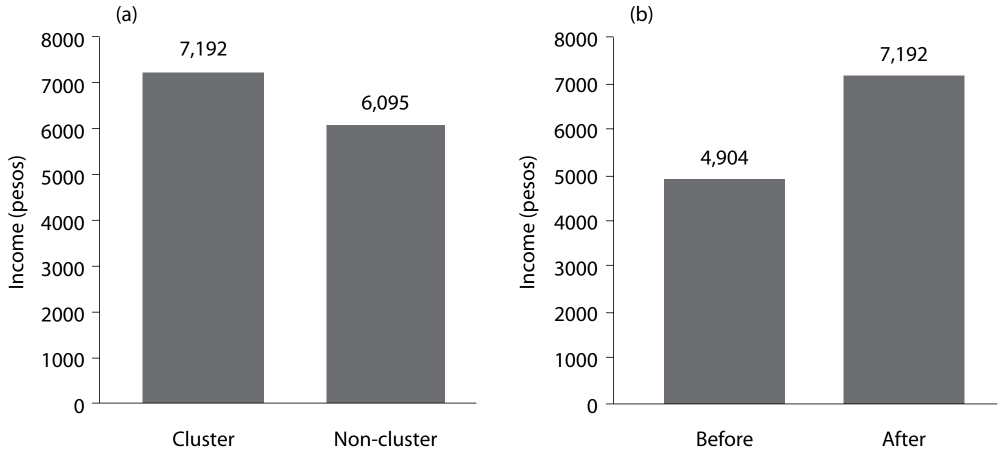

Figure 12. Farm households' average monthly incomes (a) before and after clustering, and (b) average monthly incomes of cluster versus non-cluster farms

contributions coming from ACIAR (A$799,990), Curtin University (A$193,035) and other partners including farmers (A$31,522). The benefits flowed mainly from the changes (improvement) in the net income of farmers directly affected by the project.

Four scenarios were modelled: 1. Farm-level impacts only, under no adoption; 2. Inclusion of spillover effects under no adoption; 3. Farm-level impacts, with adoption; and 4. Inclusion of spillover effects, with adoption.

Under the first scenario (Model 1), it was assumed that no-one adopted the clustering process apart from the project participants (cluster members) and that there were no spillover effects. This base model, therefore looked at only farm-level impacts. The planning period was 20 years and discount rate used was 8%. The results of this analysis showed that the net NPV of the project was 35 million pesos. The IRR was 49% and the BCR 2.5 (Table 2). The analysis further showed that the project will break even on a cumulative discounted basis in year 5.

In the second scenario (Model 2: Spillover no adoption), it was assumed that there will be some spillover effects to the community brought about by employment effects of clustering. As farmers increase their production, they are able to hire other people to help in either farm activities as hired labour or in marketing.

The results of the analysis showed that when spillover effects were taken into consideration, the NPV increased to 47 million pesos, IRR to 78% and BCR to 2.9 (Table 2). The project also breaks even faster; at 4 years on a cumulative discounted basis.

Most technologies or interventions, particularly those that are seen to be successful, are likely to be adopted. In Models 3 and 4 it was assumed that there would be a conservative 5% adoption rate. Model 3 therefore analyses the farm-level impacts of the project assuming 5% adoption of clustering. Once again, the project time frame is 20 years and the discount rate 8%.

The results of this analysis showed that NPV under this scenario was 107 million pesos, IRR was 82% and BCR 3.8. Meanwhile, for Model 4: Spillover with adoption, NPV was 134 million pesos, IRR was 144% and BCR 4.5. The project is expected to break even at 4 and 3 years, under Models 3 and 4, respectively (Table 2).

Discussion

The results of this study showed that there are significant benefits in clustering. For smallholder growers, the eight-step clustering process facilitated farmers' understanding of markets, thus enabling them to identify and meet institutional buyers' needs, and thereby participate in modern value chains. A critical outcome of clustering for smallholder farmers was the access to modern institutional markets, food processors and supermarkets. By forming clusters, farmers were able to access market information and gain bargaining power with institutional buyers. Their

Table 2. Economic analysis of the project

Indicator	No adoption		With adoption	
	Farm-level only (Model 1)	Spillover (Model 2)	Farm-level only (Model 3)	Spillover (Model 4)
Net present value (million pesos)	35	47	107	134
Internal rate of return (%)	49	78	82	144
Benefit:cost ratio	2.5	2.9	3.8	4.5

collective power for bargaining was useful not only in negotiating prices with buyers; it also enabled them to access farm inputs such as seeds, fertilisers and credit, technologies and external assistance through farm support programs.

Similarly, better understanding of what the market needs helped them to make informed decisions about what crops to grow. They were able to cultivate crops for a market that they knew about. Farmers' awareness of market specifications and standards also improved, and they were therefore able to adjust their product choices and conduct value-adding activities such as sorting, grading and packaging according to buyer specifications, assuring them access to high-value markets. Improved production and post-production practices also resulted in lower farm and postharvest losses and a reduction in the volume of rejected product, thus yielding higher returns to smallholders.

The benefits of clustering, however, go beyond the farm gate. Farmers were not the only beneficiaries in the clustering process. Clustering benefited buyers and institutional markets in terms of these downstream players having direct access to farmers, easier product consolidation and being able to obtain quality and quantity assurances from smallholders. Previously, reliable delivery of supply from smallholder growers could not be assured. Clustering has now made it possible for institutional buyers to obtain the bulk quantities they require, without having to deal with numerous smallholder growers. Furthermore, the shortage in meeting domestic market demand for fresh vegetables can now be better filled by smallholders' produce, with further impacts on food security in rural and regional areas.

There were also social impacts that resulted from clustering. The social impacts of clustering include creation of social capital, improved relationships among producers and empowerment of smallholder farmers.

Benefits to partner agencies were also noted. Farmer clusters enabled efficient use of scarce resources and services when it came to partnering with donor agencies and international development organisations. Partnering with the established clusters allowed development organisations a wider area of coverage in delivering programs and services to farmers. In fact, enhanced production-oriented livelihood, agriculture and natural resource management projects were facilitated through the clusters, resulting in win–win situations for the farmers as well as for partnering agencies. Most importantly with farmer clusters, the continuity and sustainability of interventions are likely to be better.

Summary and conclusion

The evidence from this study showed that the economic impact of clustering is positive. Clustering allowed smallholder farmers to access higher market prices for their farm produce, increased their productivity and improved profitability. In saying this, it must be stressed that grouping farmers per se, will not bring about similar impacts. Rather, the holistic approach of the eight-step clustering process is critical. Clustering's success is brought about by a multitude of factors inherent in the process that give cluster farmers a competitive advantage over non-cluster farmers. The sequential process of the eight-step clustering process, which has merged understanding of markets, building farmers' capacity to respond to market needs, linking farmers' to markets, planning and implementation, are all important for this approach to be successful.

This research proves that investment in agroenterprise development through clustering is worthwhile. Modest adoption almost doubles the return on investment. The collective power of farmers in clustering, coupled with their enhanced capacity, improved the production and marketing capability of cluster farmers. They now have a better understanding of the market they are targeting, and collectively they have better bargaining power, improved production (quality- and quantity-wise), allowing them to achieve higher market prices for their produce, and ultimately achieving increased incomes.

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Exploring opportunities in the institutional market for fresh vegetables in Mindanao and the Visayas

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Abstract

Qualitative interviews with wholesalers and retailers in traditional vegetable markets, supermarkets, food caterers and restaurateurs in Mindanao and the Visayas reveal that the market for fresh vegetables on each island is different. Given the diversity of climate types and topography, population and the household distribution of income, infrastructure development and food culture, both the supply and the demand for fresh vegetables are vastly different between islands and even within an island. While the traditional lowland *pakbet* (tropical vegetables such as squash, string beans, okra and eggplant) vegetables are readily available in most markets, the demand for the temperate chop suey (semi-temperate vegetables such as cabbage, cauliflower, chayote, Baguio beans, broccoli and Chinese cabbage) vegetables, salad greens and *lamas* (spices and herbs, especially garlic, onion, tomato and ginger) differs between market segments.

Four major markets have been identified: the plush market of hotels and resorts that cater to the upper-income population and foreign tourists; the business and budget market that serves the convention market as well as the local tourists; the trade market which serves as the link between institutional markets and wholesale and retail markets; and the traditional retailers who cater to the majority of households in the Philippines. With the exception of a few specialist gourmet vegetables and culinary herbs that are required by only the most discerning buyers, most institutional buyers are readily able to procure the fresh vegetables that they require from preferred suppliers. However, as product shortages do inevitably arise, a significant amount of trade occurs between the different types of institutional markets. In the institutional markets, the majority of the supply and quality problems arise with the higher value, semi-temperate chop suey vegetables, leafy green vegetables and herbs. For those institutional markets that service the five-star tourist hotels and resorts, the up-market restaurants and retailers, the non-availability and poor quality of salad greens (lettuce), fresh herbs and *lamas*, present the greatest problems. Suppliers who are able to respond to these problems will have the greatest chance of exploiting the opportunities arising from serving the institutional markets. Smallholder farmers who want to supply institutional markets must form collaborative marketing groups that are able to negotiate and respond to the requirements of these markets.

Introduction

While the consumption of fresh vegetables in the Philippines has remained at 39 kg/head/annum for several years (FNRI 2003), consumption patterns are changing, especially in urban areas. The increasing income of urban Filipinos has contributed to an increase in the demand for high-value vegetables, including salad vegetables. With a larger number of urban middle- and upper-income Filipinos shopping at supermarkets instead of the wet markets, the modern retailers' share of fresh produce sales

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is increasing. Furthermore, the demand for more ready-to-eat and processed foods is accelerating, with a commensurate increase in the amount of food being consumed through the food service sector and fast-food outlets (Digal and Concepcion 2008).

These shifts in consumer demand suggest that a detailed study of the institutional market for fresh vegetables in the Philippines is warranted. Institutional demand is derived from consumer demand, and shifts in consumer demand lead to changes in institutional demand. To date, the majority of the marketing studies undertaken have focused on Metro Manila, but regional differences in climate and topography will influence the range, quality and quantity of vegetables available from local producers. Differences in household income, tourism, transport and infrastructure will shape both the institutional demand and the extent to which vegetables are traded between regions. This paper explores the institutional demand for fresh vegetables in Mindanao and the Visayas, and provides suppliers and growers of fresh vegetables information on different market segments in the institutional market.

Literature review

Vegetable production and consumption in the Philippines

In 2005, some 604,000 hectares (ha) were allocated to vegetable production in the Philippines, from which some 4.7 million tonnes (t) of vegetables were produced (Macabasco 2008). According to the Bureau of Agricultural Statistics (BAS 2005), the average vegetable yield in the Philippines was 10.65 t/ha. While this compares favourably with other countries in South-East Asia, there is considerable potential to increase yields through improved farm practices and appropriate investments in new technologies (Johnson et al. 2008).

While vegetables are produced extensively throughout the Philippine archipelago, the majority of commercial production is on the main island of Luzon (72%), followed by Mindanao (17%) and the Visayas (11%) (BAS 2010). Being in the tropics, most areas in the Philippines are suitable for growing lowland, tropical vegetables. However, as altitude is able to substitute for latitude, large quantities of high-value semi-temperate vegetables are cultivated in the high elevation areas of the country. Nevertheless, vegetable production in the Philippines is highly seasonal in response to temperature, rainfall, and the frequency and intensity of typhoons.

Vegetable consumption in the Philippines is currently well below the 146–182 kg/head/year recommended by the WHO and FAO. Filipinos, in general, use vegetables only as a small part of a meat or fish dish and very seldom as a meal in itself (Digal and Concepcion 2004). Households that have the more capacity to buy will opt to purchase more meat and fish-based products. However, higher socioeconomic households are more aware of the health benefits of vegetables and tend to consume a greater variety of vegetables, especially temperate vegetables. Even so, fresh vegetables are seldom consumed because they require more preparation[1], they have a short shelf life, and many members of the household, especially young children, do not like their taste. Furthermore, with the increasing trend towards double-income families, convenience food is expected to become more popular in those households where both adults are working and have little time to cook (Concepcion 2005).

The vegetable market in the Philippines

The majority of fresh vegetables in the Philippines (75–85%) are sold through the traditional marketing system, where farmers sell their produce on the spot market to traders, consolidators, vegetable processors and wholesalers in the wet market (Digal and Concepcion 2004) (Figure 1).

In Mindanao, 90% of households prefer to buy from wet markets and *talipapas* (small neighbourhood shops). Consumers generally buy fresh vegetables in wet markets because they offer a greater variety and assortment of vegetables at lower prices than supermarkets. However, increasing income and the changing lifestyles of urban Filipinos have not only contributed to an increase in the consumption of high-value vegetables, but have also played a role in the proliferation of fast-food outlets and one-stop shopping malls and supermarkets, as high-income consumers demand greater convenience (Concepcion 2005).

[1] Philippine recipes using vegetables require peeling, slicing and dicing, which is added work for the cook.

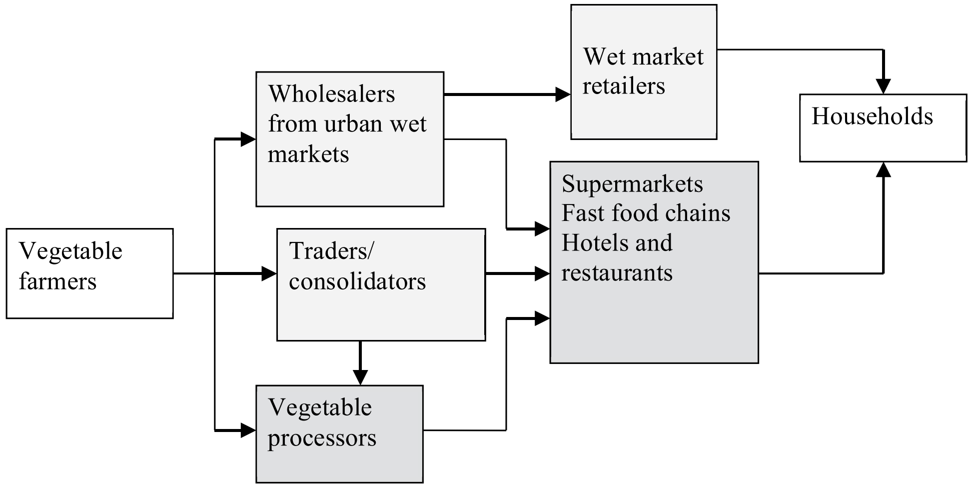

Figure 1. The vegetable supply chain in the Philippines

Methodology

According to Kotler et al. (2003), the institutional market can be differentiated from the consumer market on the basis that: (i) the customer is an organisation that purchases the product to facilitate the production process, to incorporate or use the product in the production of some other product, or to resell the product; (ii) products are purchased by organisations to meet the anticipated needs of their customers (derived demand); (iii) objective criteria such as product quality, reliable delivery and competitive price drive the choice process; (iv) many individuals are often involved in the purchase decision; and (v) the purchasing process often takes a long time and involves extensive bargaining and negotiation.

For this study, information was collected through key informant interviews with buyers from the fast-food industry, executive chefs, food service operators, wholesalers, consolidators and retailers from the cities of Cebu, Bacolod, Iloilo, Dumaguete, Tacloban and Ormoc in the Visayas, and Davao City, Cagayan de Oro City and General Santos City in Mindanao. These cities are the main business areas in each region and are more populated than the smaller cities.

Interviews were conducted from September 2008 to February 2009. Eighty-five interviews were undertaken. Key informants were identified in two parallel approaches. Tourist hotels, resorts and restaurants were identified from the internet and, wherever possible, interviews were pre-arranged with the executive chefs or the procurement officers. Upon arrival in each research area, visual inspections were made of those wet markets and supermarkets that sold fresh vegetables. Visits to local government units (LGUs), Department of Agriculture offices and other relevant government agencies and non-government organisations were also undertaken in each city, as a courtesy call, to ask them for any secondary information they may have about institutional markets for vegetables and, if necessary, to seek their assistance in contacting respondents.

Potential respondents were then approached in person and asked if they were willing to be interviewed. In-depth personal interviews were guided by an interview schedule. Interviews were most often conducted at the respondents place of work and, in many instances, while they were at work. During the interview, respondents were asked first to identify the suppliers from whom they purchased fresh vegetables. Described as ‘snowballing’ (Malholtra et al. 2006), this technique is invaluable in identifying potential respondents where there is no existing sampling frame. Where applicable, respondents were also asked to identify their key customers, thereby ensuring that the more significant institutional users were invited to participate in the study.

Following Infante (2003), the vegetables most commonly cultivated in the Philippines were initially classified into three groups: (1) the *pakbet* vegetables are the typical lowland (tropical) vegetables that are an integral part of Filipino cuisine and are widely grown throughout the archipelago. This classification includes squash, bitter gourd, string beans and okra; (2) the chop suey vegetables are the semi-temperate vegetables such as cabbage (*Brassica oleracea* var. Capitata), chayote (*Sechium edule*), broccoli (*Brassica oleracea* var. Italica), cauliflower (*Brassica oleracea* var. Botrytis), carrots (*Daucus carota*) and Baguio beans (*Phaseolus vulgaris*); and (3) the salad vegetables include the leafy green vegetables used in fresh salads and culinary herbs such as basil (*Ocimum basilicum*), thyme (*Thymus vulgaris*), sage (*Salvia officinalis*) and rosemary (*Rosemarinus officinalis*). However, in light of the discussions with institutional buyers and users, it became apparent that a further classification was needed. This additional group embraced the spices and condiments that are frequently used in cooking and included garlic, onions, ginger and spring onion. This group was described as *lamas,* the local term for spices and condiments.

Results and discussion

In the institutional market, fresh vegetables are purchased for resale, for processing or for subsequent incorporation in food service operations. Not unexpectedly, given the many different ways in which the product is used, the institutional market can be segmented on the basis of (a) the role market intermediaries perform in the supply chain, (b) where they are, (c) what customers they serve, (d) the range and volume of products required and the quality specifications required. Four discrete segments were identified, as shown in Table 1.

Based on the responses to the in-depth interviews, attributes were identified for each segment. For each respondent, their role in the chain, and their target market, were used as primary criteria for classifying the respondents into segments. Their characteristics in terms of where they are, range of products marketed, technical quality and volume required, are summarised in Table 2.

Segment 1—the plush market

Segment 1 includes those up-market establishments that need fresh vegetables to service the requirements of foreign and local tourists, and the needs of the local upper-income consumer market. This category includes the five-star hotels and resorts that serve foreign tourists, AB[2] local tourists and business clientele. However, this segment also includes those supermarkets, hypermarts and grocery stores that cater to the AB market. Geographically, institutions in Segment 1 are predominately found in Metro Manila and Cebu, but may also be present in those tourist areas that are most often frequented by foreign tourists, such as Boracay in Iloilo or Panglao Island in Tagbilaran.

Institutional buyers in this segment require the widest range of vegetables and are also the most discerning. In many cases, formal product descriptions exist for each product. In addition, suppliers must operate under an approved food-safety program, which may or may not be third-party certified, and there is often a requirement for producers to adopt sustainable farming practices.

In terms of the range of products, Segment 1 purchases mostly salads and herbs and the semi-temperate vegetables (chop suey) vegetables. While some of them venture to serve the *pakbet* vegetables, these are provided to foreign tourists because they are Filipino vegetables and may therefore be perceived as exotic. Businesses in this market require their vegetables to be delivered to them cleaned, trimmed and, if applicable, peeled.

Within this group, there is the greatest understanding of the concepts of organic and hydroponic vegetables. Geographically, Bacolod City is unique in the sense that there is a greater awareness among the institutional buyers of organic products. The City Agriculturist Office has encouraged producers to engage in the use of organic inputs, although there are no national or internationally certified organic producers.

Segment 2—the business and budget market

Segment 2 is composed of the business hotels and resorts that cater to business, government and non-government institutions, who conduct seminars and conventions on a budget, and provide special functions for the AB and C1 households, such as weddings, debuts and anniversaries. These institutions purchase the same types of vegetables as Segment 1, but they are far more conscious of price. To the

[2] Industry practice in Philippines marketing classifies households according to socioeconomic status: AB for upper class, C1 for upper middle class, C2 for middle class, DE for lower class.

Table 1. Number of respondents for each segment

City	Segment 1: Plush market	Segment 2: Business and budget market	Segment 3: Wholesalers and consolidators	Segment 4: Mostly wet market retailers	Total
Cebu City	9	9	5	2	25
Bacolod	1	1	6	1	9
Iloilo City		4	2	2	8
Dumaguete		1	4	4	9
Tagbilaran	2	7	7		16
Ormoc		2		2	4
Tacloban		1	1	1	3
Davao	2	2			4
GenSan			3		3
CDO		1	2	1	4
Total	14	28	30	13	85

Table 2. Attributes of each segment

Attribute	Segment 1: Plush market	Segment 2: Business and budget market	Segment 3: Wholesalers and consolidators	Segment 4: Mostly wet market retailers
Who they are	• Up-scale hotels, resorts and restaurants • Some supermarkets	• Business hotels • Mid-priced resorts • Supermarket chains	• Restaurants with catering • Wholesalers–consolidators	• Wet market retailers • Carenderia (buffet restaurants) • Canteens
Customers they serve	• Foreign tourists • Class AB[a] Filipinos	• AB and C1 • Expatriates • Budget tourists • Convention market	• Segments 1, 2 and 4 (for the consolidators) • C1 and C2 • Government agencies • Local businesses and non-government organisations	• C2 and DE
Geographic concentration	Metro Manila, Metro Cebu, Boracay, Panglao	Urban centres	Widely dispersed across the country, especially in urban and urbanising areas	Widely dispersed across the country
Technical quality	High	Medium to high	Low to high	Low, very price conscious
Range of products	Very broad: salads, herbs and spices, chop suey, some tropical vegetables, lamas	Narrow: each institution has a select repertoire of vegetable needs—chop suey, pakbet	Broad range, in order to supply their markets; salads, herbs and spices, chop suey, pakbet, lamas	Narrow: some temperate, mostly pakbet, lamas
Volume required	Low volume, but wide assortment	Medium volume; more than segment 2 but less than segment 3	Large	Largest volume required, of a narrow range of products

[a] Industry practice in Philippines marketing classifies households according to socioeconomic status: AB for upper class, C1 for upper middle class, C2 for middle class, DE for lower class.

maximum extent possible, they will endeavour to purchase the best-quality vegetables for the lowest possible price.

The food service institutions in Segment 2 are very flexible in the menus they offer. Most, if not all of them, base their menus on availability. If, for any reason, a product is not available, a substitute will be offered or the customers will simply be advised, at the time that they place their order, that the product is not available. They rarely serve salad vegetables, but need a regular supply of chop suey and *pakbet* vegetables.

Segment 2 includes most of the mainstream supermarket chains that offer fresh produce. The modern retailers mostly service urban markets, where their target consumers belong to the AB and C1 social classes. These consumers highly value the convenience of purchasing all their needs from one shopping area. In the large urban centres such as Cebu, greater numbers of household consumers are purchasing fresh vegetables from supermarkets rather than the wet markets. Supermarkets such as SM, Rustans and Robinsons fall into this category.

Generally, the institutional buyers in Segment 2 require only small volumes of a narrow range of vegetables. Depending on their clientele, the balance between the chop suey vegetables and *pakbet* vegetables may differ. The demand for salad greens and herbs is generally small. Invariably, their decision to purchase is ruled by availability and price. They have knowledge of special attributes such as organic, hydroponic or Fairtrade vegetables.

Segment 3—the trade market

Segment 3 includes the wholesalers–consolidators who purchase fresh vegetables from the production areas, or as near to a production area as they can get. Wholesalers–consolidators need to source the products that their downstream customers require. Their customers include both traditional and modern retailers, food-processing firms, and hotels and restaurants.

Segment 3 is widely dispersed in both urban and rural areas across Southern Mindanao. Its participants require the broadest range of vegetables in order to service their customers varying needs. The better quality produce is sold to Segments 1 and 2, while the lower quality produce is delivered to other institutional markets.

This segment purchases fresh vegetables based primarily on availability. However, while product will be sourced from wherever it is the most abundant, buyers will endeavour to purchase the best quality available at the lowest possible price. To that end, buyers often have an extensive network of contacts throughout the country. When fresh vegetable prices either rise or fall as a consequence of changes in supply, surplus product will rapidly move into or out of a region, to capitalise on the higher prices available. The extent and the speed to which fresh produce is redistributed is very much dependent upon the availability of transport, the frequency of flights (or sailings), the prevailing weather conditions (typhoons) and the nature of the long-term relationships between buyers and sellers.

Segment 4—the wet market

Segment 4 accounts for 75–80% of the retail sales of fresh vegetables in the southern Philippines. Households, restaurants and many hotels purchase the fresh vegetables that they require from retailers in the traditional wet markets. In cities like Dumaguete, Iloilo, Ormoc, Tacloban, Davao, Cagayan de Oro and General Santos, institutional buyers also purchase their vegetables from the wet market, for the volumes that they require are often too small for the wholesalers and consolidators to deliver.

Small eateries and carenderias (buffet restuarants) across the country are also part of Segment 4. They cater to the C2 and DE market segments, especially the rank and file who need to have lunch close to their place of work. Quality requirements are not very strict and the range of products narrow. Only tropical vegetables, usually the *pakbet* kinds of vegetables, are purchased. Some of these eateries and carenderias purchase pre-cut vegetables because they are lower in price and there is little to no wastage involved in preparation. Pre-cut vegetables command lower prices as they are usually the salvageable portion of damaged product.

In this segment, the demand for temperate chop suey vegetables is low compared with segments 1, 2 and 3, and the demand for salad greens and herbs is virtually non-existent. For this segment, price is the most important purchase criterion. Consequently, there is no recognition of hydroponics, organics or Fairtrade.

Sources of supply

In any analysis of vegetable supply chains in the Philippines, it is essential to differentiate between the *pakbet* and chop suey vegetables. The *pakbet* vegetables include those traditional, tropical lowland vegetables such as bitter gourd (*Mamordica* *charantia*), string beans (*Phaseolus vulgaris*), eggplant (*Solanum melongena*), okra (*Abelmoschus esculentus*), and squash (*Cucurbita* spp.) that are often intercropped with rice and maize and are an integral part of subsistence diets (Johnson et al. 2008). Not unexpectedly, most areas in the Philippines are well suited to growing tropical lowland vegetables.

With the notable exception of tomato, the trade in these products occurs primarily between proximate rural and peri-urban areas and the immediately adjacent urban centres. There is very little inter-island trade because of the widespread availability of these products and, except for natural catastrophes such as floods and typhoons, the high costs of transport will make the product too expensive for lower income consumers to purchase.

In the tropics, altitude is able to substitute for latitude. Hence, the production of chop suey vegetables occurs primarily in the highland regions. In the highlands, the production of the semi-temperate chop suey vegetables is very much dependent on the climate in the region. As there is much variability in the climate types and in the intensity and duration of the typhoons across the archipelago, farmers often plant semi-temperate vegetables in the expectation that typhoons elsewhere will significantly reduce the quantity of fresh vegetables available. Given the high incidence of typhoons in Luzon from June to November, semi-temperate vegetable growers in Mindanao have traditionally planted tomatoes and cabbages to meet the anticipated shortfall in production. Not unexpectedly, there is a high element of risk, for in those seasons when the typhoons do not come, the supply from Benguet, Mountain province in Luzon, does not diminish and prices do not increase.

Nevertheless, to meet the needs of an emerging middle class and the increasing number of foreign tourists, the institutional demand for chop suey vegetables, salad greens and *lamas* is increasing. Whereas the production of *pakbet* vegetables increased by only 1% between 2006 and 2007 (BAS 2009), the production of chop suey vegetables increased by 42%. Since many of the islands in the Visayas are currently unable to produce sufficient quantities of chop suey vegetables, there is a significant inter-island trade.

While many factors facilitate, or alternatively constrain, the trade, in the first instance, chop suey vegetables, salad greens and *lamas* will be imported only where there is a demand. The demand will come primarily from the upper-class hotels, tourist resorts and those modern retailers and food manufacturers catering to the upper AB Filipinos, foreign tourists and expatriates.

The sources of fresh vegetables and the ease with which the products move between the islands and subsequently become available, are very much dependent upon the frequency with which both boats and aircraft arrive. They are also affected by the level of infrastructure, in terms of the extent to which the islands are connected by a road system, and the availability of cold storage facilities. In Leyte, for example, boats sail daily from Cebu to Ormoc, and from Metro Manila it is an 18-hour road trip, via Samarto, Tacloban. However, from Northern Mindanao, the boat sails only once per week. With the opportunity to renew supplies almost daily, there is little need for traders and market intermediaries to invest in cold storage. Consequently, the major suppliers of semi-temperate vegetables are from Metro Manila. They source their products from Benguet and Cavite (northern and southern provinces of Luzon) and may even offer products imported from China and India.

From Cebu, product may be sourced from local producers, and/or from producers in both Luzon and Mindanao, for Cebu is the major transport hub for the Visayas. Hence, while traders and market intermediaries in Leyte may identify Baguio/Benguet and/or Cebu as the places from which they source the majority of their fresh vegetables, there is no guarantee that the product actually originated from those areas.

In sourcing the fresh vegetables that they require, the majority of institutional buyers rely upon preferred suppliers to provide them with the quantity and range of product that they need. When supplying to the supermarkets, high-class hotels and resorts, preferred suppliers must not only meet defined quality specifications, but the prices for products that meet specifications should preferably be established 1 week in advance. Significant penalties may also be imposed upon those suppliers who fail to deliver on time or the quantities specified.

However, in most cases, given the unpredictable nature of supply in the Philippines, although end customers may have a preference for fresh vegetables grown in a specific area or region, wholesalers and consolidators are free to purchase from any source that offers the best quality product at the most competitive price. With the advent of modern telecommunication systems and the enduring long-term relationships that have been established between buyers and their preferred trading partners, buyers are readily able to determine, for each alternative source of supply, the prices for those products that meet their specifications.

Furthermore, knowing what their customers want, preferred suppliers will often advise their customers when they have an abundance of good quality product or when they see an opportunity for their customer to make additional profit by importing product at a lower cost. As a result, where there is an alternative source of supply and an opportunity for market intermediaries to make additional profit, product will move into that market, thereby constraining the price.

When product shortages arise, as is inevitable, and delays in transport make it impossible for product from an alternative source to fulfil the demand, buyers often find that it is necessary to purchase elsewhere. Hence, a significant amount of trade occurs between the different types of institutional market. For example, when preferred suppliers are unable to deliver what the restaurants want, they often source the product from supermarkets. Furthermore, although a buyer may have a preferred supplier, most buyers have more than one supplier. This greatly extends their marketing reach, thereby increasing the possibility of securing the products required, while simultaneously providing a means by which the quality of the product and the price offered can be readily compared with alternative offers.

Seasonality of supply

From the many interviews conducted with institutional buyers in Mindanao and the Visayas, neither the seasonality of supply nor any seasonality in the demand presented major problems: most restaurants and food service operators simply adjusted their menus, either formally or informally, to cope with non-availability.

For the five-star hotels and tourist resorts, their margins were sufficiently high to enable them to import, either directly or indirectly via Metro Manila. Highly perishable products such as salad greens, fresh herbs and *lamas*, were often consigned by air. In other instances, because of the long-term relationships that had been established with preferred suppliers, any problems with the non-availability of product were simply referred to the concerned supplier to resolve under the terms of their contract, irrespective of the cost to the supplier.

However, many of the executive chefs spoke of particular problems associated with the supply of very specific ingredients, many of which were required for their signature dishes. In some instances, executive chefs relied upon friends and family to source the product overseas. In other instances, because of the non-availability of the fresh product, executive chefs resorted to the use of either imported canned product (tomatoes) or dried product (herbs). For those hotels catering to the lower socioeconomic classes, if fresh product was not available, patrons were simply advised of this at the time they placed their order. In this highly price sensitive market, chefs and cooks made no attempt to substitute canned or frozen product when the fresh product was not available. However, this is not to say that they did not use canned product because, in many instances, products such as champignons, corn kernels and green peas were mostly available in cans.

For food processors and manufacturers, dried product was preferred. Not only was it cheaper, but also readily available, non-perishable and easier to store. These dried products were used in the manufacture of instant noodles, ready-to-eat canned products and pastries. In one instance, where a food manufacturer preferred to use fresh product, all three products (carrots, capsicums and potatoes) had to be available in the desired quantities (joint demand). A shortage of one product would, of necessity, result in a lower demand for the other two.

However, for those food processors supplying fresh product to the fast-food chains, there is no substitute. Companies like Jollibee, KFC, McDonalds and Pizza Hut must have an assured supply of fresh lettuce, coleslaw, onions and tomatoes. Cognisant in the knowledge that seasonality does influence both the quality and availability of the product, producers and consolidators in different areas of the country were, under a variety of different mechanisms, subcontracted to deliver a specified quantity that met predetermined quality specifications. Where local producers were unable to deliver, usually as a result of catastrophic weather, imports provided an alternative source of supply.

Terms of trade

Given the importance of price in the Philippines vegetable industry, it is no surprise to find that, despite the importance of preferred suppliers, most institutional buyers had entered into some competitive bidding arrangement with two or more alternative suppliers. In supplying the modern retailers, it was usual practice for the supermarkets to invite a number of preferred suppliers to quote the prices at which they could deliver a specified volume of produce of acceptable quality standard to either a central warehouse or directly to individual stores. In submitting their offer, prices were fixed, usually for a duration of 1 week, after which the successful supplier must lodge their bid again for the following week. Suppliers who, for any reason, failed to fulfil their contract were simply not invited to submit a bid. Hence, for any potential supplier, the first hurdle that they had to overcome was to be listed as a preferred supplier.

While food safety is yet to become mandatory in supplying most of the supermarkets, many of the five-star hotels and tourist resorts operate under one or more quality assurance systems. Their preferred suppliers are often required to have hazard analysis and critical control points (HACCP) certification. However, in the Philippines, as HACCP certification has not been widely accepted at the wholesale market level and is even less well accepted at the producer level, buyers must either rely upon the reputation of the wholesaler–consolidator or visit the producer themselves to see how they operate.

Executive chefs in the five-star hotels and tourist resorts will often themselves make the purchasing decisions. In supplying the five-star hotels and tourist resorts, even though potential suppliers have been issued with a copy of the prescribed standards, these standards are highly subjective and very much dependent on the quality of the fresh produce available. When there is a shortage, the standards may be relaxed in order to secure a sufficient quantity of produce to meet the anticipated demand but, when supply is plentiful, the standards will be rigorously enforced. Suppliers therefore must bring more products than they expect to sell, to enable the executive chef to make their selection. That product which is selected must then be washed, any protective packaging removed and the outer leaves stripped before the produce is permitted to enter the kitchen.

So as to minimise their exposure to the financial risks associated with product losses arising from poor quality and postharvest handling, and short shelf life, many of the supermarkets have invited concessionaires to manage and operate their in-store, fresh produce departments. In accepting the offer, it is the concessionaire's responsibility to stock the shelves, to wrap and price the product, to prepare any pre-cut vegetable mixes, salad mixes etc., and to remove any unsold product. In return, the concessionaires pay a predetermined commission or percentage of sales to the supermarket. As it is not uncommon for two or more concessionaires to operate within one store, differences in both the quality and price may easily confuse consumers.

The terms of trade under which potential suppliers must operate in selling to the five-star restaurants, tourist resorts and supermarkets may present a major impediment for smallholder producers to market their goods to institutional buyers. As it is not unusual for payment to be made 30–90 days after delivery, accommodating the need for cash can become a major problem. Furthermore, in order to transact with many of these institutional buyers, suppliers must have certificates of registration and thus the authority to issue official invoices and receipts.

Unfulfilled needs

The majority of the problems reported arise with the higher value vegetables: the semi-temperate chop suey vegetables (cabbage, carrots, cauliflower and broccoli), leafy green vegetables and herbs. Despite the significant movement of fresh produce from the highland areas of production to the lowland areas of consumption, and between different islands and climatic zones, the supply is often insufficient to meet the demand. Although such shortages are only temporary, it is apparent that the greater the distance and the more time required to transport the produce, the greater the problem. This is a direct consequence of the lack of appropriate infrastructure and poor postharvest handling and transport.

Nevertheless, seasonality is an issue. During the hottest months, in the absence of appropriate cold storage and refrigerated display cabinets, leafy green vegetables wilt very quickly. As high temperatures are often accompanied by high humidity, rots and moulds proliferate during the wet season, and the incidence of insect pests (grubs and worms) rapidly increases.

For those institutional markets that service the five-star tourist hotels and resorts, the up-market restaurants and retailers, the non-availability and poor quality of the salad greens (lettuce), fresh herbs and *lamas*, present the greatest problems. As these products must be available on the menu or buffet, buyers often go to great lengths to assure supply through either purchasing from multiple suppliers or importing. For this market segment, other product opportunities identified included baby or gourmet vegetables, mushrooms, and vegetables such as asparagus, celery and leeks, which are not always available in sufficient quantities. Furthermore, it was not unusual to find multiple specifications for the one product in this market segment. For example, large potatoes (250–350 g) may be required for boiling and subsequent mashing, whereas small tubers (50–60 g) may be required where the potatoes are served whole and perhaps dressed with fresh herbs. If the restaurant offers baked potatoes, not only must the tubers be large (350 g) but often imported (US Russet Burbank) as the potatoes that are grown locally (e.g. Granola) are unsuitable for baking and chipping. Large, red, ripe tomatoes may be required for the preparation of pasta sauces, but cherry tomatoes are utilised in salads.

While many of the quality problems can be traced back to the lack of specifications, it is apparent that the specifications often differed among the actors in the supply chain. While wholesalers and consolidators want green tomatoes, the consumers, cooks and chefs want red, ripe tomatoes. As the majority of tomatoes in the Philippines are harvested green so that losses in the supply chain are minimised, the taste of the product is often compromised. Hence, for those market segments that are able to pass on the additional costs, opportunities are emerging for niche products such as vine-ripened tomatoes, which can be readily differentiated in the market by leaving the calyx attached.

At the other end of the market, few institutional buyers raised any issues with regard to either the sufficiency of supply or the quality of the traditional *pakbet* vegetables. As these products are widely available from the peri-urban growers around most urban centres, the product needs to be transported only a short distance. Furthermore, supplies can be renewed almost daily. In this market segment, that product that begins to deteriorate because it has not been sold or has become infested with an insect pest or disease, can be cut and incorporated into a variety of vegetable mixes which, other than cooking, require minimal to no preparation.

Differentiating the offer

The vast majority of the institutional buyers interviewed were able to associate one or more vegetables with a particular region or area of production. Not unexpectedly, Baguio City in the northern part of Luzon was primarily associated with the semi-temperate chop suey vegetables: broccoli, cabbage, carrots, cauliflower and potato. It was also evident that many buyers preferred to purchase fresh vegetables from Baguio on the basis that they were of better quality, they often looked better and, in some instances, the product had a superior taste. In particular, there was a marked preference for the 'Scorpio' cabbage, which was perceived to have a sweet taste, whereas the drumhead cabbage from Mindanao was often bitter.

Mindanao was most often recognised as an alternative source of supply for a range of chop suey vegetables: broccoli, cabbage, carrots, cauliflower, potatoes, sweet pepper and tomatoes. In the Visayas, product from Mindanao was preferred because of its lower price and more widespread availability. In some markets, broccoli from Cagayan de Oro was preferred because of the manner in which the stems had been trimmed, the heads wrapped in tissue paper and carefully packed. Indeed, the manner in which the product had been packed often provided a signal to buyers of the origin of produce. For example, in Davao, pink bags were often associated with product from Kapatagan, Digos, Davao del Sur.

In many instances, buyers did not associate the quality of the fresh vegetables with the region in which they were grown, but rather the place from which it had been shipped (Cebu) or dispatched (Metro Manila). Product from Cebu was often perceived to be fresher because it was closer, but product may have been sourced initially from Bacolod, Canlaon or Mindanao, and even from Metro Manila. As the product was often repacked by wholesalers and consolidators in the Carbon wholesale market, it was seldom possible to identify the original source.

Imported products (garlic and onions) were most often associated with Metro Manila rather than the country of origin. Even for the five-star hotels and tourist resorts that often found it necessary to import product, the country of origin was largely irrelevant, providing that the product met their specifications and was consistently available.

In purchasing fresh vegetables, institutional buyers generally believe that the product is safe to eat. However, fresh vegetables are often contaminated with soil, heavy metals, chemical residues and pathogens. While many buyers in Segment 1 require their suppliers to introduce quality assurance systems as a means of ensuring that they have taken 'all reasonable steps' to assure consumers that the food is safe to eat, producers are unlikely to receive a price premium. If they wish to supply these institutional buyers, they must either operate under a third-party-certified quality assurance system or risk exclusion from the market.

In any discussion of organic produce in the Philippines, it is important to make the distinction between that product which is certified and that which is not. In much of the Philippines, organic refers to a low-input method of production that uses natural inputs including animal manures, composts and vermicasts as a means of reducing the volume of chemical fertilisers used, and fermented plant juices and other biological control measures as a substitute for pesticide application. However, this system of production does not totally preclude the use of chemical fertilisers or pesticides: farmers choose to sacrifice yields in the interests of reducing costs (by using organic inputs) and thus their exposure to financial loss as a result of crop failure or inordinately low prices in the market is minimised.

Within the Philippines, although consumption of organic produce is widely perceived to be healthier, the majority of institutional buyers are unwilling to pay any price premium to procure organic produce. For those businesses supplying the traditional wet market, local restaurants and carenderias, and even large, multinational food processors, as price is the key purchasing criteria, they are unable to pass on the additional costs to consumers. However, among the five-star hotels, tourist resorts and those retailers who supply fresh vegetables to the wealthy AB consumer group, potential premiums of between 10–50% may be available for organic produce.

Conclusion

This study of the institutional market for fresh vegetables in Mindanao and the Visayas was primarily undertaken to assist smallholder vegetable producers and the market intermediaries that they supply to identify new, potentially high-value markets. In the past, vegetable producers in Mindanao have planted crops in the anticipation that during the typhoon season (June–November) the supply of fresh vegetables to Metro Manila from Baguio and Southern Luzon would be seriously compromised. For some products, such as tomatoes, reliance on this window of opportunity continues to be profitable. However, for other fresh vegetables, relying on the typhoons is a risky proposition. When the typhoons fail to strike with their usual frequency and ferocity, there is a marked increase in the volume of fresh vegetables available, with a commensurate reduction in price. For those smallholder farmers who draw the majority of their income from the sale of fresh vegetables, low prices threaten their very livelihoods. Furthermore, as the household needs a regular cash flow, vegetable crops must be cultivated all-year round. So as to improve the financial situation for smallholder farmers, alternative markets that have an ongoing need for fresh vegetables need to be explored.

Smallholder producers are likely to find that they will have the greatest opportunity in the market for those crops that are the most labour intensive and offer few economies of scale. This will include most of the vegetable crops that require hand-harvesting and sorting, especially baby or gourmet vegetables which often require daily harvest. For a similar reason, where end customers have very specific requirements, such a vine-ripened fruit, where the product must be peeled or pre-cut, or where the product is required in only small quantities, such as many of the herbs, smallholder farmers may have a competitive advantage. However, such niche markets exist only where there are customers who have the need and are willing to pay.

For smallholder producers to participate in modern institutional markets, it is widely recognised that one of the first steps is to encourage smallholder producers to form collaborative marketing groups. Acting independently, few smallholder farmers in the Philippines will have the capacity to engage directly with institutional buyers. Most will be forced to transact indirectly through traders, wholesalers and consolidators in the traditional marketing system. Without any direct link to end customers, producers will remain largely unaware of customer requirements in terms of volume, quality specifications, the range of product required and any alternative sources of supply. Consequently, since they do not know what to plant, when to plant, at what stage to harvest and how it should be graded and packed, smallholder producers are unable to add value. They thus remain largely price takers.

However, the formation of collaborative marketing groups in and of itself seldom results in any marked improvement in prices. The critical dimension is engagement, not only with the end customer, but also with the various support agencies that are able to provide farmers with the technical skills they require. To meet the needs of end customers, new, more appropriate varieties must often be planted and, in some instances, entirely new crops. Farmers need access to production inputs, microfinance, market information, and transport and logistics. Fortuitously, collaborative marketing also improves access to these resources, enabling smallholder producers to engage more equitably with institutional buyers.

Through collaborative marketing, smallholder farmers have the capacity to maintain the continuity of supply, to grade and sort the product to the buyer's specifications and have sufficient volume of product to negotiate more favourable transport costs. However, without formal incorporation and thus the ability to issue invoices and receipts, many groups will remain isolated and unable to access high-value markets. For many institutional buyers to accommodate smallholder farmers, changes have to be made to their procurement and payment systems and, because of this, many will choose not to engage with smallholder farmers.

Although this study did identify a number of opportunities to supply non-traditional markets in Mindanao and the Visayas, including hotels and tourist resorts, fast-food outlets and supermarkets, few customers reported any real difficulties in sourcing the fresh vegetables that they required. With the exception of imports, this means that market share can be gained only at another grower's or supplier's expense. Furthermore, because individual customer's needs and terms of trade are different, and prices are highly variable, farmer groups and or their appointed distributors will need to personally engage the intended buyer. This may take some time, for in order to make the first sale, the buyer needs to be convinced that they are receiving a superior offer. While quality, reliable supply and a competitive price are the criteria most often used in making the decision to purchase (Batt 2006), the importance of each criterion will differ among buyers depending upon the ultimate consumer's needs.

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Addressing quality impediments in fresh vegetable supply chains in Mindanao

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Abstract

Quality, price and reliable delivery are regarded as the key criteria by which buyers evaluate potential suppliers. To supply the emerging institutional market, smallholder vegetable producers in the Philippines must form collaborative marketing groups to secure a sufficient volume of good-quality produce. Even then, the ability of smallholder producers to meet the needs of their downstream buyers will be limited by external (environmental) factors, production and marketing constraints, and infrastructural and institutional impediments. To improve productivity and quality, technical support and capacity building are required to enable smallholder producers to engage with downstream buyers. Where necessary and where farmers have the capabilities, new crops are being cultivated to extend the product range. Some clusters have chosen to adopt protected cropping structures, while others are adopting low-input farming systems as a means of reducing risk. To better meet the needs of institutional buyers, farmers are washing, grading and sorting the produce before sale and adopting, where it is profitable, alternative methods of packing to reduce damage in transit.

Introduction

Traditionally, smallholder vegetable farmers in the Philippines have sold the majority of what they produce to itinerant traders who have subsequently graded, packed and transported the produce to wholesale and retail buyers in urban areas (Digal and Concepcion 2008). However, with the increasing desire by supermarkets, food processors and manufacturers to reduce costs and to improve product quality, a greater quantity of product is now being sourced directly from growers. While this shift in procurement strategy creates a number of opportunities for smallholder farmers, it also creates a number of unique challenges.

Quality, price and reliable delivery are generally regarded as the most important criteria by which organisational buyers evaluate potential suppliers (Cunningham and White 1973; Lehmann and O'Shaughnessy 1974; Dempsey 1978; Wilson 1994). Kotler and Armstrong (1999) suggest that suppliers who are the most capable of offering quality products and services, competitive prices, reliable delivery, ethical behaviour and honest communication are the most likely to be rewarded as preferred suppliers. However, other decision variables may include service capabilities, technical support, geographic proximity and performance history. Monczka et al. (1998) add financial capability and stability as key decision variables.

Hutt and Speh (1995) suggest that when industrial buyers purchase a product they also purchase a bundle of services attached to the product. While

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the exact meaning of the term 'service' varies with the nature of the product and the requirements of the buying organisation, service may encompass such things as just-in-time delivery, the provision of technical assistance and support, product innovations, credit arrangements, support for special needs, or advance notice of impending price changes or shortages in delivery. Leenders and Fearon (1993) suggest that preferred suppliers endeavour to find new ways of developing products and services that will allow customers to perform their activities more economically. A preferred supplier will react favourably to unforeseen needs, such as suddenly accelerated or decelerated volumes of business, changes in product or delivery specifications, service problems or any other legitimate request. They will provide technical support and other expertise when requested by customers or whenever the supplier believes it can assist the purchaser to be more competitive.

While price is always an important consideration in the decision to purchase, perceived value is of much greater significance. Anderson and Narus (1999) use value to express, in monetary terms, the functionality or performance of the offer in a given customer application. Fornell et al. (1996) describe perceived value as the perceived level of product quality relative to the price paid. Value is achieved when the proper function is secured for the proper cost. Costs include not only the purchase price of the product itself, but also such variables as transport, handling, product packaging and the various costs associated with the failure of the product due to poor or inconsistent quality and unreliable delivery. Furthermore, there are the various costs associated with the damage to personal reputations from having to deal with customer complaints arising from inferior quality products (Batt 2006).

Quality is a customer determination based upon the customer's actual experience with the product measured against the customer's stated requirements (Feigenbaum 1991). Here it is important to understand that quality does not always mean best; quality means 'fitness for the intended purpose'. In describing a supplier's offer quality, Grönroos (1990) differentiates between technical quality and functional quality. Technical quality describes the customer's specifications. This is a physical description of the product in terms of its size, shape, colour, freedom from pests and diseases, purity (in terms of its freedom from chemical contaminants, pathogenic organisms and genetically modified plants), maturity or freshness and the manner in which the product is packed (Batt 2006). Functional quality describes the way a supplier goes about delivering the product to the customer. While this means being able to deliver the product when the customer wants it, it also involves, by implication, many interrelated activities such as production scheduling, storage and warehousing, logistics, ordering and invoicing (Grönroos 1990). Since most market intermediaries purchase products in the expectation that they will be able to resell them, the timely arrival and efficient receipt of goods is critical to the success of most downstream food manufacturing and retail operations.

Having outlined the principles of industrial purchasing behaviour, this paper seeks to identify the key impediments that prevent smallholder vegetable farmers in the Philippines from fulfilling the needs of their downstream customers and to explore the various strategies that smallholder farmers in Mindanao are adopting to overcome these constraints.

Methodology

Marketing systems in the transitional economies are rapidly transforming. Traditional marketing channels, where prices are determined primarily by supply and demand, are being replaced with coordinated linkages among farmers, food processors and retailers. For the downstream customers and market intermediaries, formal and informal market linkages provide a more reliable and regular supply of product, and greater control over product quality and safety (Shepherd 2007).

While larger farmers can link directly to retailers, food processors and manufacturers, restaurants and fast-food chains, smallholder farmers must first, in most cases, be mobilised into groups, associations or cooperatives in order to supply the market. Such collaborative marketing arrangements typically provide farmers with more market knowledge, more negotiating power and a higher price, which may have a positive impact on farmers' incomes. However, while collaboration facilitates greater access to markets, it also requires the farmers to engage in various value-adding activities such as grading, cleaning, sorting and packing, which may increase costs and time demands.

In order to involve the smallholder farmers directly in the development process, this project used an action research process. It relied primarily on the eight-step process for agroenterprise development, developed by Catholic Relief Services (CRS–Philippines 2007) and implemented by the University of the Philippines Mindanao Strategic Research and Management Foundation (UPSTREAM) with smallholder farmer groups throughout Mindanao.

The clustering approach is a sequential process involving eight steps that prepares farmers to link with the market, assists them to effectively organise themselves into small groups or clusters, and guides them in engaging the market to provide more favourable outcomes, which may improve their income and their livelihood. The process begins with identifying the project site, building partnerships with farmers and other stakeholders such as local businesses, local government and non-government organisations (NGOs), forming a working group and providing a project and cluster orientation to farmers. Step 2 is a participatory process in which the farmers identify the community's resources, products, and production and marketing practices during the basic marketing training and then decide on the product or products that will be the focus of the cluster group (Figure 1).

Step 3 involves the farmers undertaking a market chain study. Farmers are trained how to undertake market chain studies and conduct market visits in which they develop an understanding of the chains for their selected products and conduct negotiations with potential buyers. Step 4 is the cluster formation phase, in which interested farmers form the cluster, select leaders and agree on a basic cluster agreement and objectives. Step 5, or cluster plan formulation, involves planning a planting and harvest calendar for the products of the cluster and deciding on a test-marketing plan. The test-marketing activities in Step 6 involve at least four trial product deliveries. After each delivery, meetings are held to assess performance and adjust the plan to enable improvements.

After the test markets are judged successful, Stage 7 involves planning and conducting a scaling up process. Readiness for scaling up is appraised by the cluster and facilitators against criteria that assess cluster willingness, level of product supply, market performance, management performance and financial trends. Scaling up involves producing more products or additional products to supply existing markets or more diversified markets. The final step of cluster strengthening involves undertaking activities that expand cluster capacity and networks with other clusters and businesses.

In facilitating the process of rural market development, farmers must deal with a number of impediments. In the Philippines these are numerous and multifaceted and include such variables as: the small farm size; the non-availability of high-quality seed; the high cost of inputs; limited access to credit; poor cultural practices; insect and disease

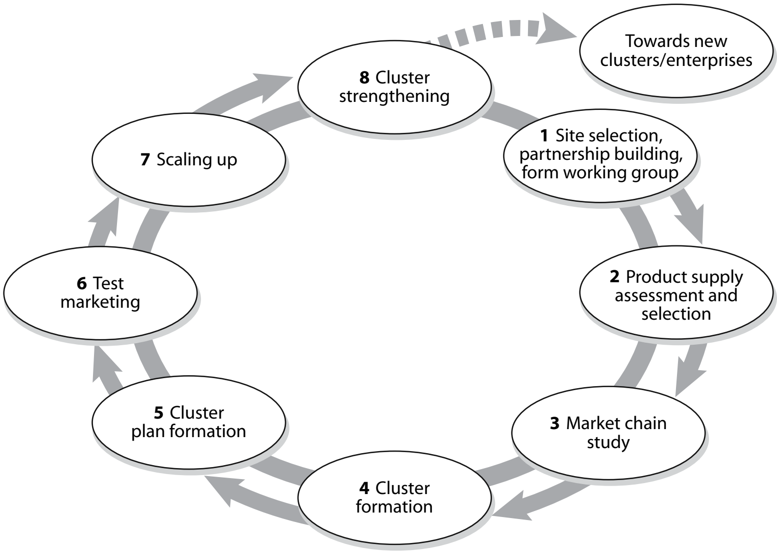

Figure 1. Eight-step process of the clustering approach to agroenterprise development

infestation; limited knowledge of proper postharvest handling methods; limited access to technical information; and limited access to market information (Panganiban 1976; Lantican 2000; Manalili 2000).

Results and discussion

Quality constraints

Arising from this 4-year study of fresh vegetable supply chains in the southern Philippines, the quality impediments identified fall into five groups, all of which are, to some extent, interrelated.

In the external environmental, extreme weather events, where it is either too wet or too dry, will have an adverse effect on plant growth, affecting both productivity and the resultant quality of the harvest. Variations in the weather also influence the incidence and the severity of pest and disease infestation. The extent to which farmers are able to control these outbreaks is somewhat dependent upon their ability to access knowledge and working capital.

Indirectly, the lack of knowledge and capital also contribute to what might best be described as production constraints. The lack of good-quality seed has been identified as a major constraint, especially for potato production in the Philippines (Balaoing and Lazo 1967; Batugal et al. 1988; Crissman 1989). While several attempts have been made to promote and establish a formal seed-certification system in the Philippines, the limiting constraint appears to be the high rate of seed degeneration, because by the time any improved seed reaches the farmers, it is already contaminated with numerous tuber-borne diseases (Schmiediche 1995). Some of the reasons for the high rate of seed degeneration include the lack of appropriate crop rotations, the high incidence of pests and diseases, seed storage constraints and the lack of capital (Batt 2003). Over the duration of this project, vegetable farmers in Bukidnon found that the variety of bitter gourd ('ampalaya') that they were cultivating was very susceptible to disease and cracking. In another instance, vegetable farmers in Davao were dismayed to find that the seeds they had been provided with from the City Agriculturist's Office failed to germinate.

Often as a result of poor-quality seed, farmers endeavour to increase productivity by increasing the use of inputs, especially fertilisers. Contrary to expectations, Rasco et al. (2005) identified that the overuse of fertilisers was common practice among Filipino vegetable farmers. For sweet pepper farmers in both Bukidnon and South Cotabato, inadequate crop rotations resulted in a marked increase in the incidence of soil-borne disease, dramatically reducing productivity. Poor hygiene, particularly with regard to the disposal of reject produce, may also provide a potential source of contagion.

In Step 3 of the CRS eight-step plan for agroenterprise development, farmers visit the wholesale market, engaging with their downstream customers, often for the first time. During this process, farmers invariably encounter a number of marketing constraints, more often than not a result of their lack of knowledge and their inability (if they continue to act independently) to provide downstream customers with a reliable supply of good-quality product. Some of these initial learnings are very elementary: farmers learn that buyers pay different prices for different sizes, different stages of maturity (colour) and different quality (in terms of freshness, shape, cuts and bruises, and level of pest and disease infestation). This should come as no surprise, for the majority of smallholder farmers traditionally sell everything that they can to traders for an all-in price, usually without any washing, grading or sorting.

However, even where the buyers may have some established quality standards, the extent to which these are enforced is largely governed by the amount of fresh produce available (Batt et al. 2011). Where, as a result of some extreme weather event there is a marked reduction in the quantity of produce available in the market, prices may suddenly escalate. In such situations, buyers will often pay high prices to secure whatever produce is available, irrespective of its quality. In many institutional markets where prices are negotiated in advance, highly volatile market prices have the potential to undermine the cluster's collective marketing effort. In other instances where the cluster is unable to consolidate sufficient product to meet the needs of the downstream buyer, the cluster may purposefully choose to introduce product which is outside the buyer's specifications. For some, they may find that the varieties they are currently cultivating are not suitable for the market; for example, one group of cluster farmers in Davao found that they were growing the wrong variety of squash.

The provision of financial services has evolved as an economic development approach intended to benefit low-income groups (Ahmad et al. 2004). Microfinance institutions target the poor through innovative approaches, which include group lending, progressive lending, regular repayment schedules and substitutes for collateral (Thapa 2006). Through these, it is expected that the poor will be empowered to move out of poverty (Oji 2006). However, most smallholder farmers do not have sufficient collateral. Furthermore, the ability to access microfinance presents additional risks, since farmers opt to borrow on the basis of anticipated crop production (Real et al. 2011). Highly exposed to natural disasters, a sudden decline in market prices, lower than expected yields, a lack of buyers, and losses arising from poor storage conditions, smallholder farmers often experience difficulty in meeting their obligations to repay loans (CGAP 2006). For those cluster farmers in Bukidnon who did take advantage of the opportunity to accept loans offered by the Bukidnon Cooperative Bank, after two successive crop failures, the level of indebtedness that they now face is a major constraint.

In other instances, the cluster may find that transacting with some institutional buyers is impossible because they are unable to issue official invoices or receipts. To be able to do this, the cluster must be registered with the Department of Labour and Employment. Furthermore, the terms of trade under which many institutional buyers operate do not favour or support smallholder farmers. In some instances, rather than to pay cash on delivery, institutional buyers may pay 14–60 days later. For smallholder farmers who depend upon the cash to purchase household necessities, such terms are unacceptable. Furthermore, many retailers have mechanisms under which, after 2–3 days, any unsold product is returned to the supplier. Collectively, these impediments are described as institutional.

However, the most significant group of constraints are those that relate to the inadequate infrastructure—lack of electricity, no running water, the lack of transport and the poor condition of the roads. For some clusters, there is no public transport or, in other instances, transport is too infrequent. Without adequate roads, produce must be manually hauled to the roadside or transported by motorcycle, carabao or horse. Invariably, this results in the produce being transported in sacks, and is thereby exposed to considerable physical damage in transit.

With the rapid advance in cellular telephone technology, most of the clusters are able to communicate with their focal customers. The extent to which they need to do so is largely dependent upon the frequency with which they transact and the extent to which the products they have delivered meet the customer's specifications. However, in some barangays it is not possible to receive a signal. In other instances, as it is the prevailing practice in the Philippines, calls between phones in the same network are free but, between networks, call charges can prove to be inordinately expensive.

Quality strategies

For smallholder farmers to access the institutional market, they must first enter into some form of collaborative marketing arrangement whereby it becomes possible to consolidate sufficient product of the desired quality to meet the downstream buyer's specifications. In one instance, with the support of the Davao City Agriculturist's Office, a confederation of clusters has been formed to meet the needs of a major supermarket chain. This has arisen primarily because the range and volume of vegetables required greatly exceed the capacity of any one cluster to deliver.

However, if the clustering approach is to be successful, the cluster members must have: 1. a common goal; 2. alternative markets; 3. strong leadership; 4. open communication; 5. trust and social cohesion; and 6. strong institutional support. Underpinning each of these pillars is the need to build capacity, thereby enhancing the capability of each member of the cluster to make better-informed decisions. However, first and foremost, for the cluster to be successful, it must be able to offer some comparative advantage (Murray-Prior 2007). In other words, the cluster must be able to deliver benefits to its members that are greater than those the members can obtain by acting independently.

At the very inception of a cluster, its members must come together for a common purpose: to collaboratively market their produce. Having identified what crops to grow, the cluster members collectively establish a production calendar, each planting many small plots of the selected crop sequentially, thereby ensuring that there is a sufficient and reliable supply. Furthermore, in most cases, prices are negotiated 7–10 days in advance, thereby enabling the farmers to make an informed choice. Ordinarily this would be considered advantageous, but as vegetable prices are highly volatile in the Philippines, occasioned by the frequency and duration of the typhoons, some cluster members may be tempted to divert product that has been committed to the focal buyer to other buyers in order to take advantage of higher prices. In order to secure sufficient product to meet the focal buyers needs and to provide, in parallel, an element of flexibility, the cluster members must decide how much of their crop is to be committed. Generally this figure is 60%. Strong leadership is also required. Those cluster members who repeatedly fail to meet their obligations must be sanctioned and, where appropriate, expelled.

From the very outset of this project, the vegetable industry in the Philippines has been conceptualised as being comprised of two parallel, yet complementary, supply chains; one supplying low-quality product to the traditional wet markets, the other supplying better quality product to supermarkets and other institutional users (Murray-Prior et al. 2004). Maintaining relationships with buyers in both chains has proven to be most advantageous for several reasons: 1. it provides an alternative outlet for that product which fails to meet the focal buyer's specifications; 2. where the quantity of product available exceeds the focal buyer's needs; or 3. where, for any reason, the focal buyer defaults. In South Cotabato, sweet pepper farmers soon realised that in supplying a major fish-canning operation, the demand for their product was contingent also upon there being an ample and sufficient supply of carrots and potatoes. Where the quantity of either product was low, the demand for sweet pepper was correspondingly adjusted downward (joint demand), leaving the farmers with additional product to sell.

Lack of technical information is one of the major obstacles that smallholder farmers face in endeavouring to improve both productivity and quality. In the Philippines, just as in most other countries, increases in government expenditure for agricultural extension have failed to keep abreast with the increased cost of delivering these services. As one-on-one consultations are simply not cost-effective, smallholder farmers have been encouraged to come together into collaborative groups. Results from the impact study confirm that one of the main benefits smallholder farmers have derived from the clustering process is greater access to technical information. Through the delivery of training programs conducted through third-party providers such as the Department of Agriculture, local government units and the City Agriculturist's Office, smallholder vegetable farmers have been able to improve productivity and quality through improved crop rotation, pest and disease recognition, integrated pest control and the judicious application of fertilisers. In Bukidnon, assistance was also received from East West Seeds which was able to identify and provide seed of a more suitable variety of ampalaya.

Furthermore, with almost 30 clusters participating in the project, facilitated in part through the annual supply chain symposium and the farmers forum organised by the University of the Philippines Mindanao and meetings conducted by the respective vegetable industry councils, the farmer groups have been encouraged to interact. As a consequence, technical exchange visits between the clusters have been facilitated, with commensurate improvements in both productivity and product quality.

As a result of these technical visits between clusters, many of the clusters have elected to adopt protected-cropping structures. Invariably, these structures have been provided as a grant from the Department of Agriculture, a local government unit or the City Agriculturist's Office. In most cases, some co-funding arrangement has been necessary, under which the cluster has provided the materials for the framework (bamboo) and the labour, while the beneficiary has provided the plastic covering and, in some instances, drip irrigation. On average, the rain shelters have been quite modest in size and provided primarily for demonstration purposes. However, the Songco cluster, through the Department of Agriculture, was able to construct four protected-cropping structures (9 m × 40 m) and the Kaatoan cluster was able to secure two structures of similar dimensions. In both cases, it was possible to access these grants because the clusters were formally incorporated.

One of the other initiatives that have been shared between the farmer groups is the increasing use of biodynamic farming. The adoption of high-input farming systems exposes the majority of smallholder farmers to a high element of risk. On the one hand, there is the very real risk of losing the entire crop at any stage as a result of heavy rain or persistent inclement weather and, on the other, if all goes well and the supply is high, prices in the market may be so low that farmers are unable to recover the costs of production. While farmers seem willing to accept the lower yields from biodynamic farming, the impact on quality has yet to be ascertained. Nevertheless, the adoption of such farming system may very well provide an opportunity for smallholder vegetable farmers to enter into a new, higher value market. Concepcion et al. (2006) highlighted the concerns that consumers in the Philippines have about the potential presence of chemical residues. With appropriate branding, an opportunity may exist to differentiate the biodynamic product in the market and to potentially generate higher returns for farmers. However, such a proposition is unlikely to appeal to all market segments, for unless the customer demonstrates a willingness to pay, the market will be more concerned about the price.

In an effort to improve the quality of the fresh vegetables offered to focal buyers, many of the clusters now choose to wash, sort and grade the produce before packing. However, in the absence of an appropriate means of transport, selected product is still being packed into bags or sacks for hauling to the nearest roadside collection point. Here the product must be re-sorted to remove any that is damaged, then reweighed. In some instances, the product may be repacked into recyclable plastic crates to prevent any subsequent damage in transit. However, for the cluster farmers to participate in these schemes, they must first purchase a number of crates so that they can be readily exchanged at the point of delivery. Not unexpectedly, there is an element of trust involved in these transactions, for the cost of the crates is considerable and few smallholder farmers can afford to use them. Furthermore, unless the buyer is willing to collect the product or to pay a substantially higher price, there are few financial incentives to encourage their more widespread adoption. For this reason, sacks or bags remain the principal means of packing fresh produce.

With appropriate knowledge and technical support, farmers are introducing new crops in response to buyers' requests for a greater range of product. In other instances, new crops have been introduced because of the high incidence of pests and diseases arising from inadequate crop rotations or adverse climatic events. However, without access to capital, farmers may be unable to take advantage of the opportunity.

One of the key benefits smallholder farmers have derived from the clustering process is the ability to access capital. Clustering provides the farmers with a more stable market, thereby providing the microfinance institutions with greater confidence in the ability of participating farmers to repay loans. As the clustering process requires the group to develop a gross margin, a planting schedule and a marketing plan, most of the information that the banks require can readily be made available. Microfinance institutions are also becoming more involved in the preparation of business plans, marketing, agronomy and technology transfer as a way of ensuring that loans are repaid. For example, the Tinubdansa Kalamboan Foundation was established by the Bukidnon Cooperative Bank to: 1. strengthen cooperatives through continuous education, gender advocacy, research-based policymaking and entrepreneurship; 2. promote and advocate resource-based financial management through savings, capital formation and financial literacy; 3. facilitate the improvement of local products through technical assistance, microfinance research and marketing; 4. advocate the value of life and property through pro-poor insurance services; and 5. facilitate financial services for smallholder farmers and village entrepreneurs. However, climatic adversity and the high incidence of pests and disease can seriously reduce productivity, thereby preventing farmers from repaying their loans.

As a result of the improved social cohesion that develops among the cluster members, many of the cluster groups have embarked upon communal farming. This is a collective approach where farmers equally share the production expenses and the proceeds of the sale to repay their individual loans. One farmer might provide some of the fertiliser required for the communal area, while others supply their labour for weeding, watering, trellising and harvesting. These communal farms provide a way for the cluster to collectively trial new crops, new varieties and, where the cluster has been able to secure a greenhouse, the means by which all cluster members can benefit, rather than a single individual.

In other instances, the cluster members collectively decide what proportion of their income they will contribute to a revolving cluster fund. Effectively, this is an informal line of credit by which cluster members are able to access the funds they require to purchase inputs, to meet unforeseen household expenses, or to meet the expenses associated with the formal incorporation and registration of the cluster. Where, for example, seeds and/or fertilisers have been provided by government or an NGO, there is an expectation that the farmers will repay the costs of these inputs into some collective fund, thereby enabling the cluster to become more sustainable.

Conclusions

Quality, when combined with the ability to deliver a predetermined volume of product, is a prerequisite to gaining access to institutional buyers who subsequently resell the product with or without processing. For this reason, smallholder farmers acting independently are unlikely to be able to produce either sufficient product or the range of product that the buyer requires. To improve this situation, the most significant intervention that can be made is to encourage and facilitate the formation of collaborative marketing groups or clusters. However, the formation of these clusters cannot be imposed upon the farmers by external parties. They must evolve from within the communities themselves and they must be market driven. Furthermore, they must be adequately supported. Support relates not simply to the provision of technical information and credit, but more to the long-term process of capacity building. Through this process, farmers' learning is directed towards finding cost-effective, agroecologically appropriate resolution of their problems. For example, based on a strong market demand from a focal customer, farmers may choose to plant a new crop or an improved variety. Depending on how much experience they have with the crop, they may need technical support. Knowing what the customer wants, the crop can be harvested at the appropriate maturity, graded and sorted to remove damaged or diseased pieces. However, what happens next will very much depend upon the farmer's location and proximity to a major thoroughfare and the buyer's willingness to either collect the product or to pay a premium price for its subsequent transport to market.

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Economics and policy

The economics of smallholder farming in the Philippines generally requires a mixed cropping system for sustainability. This farm of Mike Pedrosa in Calbayog, Samar, is a mixed enterprise of rice, jackfruit, papaya and a seedling nursery, and here Niño, Nilo and Niko follow the ACIAR–PCAARRD team across Mike's rice fields. (Photo: John Oakeshott)

Ex-ante impact assessment of the adoption of IPM strategies for mango in Region XI of the southern Philippines

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Abstract

Mango growers in Region XI are faced with a decreasing farm income and production due to increasingly ineffective broad-spectrum pesticides for the control of a number of significant insect species, necessitating a combination of selective chemical, biological and cultural controls into an integrated pest management (IPM) program. For the mango growers, there are significant changes to production and management costs associated with adopting IPM and therefore the main issue for growers is whether it is cost-effective to adopt an IPM system. This paper addresses this issue of cost-effectiveness, outlines the key benefits from adopting an IPM system for mango production and assesses the potential impacts of the recommended IPM proposed by the mango researchers on the profitability of the fruit farms in the southern Philippines. It is estimated that 40% (7,255 ha) of the total mango production area in Region XI (18,137 ha) is affected with the problem of severe pest damage caused by cecid fly, thrips and scab, which contributes to a yield loss or rejects of 40% of the total potential yield per hectare. Preliminary research has indicated that effective management of pests and diseases in mango orchards could reduce yield losses or rejects by 20% and improve yields by about 33%. The suggested IPM practices would also reduce the cost of production by 16%, derived from the 75% reduction in chemical control cost, which translates to 156% increase in income. Based on the estimates and expectations of the level and rate of management practice adoption, the expected net present value of benefits from collaborative IPM research in Region XI for mango is approximately 1.25 billion pesos (A$30.55 million) with a benefit:cost ratio of about 51:1, representing an internal rate of return of approximately 59%. In addition to clearly quantifying the potential impact of the proposed IPM recommendation, this study also provides important lessons for research and extension policy, and for the formulation of future research opportunities.

Introduction

Ex-ante impact assessment

Ex-ante technology evaluation and impact assessment is the process of assessing the potential benefits of new technologies and management practices prior to adoption taking place. Australian Centre for International Agricultural Research (ACIAR) guidelines for impact assessment state that: 'Within ACIAR, impact assessment aims to identify, provide evidence of and, ultimately, quantify the impacts of its R&D investments' (Davis et al. 2008). The same aims apply to the ex-ante impact assessment undertaken as part of this project. In particular, the approach used aims to facilitate any ex-post impact assessment that may be undertaken in the future. The assessment is based upon identifying the current practice (i.e. the baseline or 'without technology' scenario) and comparing this with the expected impacts of the new technology (the 'with technology' scenario).

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Ex-ante assessments are commonly practised to provide information to contribute to research planning and priority setting and to help guide adoption and investment decisions for new technologies. Ex-post impact assessments take place after a project has been completed and is implemented in order to estimate the impact a research project has achieved.

Being undertaken before new technologies are released and adopted, ex-ante studies inevitably involve assessing impacts of technology adoption when data are limited or even non-existent. In complex agricultural production systems, this makes the task of ex-ante impact assessments challenging. Techniques used to collate the best available information at the time rely on: field trials and experiments on yields and input costs; expert opinions of scientists, farmers and industry experts; and published information on prices and production (McClintock et al. 2010). The financial analysis of control technologies presented in this report draws on data from these available sources.

Key technologies and marketing systems for the southern Philippines fruit and vegetable industries are being developed and assessed as part of ACIAR projects HORT/2007/066 'Enhanced profitability of selected vegetable value chains in the southern Philippines' and HORT/2007/067 'Improved domestic and export competitiveness of selected fruit value chains in the southern Philippines and Australia'. The aim of project HORT/2007/067 component 5 (C5), 'Economic impacts of new technologies and policy constraints in the production of fruit and vegetables in the southern Philippines and Australia', is to evaluate a set of production technologies, marketing approaches and policy reforms identified through research undertaken in the technical components of the Southern Philippines Horticulture Program. Within the C5 team, Industry and Investment NSW and the Visayas State University are responsible for undertaking the on-farm technology evaluations of the impact of the recommendations proposed by the technical groups on the profitability of fruit and vegetable farms. This report specifically relates to the research being undertaken to develop IPM strategies for the effective control of mango pests and diseases within component 4 (C4) of the project 'Improved and sustainable value chains for mango production in the southern Philippines and Australia'.

Strong links and cooperation between the economic and technical groups are necessary for the potential impact of component research recommendations to be assessed. Information from ex-ante impact assessment can help to enhance the adoption of research recommendations where net benefits are demonstrated, and assist in identifying constraints to adoption, providing feedback to the research process and demonstrating the potential returns of research and development (R&D) to project stakeholders.

Review of literature

The importance of research evaluation and impact assessment

It is widely recognised that growth in agricultural production leads to improved economic conditions in both developed and developing countries. Nevertheless, despite high returns to agricultural research, available funds are limited. As such, there is an increasing demand from stakeholders, especially donors, for national and international research organisations to show that they are wisely investing the research dollars that have been entrusted to them. Moreover, given that malnutrition and poverty remain serious problems in Asia and Sub-Saharan Africa, and severe environmental degradation continues to threaten sustainable agricultural growth, R&D organisations working in the developing world are being asked to provide concrete evidence that the benefits to research are reaching the targeted beneficiaries—the poor and disempowered—and that these benefits are likely to be sustainable in the future.

In addition to seeking evidence that past research funds have been invested efficiently and effectively, the onus is on research institutes to systematically apply priority-setting methods to ensure limited resources are directed to those research areas that have the greatest potential to benefit the poor in a sustainable manner. However, use of priority-setting methods as a basis for agricultural research decision-making has been limited. This is because it is not enough just to have a toolkit of evaluation methods that can be readily applied to a diverse research portfolio. Nor will the development of the necessary knowledge and skills ensure the application of priority-setting methods at the institutional level. It is also necessary to develop an environment where the evaluations are encouraged, relevant and used in strategic planning and priority-setting exercises and in the development and implementation of research programs and projects. When an impacts-based evaluation system is seen as an integral part of learning and improving program and institutional management, the likelihood that the program and institution will reach its ultimate goals will be increased.

Integrated pest management

Integrated pest management (IPM) is a strategy that draws on a range of management tools with the goal of using the least ecologically disruptive techniques to manage pests in a way that maintains their damage at economically acceptable levels.

The distinguishing features of an IPM strategy are:

- the use of knowledge about the biology of pests and their interaction with their natural enemies
- knowledge of cultural and chemical control strategies
- the monitoring of pest and beneficial populations to allow growers to make profitable pest management decisions.

The term IPM was originally coined in relation to managing invertebrate pests (insects and mites) but IPM systems have now been developed to cover other types of pests, including diseases, weeds, nematodes and vertebrate pests. IPM systems for specific crops are developing, with most recommendations currently targeting invertebrate pests and plant diseases. While new scientific information has enabled farmers to make more profitable pest management decisions, particularly with respect to pesticides, it has also been a valuable input to the management of externalities associated with pests and the use of pesticides, and into the public regulation of pest management.

Study guidelines

Objectives of component 4—mango fruit research

Component 4 (C4) of ACIAR project HORT/2007/067-4 'Improved domestic profitability and export competitiveness of selected fruit value chains in the southern Philippines and Australia' aims to: develop and evaluate sustainable practices for the integrated management of mango pests and field and postharvest diseases; develop and evaluate integrated crop management strategies for productive, profitable and sustainable production of high-quality mangoes; and evaluate food safety issues that limit access and competitiveness in mango exports (Angeles et al. 2011). Fruit C4 is a large component that deals with pre-and postharvest pest and diseases management strategies as well as improving the marketing system. The focus of this farm level assessment is on only the preharvest pest and disease problems that C4 is addressing.

Role of component 5—economic impacts research

The component 5 (C5) economics and policy team is responsible for assessing the ex-ante economic impacts of new technologies and policy constraints in the production of vegetables and fruits in the Philippines. The team is undertaking a series of studies to measure the expected impact of the recommendations proposed by the technical components of the Southern Philippines horticulture program, including research undertaken in fruit component C4 (mango). The objective is to demonstrate whether there is likely to be a significant improvement for mango producers from adopting the control practices recommended by C4.

Features of the baseline (non-IPM) pest management strategy for mango

- Insect pest and disease management is based on regular, preventive chemical applications.
- Insect pests, beneficial and specific diseases are not accurately identified.
- Crops are not routinely monitored.
- Growers spray on a routine calendar basis, with some modifications depending on weather conditions or casual observations in the crop. Most mango growers spray 16 times per cropping based on the calendar spraying schedule provided by pesticide companies.
- Growers do not prune or apply fertiliser and have poor sanitation practices.

Features of IPM strategy recommended for mango

- Growers and/or IPM scouts have knowledge of key insect pests and diseases, and the recommended options for managing them.
- Prevention of insect pests and diseases is achieved through:
  - pruning of overcrowded branches and disease-affected parts to prevent pest and disease build-up
  - implementing hygiene practices such as weed management and clearing fallen fruit from the ground.
  - balanced application of fertiliser, based on soil analysis.
- Regular monitoring of pests and diseases is carried out by lightly tapping the panicle above a sheet of clean white paper, and counting the thrips that

fall onto its surface. Sampling rates of 10 panicles/tree and 10 trees/100 trees are used to determine the economic threshhold level (ETL) necessitating diversified control measures, which is 10 thrips/panicle.
- Intervention for the timely control of insect pests and diseases involves:
  - effective timing of sprays
  - excellent spray coverage.
- Crop records are maintained.

Key changes to the baseline scenario consequent on adoption of an effective IPM strategy for mango production are thus:
- implementation of routine crop monitoring
- a reduction in the percentage of the crop damaged by insect pests and plant diseases
- an increase in cultural control costs due to improved and additional cultural practices
- a reduction in the costs of spraying and chemicals due to a reduced frequency of spraying
- use of different insecticides and fungicides in rotation, so that the same fungicides or insecticides are not used twice in a row.

Results

Effects on gross margins

Tables 1 and 2 show that adopting the recommended IPM management practices will make changes in the production output and costs in managing mango orchards. Effective management of pest and diseases through IPM in mango orchards is expected to reduce crop damage by 20%, with a corresponding increase in yield per hectare of 33%. Adoption of recommended cultural management practices is likely to involve additional costs for

Table 1. Assumptions used in calculating gross margins with and without integrated pest management (IPM)

	Without IPM	With IPM
Yield loss (% damaged fruit)	40	20
Flowering trees (trees/ha)	80	80
Age of trees (years)	10	10
Planting distance (m ´ m)	10 × 10	10 × 10
No. of fruit/tree	500	500
Fruit/ha/year (including damaged fruits)	40,000	40,000
Average fruit weight (kg)	0.20	0.20
Farm gate price (pesos/kg)	24	24

Table 2. Costs, returns and margins per hectare, with and without integrated pest management (IPM)

	Without IPM	With IPM
Income		
Yield—without IPM: 4,800 kg/ha	115,200 pesos	
Yield—with IPM: 6,400 kg/ha		153,600 pesos
Variable costs		
Chemicals and application (spraying + monitoring)	70,385.00	18,620.93
Fertilisers and application (based on soil analysis)	0	34,188
Pruning	0	1,155
Sanitation (weeding), herbicide	0	1,762.50
Flower induction	2,083	2,083
Bagging	7,000	7,875
Harvesting	2,800	3,733
Total variable costs	82,268 pesos	69,417 pesos
Gross margin per ha	32,933 pesos ($US758)	84,183 pesos ($US1,9360)
Gross margin per tree	329 pesos ($US8)	842 pesos ($US19)

Source: Farmer focus group discussion with mango growers and data from a farmer collaborator in Samal, April 2012 pruning, improved orchard hygiene practices and fertiliser application. It is estimated that controlled use of chemicals in IPM will reduce per-hectare costs by a net 53,077 pesos (75%) over the current 'without' research chemical control, which is 70,385 pesos. The changes in chemical and cultural control practices for pests and diseases for mango would result in an overall reduction of 16% in the cost of production. This saving is due to the reduced frequency of spraying in IPM as well as spraying the right amount of chemicals needed, based on the monitored economic threshold of the pests and diseases. The total adoption of IPM practices will result in an increase of about 156% in the gross margin per hectare.

Issues/risks regarding adoption of IPM

1. Most farmers (80%) are in contract-growing schemes. The farmers do not decide on the spraying activity or the pest management of their mango orchard. A calendar-based spraying program is implemented by contractors. In Samal alone, there are 80 contractors recorded in the city office. The majority of them are businessmen from outside Samal. The question is: Are these contractors willing to change their spraying program into the recommended IPM practices for mango; will they spray only as needed based on monitoring or will they prefer to continue their practice of spraying without monitoring? Key researchers under the extension subcomponent of the C4 mango fruit project pointed out that the possibility of change is high, because an ordinance (no. 2010–168) for mandatory registration of mango contractors had already been released and was being implemented. Part of the ordinance aims to regulate the use of pesticides and/or in totality regulate production and marketing to world Codex standards. This is one of the most significant accomplishments of the extension subcomponent under the ACIAR project C4 component. Several training sessions have also been conducted, and brochures and guides giving recommendations have already been provided to the growers and interested stakeholders.
2. There are few experienced IPM consultants. They may need to employ additional crop scouts/consultants and/or train staff members, or the farmers may need to be trained to undertake their own monitoring.
3. Significant time may be needed to build-up knowledge of the new practices.
4. Partial adoption—relying on only some of the recommended practices, such as pruning and monitoring, but not adopting good sanitation practices to limit the arrival or spread of pests—is a possibility.
5. Most farmers are relying on chemical control only and may not be willing to make changes in their current practices, such as adopting sanitation and pruning.

Issues/risks if IPM is not adopted

1. Crop failure—without regular monitoring and record-keeping it is difficult to evaluate the effectiveness of control measures and a failure may result in unexpected damage at harvest. Since its cause cannot be identified, there is no means of learning from mistakes.
2. Potential for excessive chemical residues and breaches of maximum residue limits.
3. Potential to induce pesticide resistance from overuse of chemicals
4. Potential to induce major outbreaks of pesticide-resistant pests due to unintentional killing of beneficial organisms during spraying.

Estimating the benefits associated with adoption of IPM

Measuring the adoption of mango IPM research recommendation

Mango IPM research generates benefits when the recommended practices for managing mango orchards are taken up and applied by farmers in their respective farms. The new IPM strategies for mango will deliver various benefits, including reduced fruit

Table 3. Mango farm costs (pesos/hectare) with and without integrated pest management (IPM) technologies

Technology	Without recommended technology (traditional practices)	With recommended technology (IPM)	Net change
Cultural control	7,000	46,293	+39,293 (561% increase)
Chemical control	70,385	17,308	–53,077 (75% reduction)
Frequency of spraying	12×/crop	16×/crop	

damaged or yield losses, reduced cost of production and improved yields. The first step in calculating the benefits of IPM research is to determine the size of the industry; second, the extent of the area affected of the pest and disease problem covered by the research is estimated; and third, the likely level of adoption within the affected region is determined.

Researchers were interviewed to determine their opinion, experience and own assessment of the extent of the problem being addressed by their research and the potential impacts of the research outputs, and what, in their opinion, will be the likely levels of adoption within the affected region.

From the researcher interviews it was estimated that 40% of the total mango production area in Region XI is affected by the problem of fruit damage caused by thrips, cecid fly and scab (preharvest pests and disease), which are the focus of the current IPM research being done in the fruit C4 component. In the interviews, the researchers were also asked about their expectations on the likelihood of their recommendations being adopted on mango farms in Region XI. Information was collected on: 1. expected adoption level (%) in the first, second and subsequent years; 2. expected maximum level (%) of adoption; and 3. expected time (years) to reach maximum.

Adoption profile for mango IPM in Region XI

A preliminary estimate of the adoption rate has been made by key researchers and extensionists involved in the project. It is expected that adoption will occur from 2014, allowing 2 years for building-up knowledge and training scouts/pest monitors. Adoption will reach a maximum of 80% after 7 years (at year 2020) as a result of research and extension activities (Figure 1).

Financial analysis

To account for time preference or the priorities applying to use of money (opportunity cost), future benefits and costs were discounted to present values (PV). All dollar costs and benefits were expressed in constant dollar terms and discounted to the current financial year. Investment benefits were measured using the investment criteria of net present value (NPV) and benefit:cost ratio (BCR). The NPV is the difference between the PV of benefits and the PV of RD&E costs, while the BCR is the PV of benefits divided by the PV of the research costs. The NPV is also shown on an annualised basis over 20 years.

Tables 3 and 4 show the results of the financial analysis done for mango IPM research. The 5% discount

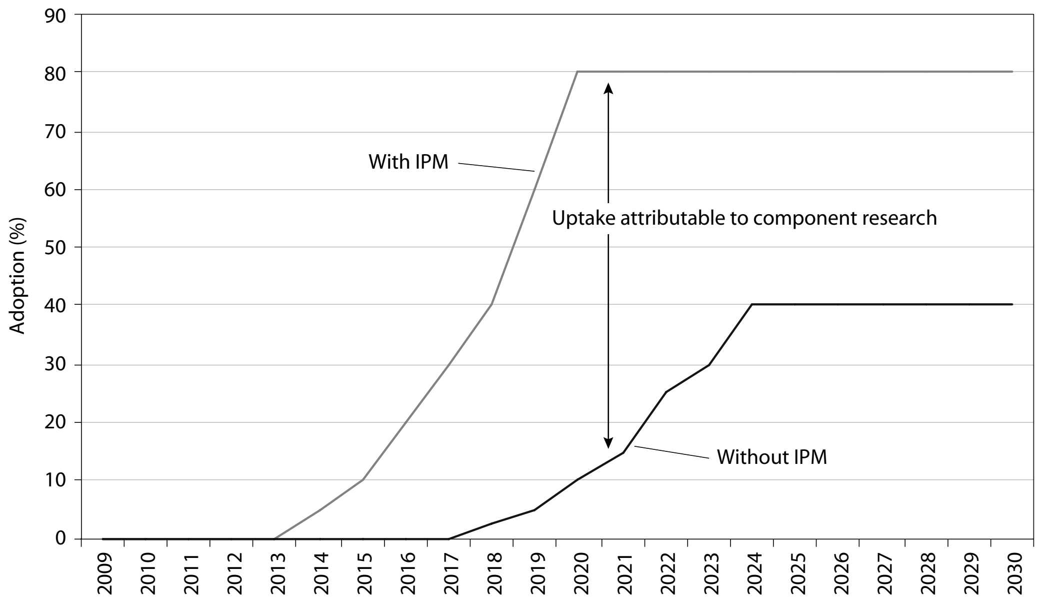

Figure 1. Adoption profile for the recommended integrated pest management (IPM) practices for mango in Region XI

Table 3. Calculation of benefit:cost ratio (using a 5% discount rate)

Standard measures	Pesos	A$
Present value of benefits	1,270,251,024	31,084,313
Present value of costs	21,561,066	527,620.85
Net present value	1,248,689,958	30,556,691.95
Internal rate of return (%)	59	
Benefit:cost ratio	51:1	

Table 4. Sensitivity testing

Discount rate (%)	Present value of benefits	Present value of costs	New present value ('000 pesos)	Net present value (A$ '000)	Benefit:cost ratio
0	2,556,161,996	29,329,722	2,526,832,274	61,834,113	87.2
10	675,946,241	22,684,375	653,261,866	15,985,971	29.8

rate was used as this is the rate used in ACIAR assessments. Sensitivity testing was undertaken at 0% and 10%, as per ACIAR guidelines for assessing impacts of their research activities (Davis et al. 2008)

At 5% discount rate the expected net present value of mango IPM research in Region XI result is 1.25 billion pesos (A$30.55 million) with a benefit:cost ratio of 51:1, which means that for every peso invested in adopting the IPM in mango, we can expect a benefit of 51.00 pesos, representing an internal rate of return of approximately 59% (Table 3).

At 0% and 10% discount rates the benefit:cost ratio results are 87.2 and 29.8, respectively (Table 4).

Discussion and conclusion

Preliminary research has indicated that effective management of pests and diseases in mango orchards are expected to reduce yield losses or rejects by 20% and improve yields by about 33%. The suggested IPM practices would also reduce cost of production by 16%, derived from a 75% reduction in chemical control cost, which translates to a 156% increase in income. Based on estimates of the level and rate of adoption of the recommended management practices, the expected NPV of benefits from collaborative IPM research in Region XI for mango is approximately 1.25 billion pesos ($US27.8 million) with a BCR of about 51:1, representing an internal rate of return of approximately 59%.

Determination of the key technology characteristics and the farm-level impacts presented in this report will guide those farmers considering adoption of the technology. This would also have relevance for researchers, in terms of how their research and analysis can be designed to overcome or address issues and constraints affecting adoption and to increase the appeal of technologies which will deliver genuine net benefit to farmers.

Mango IPM research being undertaken by the fruit C4 activity is intended to increase the volume and quality of mango production. The research will lead to a shift in the supply of mangoes as production increases. If the increase in mango production is large enough to affect the prices received by farmers in the region, consumers will benefit most via lower prices. However, if the demand for mango is very strong and producers have good access to large markets or demand centres, the increase in production may have little effect on prices, and producers will benefit from the research. The magnitude of the shift in the supply is estimated by aggregating farm-level impacts using information about the extent and rate of adoption expected. The shift in supply is referred to as the 'k-shift' in welfare economics. Estimation of the 'k-shift' associated with the component technologies is the link between the farm and regional level work undertaken in this report and the welfare analysis being prepared by the Philippine Institute of Development Studies to estimate the ex-ante net returns from research.

This report focuses on a financial assessment of the expected impacts at the farm to regional level and not, as yet, the economy-wide (national level) impacts of the control technologies. As such, the results reported on returns to the research investment may be revised as new information comes available.

Acknowledgments

The authors appreciate the time that researchers, mango farmers and farmer collaborators of the technical component Fruit – C4 have shared for interviews and discussions to get their feedback on the technologies and recommendations. The contributions of Dr Anthea McClintock and Dr Leanne Orr, former members of the C5 Team, are also acknowledged. Thanks are also extended to Dr Roehlano Briones, Dr Kirrily Pollock and Dr David Hall for their comments and suggestions for the improvement of this report.

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Ex-ante impact assessment of *Phytophthora* disease control for jackfruit in Region VIII, southern Philippines

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Abstract

Jackfruit is a very popular domestic fruit in the Philippines. It is grown throughout the country. Jackfruit decline is a major constraint to jackfruit production in the Eastern Visayas, where it is a flagship commodity. In some areas, up to 90% of jackfruit trees are reported to be affected by decline syndrome, which is manifested by leaf yellowing and drop, girdling stem lesions and rot, and eventually wilting and death. *Phytophthora* has long been associated with the disease and consequent yield and tree losses in durian. Since the commencement of the project, *Phytophthora palmivora* has been identified as the species causing of severe decline in jackfruit in Leyte and Samar in the Eastern Visayas. Despite knowledge of the causal organism and the availability of management strategies, the dissemination and implementation of management options has been a problem across the region, with few farms practising best management strategies. The collaborative research funded by the Australian Centre for International Agricultural Research titled 'Integrated management of *Phytophthora* disease of durian and jackfruit in the southern Philippines' is developing strategic technologies for integrated disease management practices that will reduce yield loss associated with the disease, improve fruit quality and, ultimately, improve farm incomes. In this paper, the potential impact of the effective management of *Phytophthora* using the research recommendations is discussed. It is estimated that approximately 57.5% of 578 ha jackfruit area in Region VIII are affected by Phytophthora disease. The key management practices recommended include the construction of drainage canals, mounding, pruning, sanitation and application of a new chemical (Agri-Fos) through trunk injection. A combination of chemical application and improved cultural practices is expected to offer farmers the most effective method of controlling the disease. Preliminary research has indicated that effective management of *Phytophthora* can significantly reduced yield losses by approximately 22% per hectare and reduced tree mortality by approximately 11%. Changes in yields and production costs associated with the adoption on best practice for *Phytophthora* control will increase the gross margin per hectare by 93%. Based on the estimates of benefit–cost analysis and predictions of the level and rate of management practice adoption, the expected net present value of benefits from collaborative *Phytophthora* research in Region VIII is approximately 224.68 million pesos (A$5.49 million) with a benefit:cost ratio of about 48:1, representing an internal rate of return of approximately 43%. In addition to clearly quantifying the potential impact of *Phytophthora* control, the research also provides important lessons for research and extension policy, and for the formulation of future research opportunities.

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Introduction

Ex-ante impact assessment

Ex-ante technology evaluation and impact assessment is the process of assessing the potential benefits of new technologies and management practices prior to adoption taking place. ACIAR guidelines for impact assessment state: 'Within ACIAR, impact assessment aims to identify, provide evidence of and, ultimately, quantify the impacts of its R&D investments' (Davis et al. 2008). The same aim applies to the ex-ante impact assessment undertaken as part of this project. In particular, the approach used aims to facilitate any ex-post impact assessment that may be undertaken in the future. The assessment is based upon identifying the current practice (i.e. the baseline or 'without technology' scenario) and comparing it with the expected impacts of the new technology (or 'with technology' scenario).

Ex-ante assessments are commonly practised to provide information to contribute to research planning and priority-setting, and to help guide adoption and investment decisions for new technologies. Ex-post impact assessments take place after a project has been completed and implemented, in order to estimate the impact a research project has achieved.

Being undertaken before new technologies are released and adopted, ex-ante studies inevitably involve assessing impacts of technology adoption when data are limited or even non-existent. In complex agricultural production systems, this makes the task of ex-ante impact assessments challenging. Techniques used to collate the best available information at the time rely on: field trials and experiments on yields and input costs; the opinions of scientists, farmers and industry experts; and published information on prices and production (McClintock et al. 2010). The financial analysis of control technologies presented in this report draws on data from these available sources.

Key technologies and marketing systems for the southern Philippines vegetables and fruit industries are being developed and assessed as part of ACIAR projects HORT/2007/066, 'Enhanced profitability of selected vegetable value chains in the southern Philippines', and HORT/2007/067, 'Improved domestic and export competitiveness of selected fruit value chains in the southern Philippines'.

Component 5 (C5) in the projects is titled 'Economic impacts of new technologies and policy constraints in the production of fruit and vegetables in the southern Philippines and Australia'. Its purpose is to evaluate a set of production technologies, marketing and policy reforms identified through research undertaken in the technical components of the Southern Philippines Horticulture Program. Within the C5 team, Industry and Investment NSW and Visayas State University are responsible for undertaking the on-farm technology evaluations to assess the impact on the profitability of fruit and vegetable farms of the recommendations proposed by the projects' technical groups. This report specifically relates to the research being undertaken to develop technologies for the effective control of *Phytophthora* in jackfruit production.

Strong links and cooperation between the economic and technical components are necessary in assessing the potential impact of component research recommendations. Information from ex-ante impact assessment can help: 1. enhance the adoption of research recommendations where net benefits are demonstrated; 2. identify constraints to adoption; 3. provide feedback to the research process; and 4. demonstrate the potential returns on research and development to the project stakeholders (McClintock et al. 2010).

Review of literature

Phytophthora diseases

Many tropical tree crops are severely affected by diseases caused by the polyphagus, cosmopolitan, soil-borne pathogen *Phytophthora palmivora.* On durian, symptoms appear as root rot, seedling/tree dieback, patch canker and pre- and postharvest fruit decay (Lim and Chan 1986; Chan and Lim 1987; Lim 1990). Infection is most severe during the rainy season, when spores of *P. palmivora* are dispersed from the soil, or from tree canker infections, to ripening fruits. Rainwater drops at the stylar end of the fruit induce spore germination. The resulting rot spreads rapidly into the flesh, especially during storage and transit, causing the skin to split, and rendering the fruits unsaleable within days.

Extent of the problem

The genus *Phytophthora* is one of the most important plant pathogens worldwide and many plant species, including those covered by the ACIAR project HORT/2007/067 component 2 (C2) 'Enhancing the profitability of selected fruit value chains in the southern Philippines and Australia', are susceptible.

The target fruit crops for this research are durian, jackfruit and papaya. *Phytophthora* diseases thrive in wet-tropical climates such as that of the southern Philippines and are able to cause multiple diseases on the same host plant at various stages of its life cycle (Drenth and Guest 2004). In durian and jackfruit, diseases such as seedling dieback, leaf blight, root rot, truck cankers and preharvest and postharvest fruit rots are all caused by *Phytophthora*. Lim (1998) estimates that postharvest fruit rot results in 10–25% losses of durian fruit in Malaysia. Drenth and Guest (2004) estimate that overall disease loss from *Phytophthora* in durian ranges between 20% and 25% of production.

Jackfruit is seriously affected

Jackfruit is a very popular domestic fruit in the Philippines. It is grown throughout the country. Jackfruit decline is a major constraint to jackfruit production in the Eastern Visayas where it is a flagship commodity. In some areas, up to 90% of jackfruit trees are reported to be affected by decline syndrome manifested by leaf yellowing and drop, girdling stem lesions and rot, and eventually wilting and death (Figures 1 and 2)

In the disease surveys conducted since the start of the project, jackfruit decline is identified as the major constraint to jackfruit production in the region. Thirteen of the 24 plantations surveyed indicated a disease incidence greater than 50%. However, across the plantations surveyed, disease incidence ranged from 0 to 100% of trees affected (Table 1). The incidence of the disease appeared to vary depending on the age of trees and the management practices of individual farmers.

Results and discussions

Phytophthora management recommendations

The key management practice recommendations arising from the Southern Philippines Horticulture Program's research on Phytophthora disease control on jackfruit are:

- construction of drainage channels and/or mounds in the orchard
- removal of diseased fruits from the orchard
- pruning, mulching and ring weeding
- regular and complete harvesting of all fruit from the tree

Figure 1. A healthy jackfruit seedling (far left) and inoculated seedlings, showing different stages of decline, yellowing and wilting until death

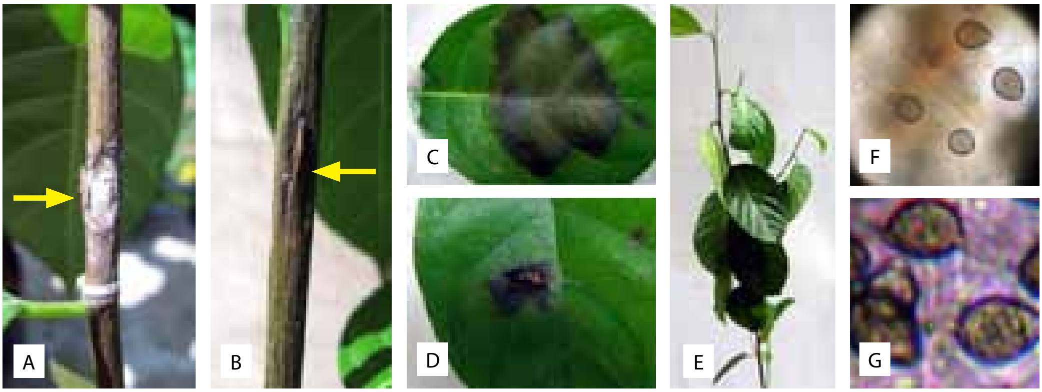

Figure 2. (a–b) Canker lesion on an inoculated stem; (c–d) blight lesion on inoculated leaves; (e) wilting of an inoculated seedling; (f–g) sporangia recovered from inoculated lesions

- minimal contact between the fruit and soil during harvesting
- In addition to these cultural control practices, the use of chemicals for *Phytophthora* control, such as Agri-Fos, and addition of fertiliser or compost to the production system will enhance the ability of farmers and nurseries to improve the level of *Phytophthora* control and the overall health of the orchard. It is the combination of both chemical and cultural practices for *Phytophthora* control in an integrated pest management (IPM) strategy that comprises the best practice recommendation.

Gross margin impacts

Tables 2 and 3 shows that adopting the recommended *Phytophthora*-control management practices induced changes in the production output and production cost in managing jackfruit orchards. Effective management of Phytophthora diseases in jackfruit orchards is expected to increase the number of fruit-bearing trees by about 11% and improve yields by about 88% due to the increased number of bearing trees and reduced yield losses. However, adopting the recommended cultural and chemical practices for *Phytophthora* control would contribute to a 61% increase in production costs. Adoption of cultural control practices is likely to involve additional costs for construction of drainage channels and mounds in the orchard, and for improved orchard hygiene practices. It is estimated that the use of new IPM chemicals for *Phytophthora* control such as Agri-Fos for trunk injection will incur an additional net cost of 6,182 pesos. These changes in yield and production costs with the adoption of the best practices would result in an increase in gross margin per hectare of about 92%.

Table 1. Disease incidence data from surveyed jackfruit farms

No.	Location	No. of trees (age)	Disease incidence (%)
1	San Isidro Mahaplag Leyte	980 (8 years old)	90
2	Curva, Ormoc City, Leyte	225 (10 years old)	87
3	Alibaba, Calbayog City	240 (10 years old)	95
4	Carayman, Calbayog Samar	320 (7 years old)	20
5	Balinsasayao, Abuyog, Leyte	160 (8 years old)	80
6	Tagbuhangin, Ormoc City	126 (5 years old)	6
7	Tagbuhangin, Ormoc City	73 (3 years old)	0
8	Green Valley, Ormoc City	300 (5 years old)	50
9	Carayman, Calbayog, Samar	160 (6 years old)	1.25
10	Nabang, Oquendo, Calbayog, Samar	160 (6 years old)	5
11	Casilda, Merida, Leyte	4,000 (2–3 years old)	1
12	Malinao, Mahaplag, Leyte	140 (11 years old)	100
13	Luna, Ormoc City	159 (6 years old)	0
14	Luna, Ormoc City	75 (7 years old)	65
15	Dolores, Ormoc City	65 (17 years old)	75
16	Dolores, Ormoc City	80 (6 years old)	95
17	Cob, Libertad, Ormoc City	66 (2.5 years old)	1
18	San Vicente, Ormoc City	156 (2 months old)	0
19	Donghol, Ormoc City	142 (7 years old)	75
20	Margen, Ormoc City	196 (7 years old)	25
21	Catmon, Ormoc City	46 (5 years old)	90
22	Catmon, Ormoc City	156 (7 years old)	50
23	Catmon, Ormoc City	46 (7 years old)	35
24	Cangag, Isabel, Leyte	100 (1 year old)	0

Table 2. Assumptions used in computing gross margins with and without integrated pest management (IPM)

Assumptions	Without IPM (farmers' current practices)	With IPM (best practice)
Tree spacing (m × m)	8 × 8	8 × 8
Mortality (% trees/ha)	13	3
Bearing trees (trees/ha)	136	151
Number of fruit/tree/year	20	20
Fruit/ha/year (including damaged fruits)	2,714	3,026
Average fruit weight (kg)	9.5	12
Yield loss (% damaged)	33.25	11
Balanced yield (kg/ha/year)	17,213	32,322
Age of trees (years)	10	10
Farm gate price (pesos/kg)	15	15

Table 3. Income, costs and gross margins (pesos) for jackfruit production, with and without *Phytophthora* integrated pest management

	Without IPM	With IPM
Income		
Yield without (kg/ha/year)	17,213	
Yield with (kg/ha/year)		32,322
Gross income @ 15 pesos/kg	258,190	484,829
Variable costs		
Ring weeding	0.00	3,840.00
Underbrushing	2,520	2,520.00
Fertilising (fertilisers and labour)	9,610.29	12,118.00
Pruning branches	0	1,560.00
Bagging	3,000.00	5,160.00
Drainage construction and maintenance	0	600.00
Mounding (every 6 months) ×2	0	2,400.00
Mulching (quarterly) ×4	0	1,440.00
Trunk injection (every 6 months) ×2 (Agri-Fos and labour)	0	6,181.00
Harvesting	4,200	7,200.00
Supplies	21,940	24,361.20
Land rental	1,500	1,500.00
Total variable costs	42,770	68,881
Gross margin per ha	215,420	415,949
Gross margin per tree	1,587	2,749

Source: Interviews with project component 2 (C2) fruit scientists and farmer collaborators in October 2012 at Visayas State University (Orr et al. 2010).

Estimating the benefits associated with adoption of IPM

Measuring the adoption of mango IPM research recommendation

Research to control *Phytophthora* generates benefits when the recommended practices introduced for managing jackfruit orchards are taken up and applied by farmers. The *Phytophthora* control strategies for jackfruit will deliver various benefits, including reduced fruit damaged or yield losses and improved yields. The first step in calculating the benefits of IPM research is to determine the size of the industry; the second is to estimate the area affected by the Phytophthora disease problem covered by the research; and the third is to determine the likely level of adoption within the affected region.

Researchers were interviewed to obtain their assessment, based on their own experience, of the extent of the problem being addressed by their research and what will be the potential impacts of the research and the likely levels of adoption within the affected region.

From the researcher interviews it was estimated that 57.5% (332.5 ha) of the total jackfruit production area in Region VIII is affected by the disease. In the interviews, the researchers were also asked about their expectations on the likelihood of their recommendations being adopted on the jackfruit farms in Region VIII. Information was collected on the expected adoption rate (%) after the first and subsequent years, up to a maximum level of adoption, and the expected time (years) to reach that maximum level.

Estimates of likely adoption

A preliminary estimate of the adoption rate has been made by key researchers involved in the project. They expect that adoption will occur from 2016 onwards, allowing 3 years for the evaluation and registration of new chemical control recommendation. Adoption of the best practices (combined chemical and cultural control) will reach a maximum adoption level of 77% after 4 years at year 2019 as a result of research and extension activities. It is also expected that it is possible that there would be some gradual adoption of the technology practices over time, even without this research project. This might occur due to other research taking place and from farmers conducting their own investigations or applying what they have learned from participation in other training activities and forums. The research reported here simply brings the time of adoption forward by

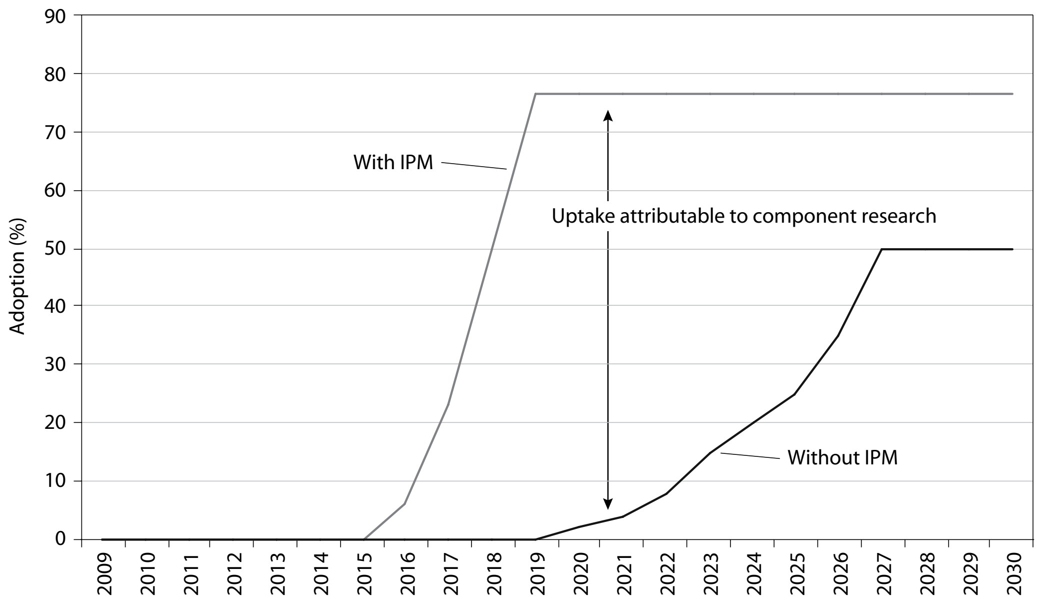

Figure 3. Adoption profile for *Phytophthora* research on jackfruit in Region VIII, with and without integrated pest management (IPM)

4 years. That is, if ACIAR had not funded the project it would have been another 4 years before the advice on Phytophthora disease management practices would be applied.

Financial analysis

To account for the time preference or priorities for use of money (opportunity cost), future benefits and costs were discounted to present values. All dollar costs and benefits were expressed in constant dollar terms, converted to Philippine pesos and discounted to the current financial year. Investment benefits were measured using the investment criteria of net present value (NPV) and benefit:cost ratio (BCR). The NPV is the difference between the PV of benefits and the PV of research, development and extension costs, while the BCR is the PV of benefits divided by the PV of the research costs. The NPV is also shown on an annualised basis over 20 years.

Tables 4 and 5 showed the results of the financial analysis done for jackfruit IPM research. The 5% discount rate was used as this is consistent with the rate used in ACIAR assessments. Sensitivity testing was undertaken at 0% and 10% as per ACIAR guidelines for assessing the impacts of its research activities (Davis et al. 2008).

At a 5% discount rate, the expected net present value of jackfruit *Phytophthora* research in Region VIII is 224.68 million pesos (A$5.49 million) with a benefit:cost ratio of 47:1, which means that for every peso invested in the research to control *Phytophthora* in jackfruit, we can expect a benefit of 47 pesos, representing an internal rate of return approximately 43% (Table 4).

The sensitivity of the investment returns to the use of different discount rates was tested. Table 5 indicates that at, 0% and 10% discount rates, the benefit:cost ratio results are 70:8 and 23.8, respectively.

Conclusions

Preliminary research has indicated that effective management of *Phytophthora* can reduce yield losses in jackfruit by approximately 22% per hectare and tree mortality by about 11%. Changes in yield and production cost associated with the adoption of best practice *Phytophthora* control will increase the gross margin per hectare by 93%. Based on the estimates of benefit–cost analysis and expectations of the level and rate of management practice adoption, the expected net present value of benefits from collaborative *Phytophthora* research in Region VIII is approximately 224 million pesos (A$5.49 million) with a benefit:cost ratio of about 47:1, representing an internal rate of return of approximately 43%.

Determination of the key technology characteristics and the farm-level impacts presented in this report will guide those farmers considering adoption of the technology. This would also have relevance for researchers, in terms of how their research and analysis will be designed to overcome or address any issues and constraints regarding adoption and to increase the appeal of technologies for which there is a genuine net benefit to farmers.

Jackfruit *Phytophthora* research being undertaken by the fruit C2 team in the overall project is intended to increase the volume and quality of jackfruit production. The research will lead to a shift in the supply

Table 4. Calculation of the benefit:cost ratio, using a 5% discount rate

Standard measures	Pesos	A$
Present value of benefits	229,483,894	5,615,700
Present value of costs	4,801,582	117,499
Net present value	224,682,312	5,498,200
Benefit:cost ratio	47:1	
Internal rate of return (%)	43	

Table 5. Sensitivity estimates

Discount rate (%)	Present value (PV) of benefits (pesos)	PV of costs	Net present values (pesos)	Net present value (A$)	Benefit:cost ratio
0	460,277,208	6,504,439	453,772,769	11,104,273	70.8
10	121,199,257	5,084,955	116,114,302	2,841,433	23.8

of jackfruit as production increases. If the increase in jackfruit production is large enough to affect the prices received by farmers in the region, consumers will benefit most via lower prices. However, if the demand for jackfruit is very strong and producers have good access to large markets or demand centres, the increase in production may have little effect on prices and producers will benefit from the research. The magnitude of the shift in supply is estimated by aggregating farm-level impacts using information about the extent and rate of adoption expected. The shift in supply is referred to as 'k-shift' in welfare economics. Estimation of the 'k-shift' associated with the component technologies is the link between the farm and regional level work undertaken in this report and the welfare analysis being prepared by the Philippine Institute of Development Studies to estimate the ex-ante net returns from research.

This report focuses on a financial assessment of the expected impacts at the farm to regional level and not yet the economy-wide (national level) impacts of the control technologies. As such, the results reported on returns to research invested may be revised as new information comes available.

Acknowledgments

The authors appreciate the time the researchers and farmer collaborators of the technical components Fruits—C2 Jackfruit and Durian *Phytophthora* have shared during the interviews and discussions to get feedback from them regarding the technologies.

The great contributions of Dr Anthea McClintock and Dr Leanne Orr, former members of the C5 Team, are also acknowledged. Thanks are also extended to Dr Kirrily Pollock and Dr David Hall for their comments and suggestions for the improvement of this paper.

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Gross margin impact analysis on adoption of *Phytophthora* control strategies for durian in Region XI, southern Philippines

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Abstract

In the Philippines, durian is marketed as 'flagship fruit' for Mindanao and is a high-value crop commanding high prices and with the potential to provide sustainable incomes for local farmers. *Phytophthora* has been associated with disease and consequential high yield and tree losses in durian. Collaborative research funded by the Australian Centre for International Agricultural Research in its project 'Integrated management of *Phytophthora* for durian and jackfruit' is developing strategic technologies for integrated disease management practices that will reduce yield loss associated with the disease, improve fruit quality and, ultimately, increase farm incomes. Part of the recommendation is to develop different levels of management options so that farmers, especially cash-constrained farmers, can be able to choose what level or kinds of practices they will adopt, depending on their financial resources and management skills. In this paper, the profitability of these effective management options for *Phytophthora* control at the farm level is discussed. It is estimated that 40% (4,520 ha) of the total production area (11,299 ha) is affected by *Phytophthora*. Preliminary research has indicated that effective management of *Phytophthora* can significantly reduce yield losses and improve yields from an increased number of bearing trees and reduced fruit losses. Changes in production output and production cost associated with the adoption of the recommended practices—low, medium or high management options for *Phytophthora* control—will provide farmers an increase in income of 26%, 47%, and 107%, respectively. A preliminary estimate of the adoption rate has been made by key researchers involved in the project. It is expected that adoption will occur from 2015 onwards, allowing a 2-year interval for the trialling and registration of new control chemicals. Adoption will reach a maximum of 30% after 6 years, in 2021, as a result of research and extension activities.

Introduction

Gross-margin analysis

The method used to evaluate the ex-ante farm-level benefits and costs of *Phytophthora* control technologies is based on the standard approach of gross-margin analysis. A gross margin is the total income from producing a crop minus the variable costs incurred in growing the crop. Gross-margin budgets are developed for selected crops using farmers' 'current practice' as the baseline. A set of 'with technology' gross-margin budgets is also prepared, based on the experience and judgments of experts. It is assumed that the relevant experts are the members of the research team developing the new or modified technology.

Gross-margin analysis ensures comparisons are made on a common unit basis, usually per hectare (ha), and that the analysis captures the main information useful for farmers to make a comparison between two alternative technologies or practices. By comparing the 'with' and 'without' technology,

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crop gross margins, an estimate of the net impact of the technology is obtained.

The genus *Phytophthora* is one of the most important plant pathogens worldwide and many plant species including those covered by the ACIAR project HORT/2007/067 component 2 (C2), 'Enhancing the profitability of selected fruit value chains in the southern Philippines and Australia', are susceptible. The target fruit crops for this research are durian, jackfruit and papaya.

Phytophthora diseases thrive in wet-tropical climates such as that of the southern Philippines and are able to cause multiple diseases on the same host plant at various stages of its life cycle (Drenth and Guest 2004). In durian and jackfruit, diseases such as seedling dieback, leaf blight, root rot, truck cankers and pre- and postharvest fruit rots are all caused by *Phytophthora*. Drenth and Guest (2004) estimate that overall disease losses from *Phytophthora* in durian range between 20 and 25% of production.

From the researcher interviews, it is estimated that 40% of the total durian production area in Region XI is affected by *Phytophthora*. It is also estimated that up to 25% of durian trees on a 1 ha farm were killed and 50% of the production of the remaining trees was lost or downgraded by the disease.

Phytophthora project expected outcomes

This work, conducted in collaboration with ACIAR, the University of Sydney and Philippine researchers from Visayas State University and the Bureau of Plant Industry, will lead to the following project outcomes:

- demonstration of effective *Phytophthora* disease control practices through participatory action research trials and dissemination of research results
  - effective control of *Phytophthora* disease in southern Philippines durian and jackfruit orchards
  - reduced tree losses, due to control of *Phytophthora* root rot
- improved yields, due to control of *Phytophthora* fruit rot
  - effective control of *Phytophthora* disease in the southern Philippines durian and jackfruit nurseries
  - reduced seedling losses, due to control of *Phytophthora* disease
- increased availability of disease-free seedlings for orchardists.

Results and discussion

Phytophthora management options (low, medium, high)

Table 1 shows the different practices in the three management options recommended. Baseline farmers practice only spraying and pruning. The different levels of management involve additional practices over and above current practices. The 'low management' option would involve sanitation, ring weeding, mulching, mounding and construction of a drainage canal. Additional practices such as the applications of organic soil amendments and effective micro-organisms (EM) + chicken dung, using garden balsam extract as a biocontrol for canker treatment and the use of *Trichoderma*, are key practices involved in the 'medium management' option. The 'high management' option includes all the recommended practices identified by research for durian *Phytophthora* control. It involves a combination of cultural and biological approaches, and chemical application, including use of new chemicals, particularly Agri-Fos®.

Gross-margin impacts

Table 2 shows the changes in production costs and output that adopting the *Phytophthora* control management options recommended from component 2 of the research project will make. These changes are discussed below.

Changes in yield and production costs

Changes in yield

Effective management of *Phytophthora* diseases in durian orchards is expected to increase the number of bearing trees and reduce yield losses. Adopting the recommended low management level will increase yield by 30%, from 5.2 tonnes (t) (farmers' current practice) to 6.8 t. It is also expected that, as additional practices or control strategies are applied, there will be further increases in yield. Applying the medium and high management option will contribute to increases in yield by 64% and 128%, respectively, over the yield from farmers' current practice.

Changes in production costs

Applying new technologies and practices for controlling *Phytophthora* entail extra costs. Adopting the recommended low management option will increase productions costs by 99% compared with farmers' current practice; from 8,100 pesos/ha to 16,134 pesos/ha. Production increases as farmers apply higher levels of management. Applying the medium management level will increase production costs by 432% over farmers' current practice. The medium management option involves improved cultural practices plus the application of effective micro-organisms, garden balsam extract and Trichoderma. The 'high management' option includes

Table 1. Comparison of current farmers' practices (without new technologies) and recommended practices (with new technologies) for *Phytophthora* control

'Without'	'With'		
Baseline (farmers' current practices)	Low management	Medium management	High management
Spraying	Sanitation (removal of leaves and fruit on the ground)	General weeding (ring weeding + under brushing) 2×	Sanitation (removal of leaves and fruits on the ground)
Pruning	Ring weeding (5×)	Mulching	Mulching
	Mulching	Pruning	Pruning
	Spraying	Mounding (Vermicast)	Mounding (Vermicast)
	Pruning	Drainage canal construction	Drainage canal construction
	Mounding (soil only)	Organic soil amendments (4×)	Organic soil amendments (4×)
	Drainage canal construction	Application of effective micro-organisms (EM) + chicken dung (2×)	Application of EM + chicken dung (2×)
		Canker treatment biocontrol (garden balsam extract) (6×)	*Trichoderma* application (4×)
		Trichoderma application (4×)	Inorganic nutrient management (calcium, boron) 2×
			Canker treatment with chemicals (Aliette®, Kocide®) (6×)
			Phosphonate injection (Agri-FOS®) (1×)
			Insecticide application (4×)

Source: Workshop with Fruit Component 4 researchers and farmer collaborators

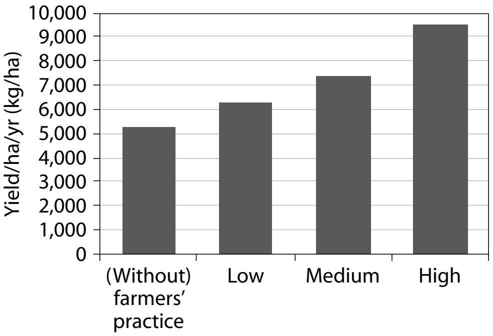

Figure 1. Increases in yield over farmers' current practice as a result of application of the different management options

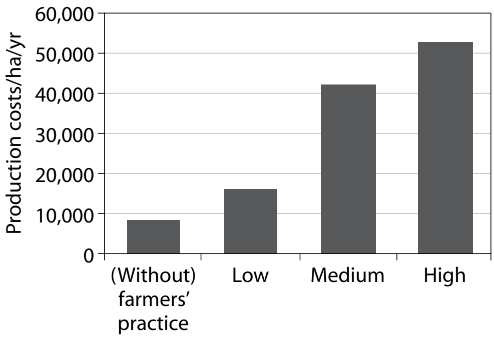

Figure 2. Changes in production costs associated with adoption of the different levels of management

Table 2. Durian gross margins 'with' and 'without' *Phytophthora* control

Income and costs	Without	With		
	Farmers current practices	Low management	Medium management	High management
INCOME (pesos/ha)				
Without (kg/ha)	5,265			
With (kg/ha)		6,823.44	8,648.64	12,004.20
GROSS INCOME @ 30 pesos/kg	157,950	204,703.20	259,459.20	360,126.00
VARIABLE COSTS				
Sanitation (manual or herbicide)	0.00	2,400.00	3,000.00	3,628.00
Mulching	0	4,350.00	4,350.00	4,350.00
Pruning	300.00	300.00	300.00	300.00
Chemical spraying (insecticide and fungicide application (4×))	3,150	1,884.00	1,884.00	2,236.80
Mounding (soil only)	0	300.00	300.00	300.00
Drainage canal construction	0.00	1,200.00	1,200.00	1,200.00
Organic soil amendments (4×)	0	0.00	624.96	624.96
Application of effective micro-organisms + chicken dung (2×)	0	0.00	20,600.00	20,600.00
Trichoderma application (4×)	0	0.00	2,472.00	2,472.00
In-organic nutrient management (calcium, boron) 2×	0	0.00	0	300.00
Canker treatment with biocontrol (garden balsam extract)	0	0.00	1,596.00	0.00
Canker treatment with chemicals (Kocide®, Aliette®) (6×)	0	0.00	0.00	6,636.00
Phosphonate injection (1×)	0	0.00	0	3,420.00
Harvesting	3,150	4,200.00	5,289.94	7,342.37
Land rental	1,500	1,500.00	1,500.00	1,500.00
TOTAL VARIABLE COSTS	8,100	16,134	43,116.90	54,910.13
GROSS MARGIN PER HA	149,850	188,569	216,342	305,216
GROSS MARGIN PER TREE	960.58	1215.51	1424.75	2000.56

all the recommended practices identified by research for durian *Phytophthora* control. It involves a combination of cultural and biological approaches, and chemical application, including use of new chemicals.

Changes in income (gross margins)

Changes in yield and production costs when adopting one or other of the recommended management options will result in changes in income and gross margin. Adopting the low management option will increase farmers' incomes by 26%. If farmers are willing to put in additional capital to get even higher yields, the medium and high management options would provide farmers with additional income of 44% and 104%, respectively, over that gained from use of their current practice.

Financial benefits and costs to growers per hectare

The costs and benefits to growers, in percentage terms, are as follows:

- If the low management option is adopted, the increase in yield is 30%, with an increase in production costs of 99%.
- If the medium management option is adopted, the increase in yield is 64%, with an increase in production costs of 432%
- If the high management option is adopted, the increase in yield is 128%, with an increase in production costs 578%
- If the low management option is applied, the increase in income is 26%.

- If the medium management option is applied, the increase in income is 44%.
- If the high management option is applied, the increase in income is 104%.

These statistics are summarised in Table 3.

Adoption

Estimates of adoption rates

Key researchers involved in the project have made a preliminary estimate of the adoption rate. They expect that adoption will occur from 2015 onwards, following a 2-year interval for the trialling and registration of new chemical control aspects. Adoption will reach a maximum of 30% after 6 years, at year 2021, as a result of research and extension activities.

Adoption expectations

Four important considerations were identified in the researcher interviews relating to durian and jackfruit farmers adopting cultural and chemical *Phytophthora* control recommendations:

1. willingness to uptake changes in crop management practices
2. availability of chemicals
3. availability of funds to implement recommendations
4. dissemination of research recommendations.

Project Component 2 researchers point out that most durian growers in the southern Philippines are small-scale farmers, the majority with an area planted to durian of 1–3 hectares. They therefore have limited financial capacity.

Another important point which comes through in the scientist interviews is that, in general, farmers are reluctant to adopt management strategies when they cannot actually see for themselves the results of the research. Farmer forums, field days and other dissemination campaigns will assist in the extension of the research recommendations. All those surveyed considered that the effectiveness of the extension service in disseminating new technologies is the key factor in determining the rate and extent of adoption of *Phytophthora* control strategies for durian in the southern Philippines.

Conclusion

Preliminary research has indicated that effective management of *Phytophthora* can significantly reduce yield losses and improve yield from an increased number of bearing tress and reduced fruit losses. Changes in production and production costs

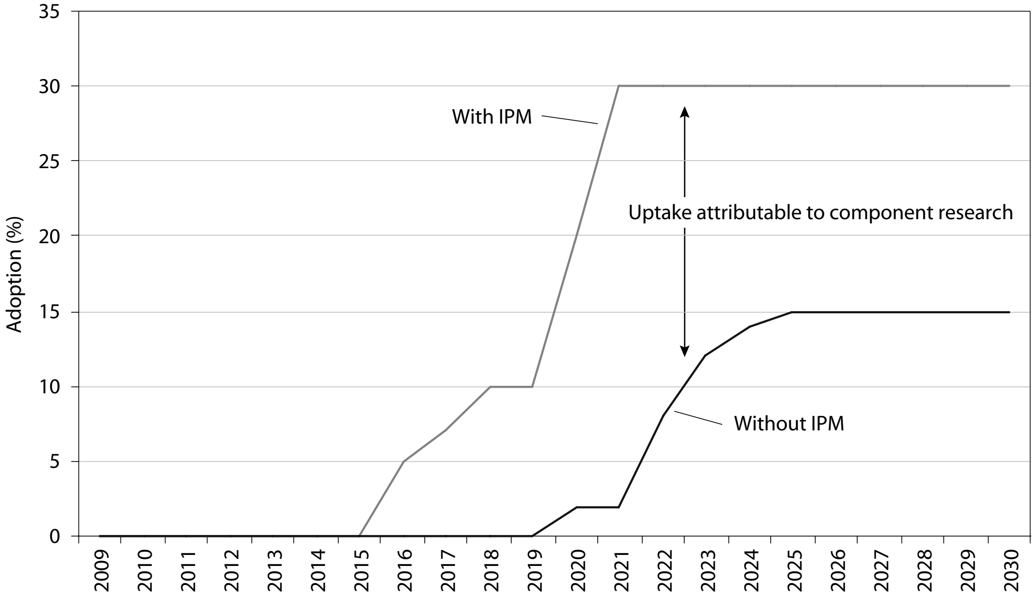

Figure 3. Adoption expectations for the new *Phytophthora* control strategies in durian in Region XI, with and without integrated pest management (IPM)

Table 3. Summary of financial benefits and costs to growers. FP = farmers' current practice; low, medium and high are different levels of management

'Without' – 'with'	Change in costs (%)	Change in yield (%)	Change in gross margin (%)
FP – Low	99	30	26
FP – Medium	432	64	44
FP – High	578	128	104

associated with the adoption on the recommended practices—low, medium, and high management options—for *Phytophthor*a control will provide farmers an increase in income of 26%, 44% and 104%, respectively.

A preliminary estimate of the adoption rate has been made by key researchers involved in the project. It is expected that adoption will occur from 2015, following a 2-year interval for the trialling and registration of new chemical controls. Adoption will reach a maximum of 30% after 6 years, in 2021, as a result of research and extension activities.

Determination of the key technologies' characteristics and the farm-level impacts presented in this report will guide those farmers considering adoption of this technology. This would also have relevance for researchers in terms of how their research and analysis should be designed to overcome or address some issues and constraints regarding adoption and to increase the appeal of technologies that have a genuine net benefit to farmers.

This report focuses on the expected technology impacts of control technologies at the farm level available from the research to date. As such, the results reported here are preliminary and may be revised as new information comes available through the ongoing research.

Acknowledgments

The authors appreciate the time the researchers and farmer collaborators of the technical components Fruits – C2 jackfruit and durian *Phytophthora* of the ACIAR project 'Integrated management of *Phytophthora* for durian and jackfruit' have shared during the interviews and discussions to get feedback from them regarding the technologies.

The valued contributions of Dr Anthea McClintock and Dr Leanne Orr, former members of the C5 Team, are also acknowledged. Thanks are also extended to Dr Kirrily Pollock and Dr David Hall for their comments and suggestions for the improvement of this report.

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Analysing the performance of smallholder cabbage farmers in the southern Philippines

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Abstract

The leading producers of cabbage in southern Philippines are Bukidnon in Northern Mindanao and Davao del Sur in Southern Mindanao. With declining farm-gate prices along with increasing production costs, farmers' profits are falling. This study examined the productivity, technical efficiency and profitability of farmers situated in these areas. Wholesalers, followed by the farmers, gain the highest net margin among the three actors in the chain considered. Net earnings of the farmers are primarily affected by the two classifications of cabbage—'good' or 'reject'—with the former contributing more to profit. Rejects constitute about 20% of the total production of Bukidnon and 15% of the total production of Davao del Sur farmers. This poor quality produce is associated with limited training in cabbage production and postharvest practices, poor road condition and poor storage facilities. Training could improve farmers' incomes by 22,026 pesos per cropping season. Productive farmers are described as those who are relatively older and have a higher education level. Among the inputs considered, increasing land area is the primary factor for increasing production. On the other hand, efficient farms are those that are relatively large, at least 1 ha, with older and more experienced farmers located in Kapatagan, Davao del Sur. Quantity of seeds and total cost negatively contribute to the total farm profit, while land area, price of good classification cabbage and total yield are positively contributing to farm profit. Thus, helping farmers generate more profit is not a straightforward approach. It needs an enabling environment such as training and infrastructure. It also takes time, as suggested by age, education and experience variables. Lastly, it takes additional land resources to further increase farmer's productivity, efficiency and farm profit.

Introduction

In the Philippines, the Cordillera Administrative Region in northern Luzon is the leading producer of cabbage growing about 79% (98,942 tonnes) of the country's total production in 2011 (125,309 tonnes). The Central Visayas region ranked second (6%) with 7,947 tonnes, while Northern Mindanao ranked third (5%) with 5,751 tonnes. In Mindanao, the northern and southern regions are the top cabbage producers, constituting about 47% and 34%, respectively, of Mindanao's total production in 2011 (BAS 2012). The majority (84%) of the cabbage in Northern Mindanao is produced in Bukidnon (4,835 tonnes) while the bulk (63%) of Southern Mindanao's cabbage production is concentrated in Davao del Sur (2,645 tonnes). While Northern Mindanao's production consistently increased to about 230% from year 1990 to 2009, the production in Southern Mindanao barely increased in the same time period (Figure 1).

Despite increasing wholesale and retail prices, farm-gate prices (expressed in real terms) in Northern Mindanao and Southern Mindanao declined by about 44% and 27%, respectively, from 1990 to 2011. This is

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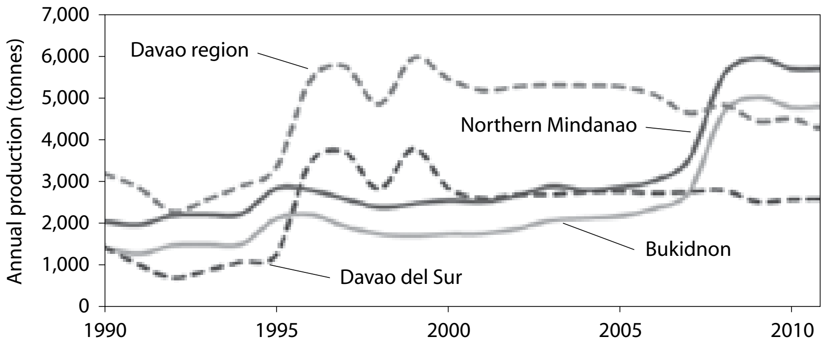

Figure 1. Cabbage production in the southern Philippines. Source: BAS (2012)

primarily due to increase in the volume of production. Production costs have increased by nearly 28% from 1990 to 2011 (BAS 2012). The decline in the prices received by the farmers, along with the increase in production costs, poses a threat to farmers' profit. Hence, this study seeks to identify the significant factors affecting profitability of the farmers. In the process, the productivity and technical efficiency performance of cabbage farmers in the southern Philippines are also measured. This study also aims to identify other issues affecting small-scale cabbage producers.

Methodology

Several approaches were used to examine the performance of farmers in the value chain. These include value-chain analysis, net-margin analysis, and statistical and econometric analyses that involve the estimation of productivity, technical efficiency and profitability of farmers.

The respondents in the study are from key cabbage-producing areas in the southern Philippines (Table 1). The major producing area in Northern Mindanao is Bukidnon, while Kapatagan in Davao del Sur is the main producer of cabbage in Southern Mindanao. Hence, the study focused the analysis on farmers situated in these production areas.

Purposive sampling was employed, involving groups of farmers, wholesalers and retailers. Purposive sampling is a non-probability sampling technique, wherein respondents are chosen based on researchers' limitations and purpose. In this study, the number of respondents is limited due to availability of respondents, and time and budget constraints.

Value-chain and net-margins analyses

A value-chain approach is necessary to understand the environment that affects the performance of small-scale producers. The value-chain and net-margins analyses provide background information on the current status and activities performed by value-chain actors across key-producing areas in the southern Philippines.

The value chain for cabbage in the southern Philippines was mapped, based on interviews among value-chain actors, key informants and review of the literature. The functions and activities performed by each player in the chain were also described.

To compare the performance of the farmers relative to other players in the chain, net-margins analysis was employed. The analysis of net margins is an examination of the profit (per kg) of each player in the chain. In this study, the actors considered are limited to

Table 1. Distribution of respondents

Location	Farmers	Wholesalers	Retailers	Wholesaler– retailer	Total
Davao del Sur	55	–	–	–	55
Davao City	–	4	4	–	8
Bukidnon	34	–	4	1	40
Cagayan de Oro City	–	6	5	–	11
Total	89	10	13	1	114

farmers, wholesalers and retailers. The net margin is the net earning received by the actor after deducting all costs incurred, and is computed as follows.

$$NetMargin = \frac{P_s(Q_s) - [P_b(Q_b)+MC]}{Q_s} \quad (1)$$

where
P_s = selling price
Q_s = quantity sold
P_b = buying price
Q_b = quantity produced/bought
MC = marketing cost

Quantity produced or bought may not be equal to the quantity sold whenever there are postharvest losses, storage and handling losses, and marketing losses. High losses usually translate to a lower net margin.

Productivity analysis

A production function is an expression of output in terms of inputs used. Several production functions are available in the literature, but the most widely used among them are: 1. neo-classical; 2. neo-classical with interaction; 3. Cobb–Douglas like; 4. transcendental; and 5. transcendental with interaction (Debertin 1986). Production function modelling is widely applied in agriculture (Tvrdon 2003; Ekbom and Sterner 2008).

The neo-classical production function captures the three stages of production (i.e. increasing output at an increasing rate, increasing output at a decreasing rate, and decreasing output). This is modelled using a polynomial function of either degree 2 or 3. In this study, to preserve the degrees of freedom, a polynomial function of degree 2 is used. Interaction among inputs could also be introduced through a multiplicative factor to further improve the model. On the other hand, the Cobb–Douglas-like production function is the most popular among them because of its simplicity. The use of constant elasticities, which in most cases are less than 1.0, implies diminishing returns to scale, which depicts stage II of the production. This is modelled using double-log model. Lastly, the transcendental function is a modification of the Cobb–Douglas-like production function capturing the three stages of production. This is modelled using double-log model plus linear effects of the inputs. Interaction among inputs is also possible in this model.

Land, labour, inorganic fertiliser, organic fertiliser, pesticide and seeds were the identified production inputs for cabbage production. Farm attributes such as land tenure, source of capital, mode of transportation, farm location, road type and farmers' perceptions of the road condition from farm to highway. Also included in the production models as having a linear relationship to output were farmer characteristics such as age, gender, household size, level of education, cabbage-farming experience, total years of farming experience, and membership of producer organisation. This was performed to capture the important factors affecting productivity aside from the use of direct inputs. The productivity equation is expressed as:

$$\begin{aligned} \text{Output} = {} & f(\text{Land}, \text{Labor}, \text{Fert}_{\downarrow}\text{in}, \text{Fert}_{\downarrow}\text{or}, \\ & \text{Pest}, \text{Seed}, \text{Agefarmer}, \text{Gender}, \\ & \text{HS}, \text{Educ}, \text{CabExp}, \text{Exp}, \text{Member}, \\ & \text{Tenure}, \text{Transpo}, \text{OwnCap}, \\ & \text{RdType}, \text{RC}, \text{Bukid}) \end{aligned} \quad (2)$$

where
Output = total harvest (in kg)
Land = land area of productive tomatoes (in ha)
Labour = own plus hired labour (in person-days)
$\text{Fert}_{\downarrow}\text{in}$ = inorganic fertiliser (in sacks)
$\text{Fert}_{\downarrow}\text{or}$ = organic fertiliser (in sacks)
Pest = cost of pesticide (in pesos)
Seed = cost of seeds (in pesos)
Agefarmer = age of the farmer (in years)
Gender = dummy variable for male – 1, otherwise – 0
HS = household size (number of household members including the farmer)
Educ = ordinal variable for educational attainment 1–6
CabExp = cabbage-farming experience (in years)
Exp = total farming experience (in years)
Member = dummy variable for producer organisation membership – 1, otherwise – 0
Tenure = dummy variable for ownership of land – 1, otherwise – 0
Transpo = dummy variable for motorised transportation – 1, otherwise – 0
RdType = dummy variable for paved type of road – 1, otherwise – 0
RC = dummy variable for farmers' perception on good road condition – 1, otherwise – 0
OwnCap = dummy variable for farmers who own their capital – 1, otherwise – 0
Bukid = dummy variable for Bukidnon – 1, otherwise – 0

The use of cost for the pesticide and seed variables, rather than quantity, was due to the differences in the types of pesticides used (different pesticide type for different pest) and units (liquid versus solid), and seed packs (marketed in different packs). This implementation was consistent with the work of Khai and Yabe (2011). Furthermore, inclusion of Davao del Sur as a dummy variable for location would result in perfect multicollinearity, and it was thus excluded from the model.

In analysing the importance of each input in translating into output, elasticity was used. A Cobb–Douglas-like function returns a constant elasticity while mean elasticity was used for the other four production functions. Higher elasticity implies that the output is more responsive to the use of the particular input.

GNU regression econometrics and time-series library (GRETL) software (Adkins 2010) was used to perform the ordinary least squares (OLS) estimation.

Technical efficiency analysis

Technical efficiency is the ability of a firm to produce the optimal output given a set of inputs (Kumbakher and Lovell 2000). The two principal methods that have been used are data envelopment analysis (DEA), which involves mathematical programming, and stochastic frontier analysis (SFA), which involves econometric estimation (Coelli 1996a).

Data envelopment analysis and Tobit analysis

DEA has the capacity to detect fully efficient decision making units (DMUs) within the sample size. It has a broad application in the field of agriculture (Thiam et al. 2001; Guyader and Daures 2005; Gul et al. 2009). The DEA component can be expressed as:

$$\begin{aligned} &\min_{\lambda, x_i^*} w_i' x_i^* \\ st \quad & -q_i + Q\lambda \geq 0, \\ & x_i^* - X\lambda \geq 0, \\ & I1'\lambda = 1, \\ & \lambda \geq 0, \end{aligned} \tag{3}$$

where: w_i is a Nx1 vector of input prices for the ith DMU; x_i* is the cost-minimising vector of inputs calculated by the linear programming model given the input prices w_i and the output levels q_i ; λ is a Ix1 vector of constants; and I1 is an Ix1 vector of ones. The value of θ obtained is an efficiency score of the ith DMU which satisfies $0 \leq \theta \leq 1$.

Using DEA methodology, two approaches are possible; input-orientated or output-orientated standpoints. The former minimises the inputs while producing the same level of output while the latter maximises the output using existing inputs. Adjustments are possible due to slack inputs/output. Furthermore, two assumptions are possible: constant returns to scale (CRS) and variable returns to scale (VRS). In this analysis, VRS was assumed since perfect competition in the market cannot be assumed, and there are contraints to finances. DEAP v2.1 written by Coelli (1996a) was used.

After getting the efficiency score, it is subjected to regression on various farm attributes and the farmer's profile, which can identify variations in technical efficiencies of the farmers. This uses either the OLS method or Tobit regression (Thiam et al. 2001). In this study, Tobit analysis (Sigelman and Zeng 1999) was employed using Equation (4):

$$\begin{aligned} & y_i^* = x_i\beta + \varepsilon_i \\ & y_i = y_i^* \, if \, y_i^* > 0 \\ & y_i = 0 \, if \, y_i^* \leq 0 \end{aligned} \tag{4}$$

where y_i^* is the dormant dependent variable, y_i is the observed dependent variable, x_i is the vector of independent variables, β is the vector of coefficients, and the ε_i's are assumed to be independently normally distributed $\varepsilon \sim N(0,\sigma)$ which implies that $y_i \sim N(x_i\beta, \sigma)$.

Tobit regression was performed using GRETL (Adkins 2010).

Stochastic frontier analysis

SFA is a parametric approach to estimating frontiers. It is widely known, imposing a functional form on the production and making assumptions about the data. SFA measures technical efficiency through the use of an error term in the production frontier. This error term is classified into two components: 1. statistical noise and 2. associated factors handled by the farmer (Bakhsh 2007). The second component forms the technical inefficiency model. SFA is unable to handle zero input or output and multiple outputs (FAO 2011). Despite this, SFA is preferred because of its intrinsically random process, which is useful in the efficiency evaluation of any agriculture-related studies (Ekunwe and Emokaro 2009).

Thus, the stochastic production function is written as:

$$y_i = f(x_i\beta)e^{\varepsilon}; \; \varepsilon_i = \upsilon_i - \mu_i \tag{5}$$

where y_i represents the output of ith farm, x_i represents the input, β represents the vector of the unknown parameter, υ_i represents the random error, and μ_i represents the error associated with technical inefficiency, which is under the control of the farmer.

As argued by Battese and Coelli (1995), the two-stage approach is not coherent in its supposition on the technical inefficiency effect. As a result, a one-stage approach was formulated where both the stochastic production function and technical inefficiency effect in the frontier are simultaneously estimated through maximum likelihood estimation. Cobb–Douglas and Translog production function are considered in this study through FRONTIER v4.1 written by Coelli (1996b).

Farm profit analysis

Understanding the farmer's profit and the factors affecting it are the most commonly used approaches to assessing the performance of small-scale producers. Econometric analysis was used to identify the factors affecting farmer's profit. This approach is widely applied in fisheries (Hyuha et al. 2011), agriculture (Juszczyk 2005; Olawepo 2010) and agroforestry (Safa 2005). OLS regression was used to model farm profit given in the equation:

$$\text{Farm Profit} = f(\text{Vol}, \text{PrGood}, \text{PrRJ}, \text{TC}, \text{MktgCost}, \text{ProdnCost}, \text{Fert}, \text{Pest}, \text{Labor}, \text{Seed}, \text{Land}, \text{Agefarmer}, \text{Gender}, \text{HS}, \text{Educ}, \text{Exp}, \text{Train}, \text{Member}, \text{Tenure}, \text{Transpo}.\text{OwnCap}, \text{Bukid}) \quad (6)$$

where:
Farm Profit = revenue – cost (in pesos/ha)
Vol = volume sold (in kg/ha)
TC = total cost of production plus marketing (pesos/ha)
PrGood = price of good cabbage
PrRJ = price of reject cabbage
MktgCost = total marketing cost (pesos/ha)
ProdnCost = total production cost (pesos/ha)
Fert = quantity of fertiliser used (sacks/ha)
Pest = cost of pesticide used (pesos/ha)
Labour = quantity of labour used (number of persons/ha)
Seed = quantity of seeds used (grams/ha)
Land = total land area devoted for cabbage farming (in ha)
Agefarmer = age of the farmer (in years)
Gender = dummy variable for male – 1, otherwise – 0
HS = household size (number of household members including the farmer)
Educ = ordinal variable for educational attainment 1–6
Exp = cabbage farming experience (in years)
Train = dummy variable for cabbage-related training – 1, otherwise – 0
Member = dummy variable for producer organisation membership – 1, otherwise – 0
Tenure = dummy variable for ownership of land – 1, otherwise – 0
Transpo = dummy variable for motorised transportation – 1, otherwise – 0
OwnCap = dummy variable for farmers who own their capital – 1, otherwise – 0
Bukid = dummy variable for Bukidnon – 1, otherwise – 0

Davao del Sur as a dummy variable for location was excluded due to perfect multicollinearity. GRETL software (Adkins 2010) was used to perform OLS estimation.

Diagnostic tests

Aside from the significance of the model and adjusted *R*-squared as criteria to validate the model, several diagnostic tests were performed to satisfy the assumptions of the classical linear regression model (CLRM). Ramsey's regression specification error test (RESET) was used for evaluating the correct specification of the model. Mis-specification appears when the model lacks the necessary data, includes unnecessary variables and when the wrong functional form is used (Gujarati 2006). White's test for heteroscedasticity was used to check for the assumption of constant variance of the error terms (i.e. homoscedastic variance). The violation of homoscedasticity affects the efficiency of the model. Should the model suffer from heteroscedasticity, it is remedied using a heteroscedasticity-corrected model,which makes use of the generalised least squares approach. Testing for autocorrelation is not applicable since the data used were cross-sectional and the ordering of the data is random. The issue of near-perfect multicollinearity was immaterial for the farm inputs, since they are believed to have a direct effect on production and are considered independent from each other. Moreover, the theoretical specification of the production models suggests including all the direct inputs. Normality of the error terms, which is critical for a small sample size, was also tested using Jarque–Bera test.

Statistical analysis

The significant differences between profit, revenue, cost, production losses, marketing losses, yield, price, net margin, and efficiency with respect to the farm attributes, farmer's profile and farm practices where analysed using the Statistical Package for the Social Science (SPSS). Independent samples t-tests using equal and not equal variances (whichever is appropriate) were used for the analysis involving two factors. One-way analysis of variance (ANOVA) using Tukey for equal variances and Tamhane T2 for unequal variances was used for analysing three or more factors. The level of significance used for both analyses was 10%. These methods were performed to further explain the factors affecting the performance of farmers in the value chain in the southern Philippines.

Value chain of cabbage in the southern Philippines

The value chain was mapped based on surveys among respondents and from related literatures. The roles and functions of each actor were described based on conducted interviews. Cabbages from Mindanao are supplied within the region and are also shipped to Luzon and Visayas markets (Figure 2).

Input supplier

Barangay Kapatagan in Digos City, Davao del Sur, is approximately 77 km from Davao City and about 25 km from Digos City proper. In Kapatagan, farmers cannot bargain for lower input prices because there are only two agri-supply stores in the area. When these suppliers run out of the inputs needed for production, farmers buy inputs from Davao City or Digos City. The farmer-respondents have built a good relationship with the input suppliers, hence they are allowed to purchase on credit without a written agreement. The materials purchased on credit are often paid for after the harvest season.

Bukidnon farmers, on the other hand, buy inputs in the nearest agri-supply market or in trading areas, which are located in the cities of Malaybalay and Valencia in Bukidnon and Cagayan de Oro City. There are a number of agri-supply stores in Bukidnon and farmers are thus able to choose an input supplier who offers the best prices. In most cases, farmers buy the needed inputs in Cagayan de Oro City, after transporting the produce to the wholesale market.

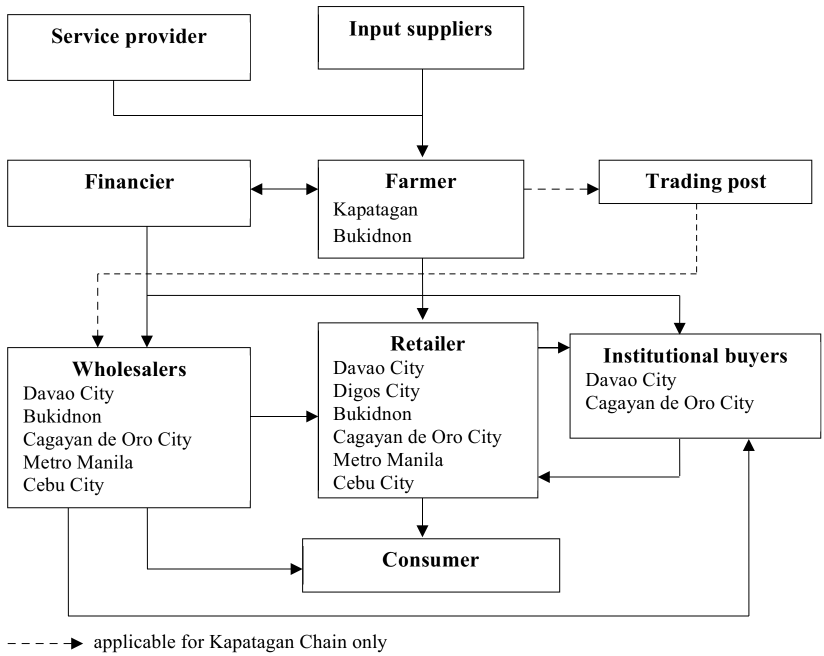

Figure 2. Value chain for cabbage in the southern Philippines. Source: Survey 2012

Farmers prefer to buy inputs in Cagayan de Oro because there are more agri-supply stores and input prices are relatively lower than those in Bukidnon.

Farmer

Most of the farmers in Kapatagan and Bukidnon engage in cabbage farming because they can sell the cabbages after 3 months. 'Wakamini' is the common variety planted in Kapatagan, while 'Resist Crown' is the common variety planted in Bukidnon.

In Kapatagan, farmers can have, at most, four cropping periods in a year. However, in Bukidnon, they choose to have, at most, two cropping periods in a year. According to some Bukindon farmers, it is not good to plant the same crop continuously, for two reasons: 1. demand is not stable, so they plant cabbage on occasions where they can anticipate a higher price; 2. pests will easily adapt and reproduce, so they have to change the crop to manage the pests.

In both areas, farms located near the roads have fewer problems in transporting their produce because any means of transportation can be used. However, there are some farm locations where non-motorised modes of transportation (such as horses, carabao or manual carrying) are used. This is one of the major problems of the farmers, because a horse, for instance, can carry a maximum of only three sacks. They also takes many hours to transport the harvest to the designated area. During transport of the harvest, poor road conditions cause the sacks to fall from draft animals. This results in crop damage and thus increases marketing losses.

Financier

There are few cases in Bukidnon where cabbage-farmers' capital is financed. The majority use their own money for farming because they are sure that they have income after the harvest. According to the farmer-respondents in Bukidnon, they do not gain enough from financing because of high interest rates. The situation becomes worse if production fails. However, some farmers who are clients of financiers said that financing was beneficial. They also added that financiers provide all the inputs needed, which is convenient for the farmer. They are also assured that harvests are marketed, because the financier either seeks buyers or markets the produce.

In contrast, most of the Kapatagan farmers source their capital from financiers. In fact, when farmers were asked about the production problems they encounter, they report a lack of possible financiers who could provide inputs. Farm maintenance was also mentioned. Arrangements are dictated by the financiers. The following are the most common arrangements: 1. the farmer pays for the financed inputs plus interest at 2.00 pesos/kg; 2. The farmer pays a percentage of profits, which is usually 60:40 or 70:30, with the higher percentage going to the financier. There are also financiers who have a 50:50 arrangement on percentage profits.

There are farmers in Kapatagan who are also financiers. Most of these financiers have relatively big farm areas and are able to produce large volumes of vegetables. They also plant different kinds of crops, aside from cabbages.

Wholesalers

Some of the financiers in Kapatagan are also wholesalers. Due to the absence of financiers during the conduct of the survey, the clients of financiers were interviewed instead. One of the farmer-clients said that his financier is a wholesaler in Bankerohan, Davao City. He directly sells his harvests to the financier. The wholesale price is based on the prevailing wholesale price in Davao. However, the wholesaler deducts 25% of the total weight of the produce, which is equivalent to 25–30 kg. The 25% of the total weight is assumed to be those parts of the plants that are non-consumable, commonly known in the area as *reseko*. In this case, the farmers absorb the wastage cost. Furthermore, wholesalers appear to gain more from wastage as they sell the cabbages as is, i.e. uncleaned.

The same payment mechanism is practised in Bukidnon and Cagayan de Oro. Most of the wholesalers in Cagayan de Oro come from different provinces. Most of the wholesalers are situated in Bulua West-Bound Market. They are located in the *bodega*, an assembly area where farmers coming from different areas drop off their crops. The wholesalers rent spaces in the *bodega* and wait for the other wholesalers and *viajedors* to contact them and get their orders. There are also walk-in wholesalers who do not have established relationships to co-wholesalers. In Cagayan de Oro, wholesalers who were posted in Agora Market were transferred to Bulua, West Bound Public Market in August 2011.

Service providers

In this study, three kinds of service providers are identified: farm labourers, hauling and trucking services, and storage and trading facilities.

Farm labourers

In Kapatagan, farm labour is called *hurnal*. They are paid to do the following tasks:

- Bagging of seeds—in Kapatagan, baggers are paid 80–90 pesos for every 1,000 seeds, while in Bukidnon, they are paid 50–80 pesos for every 1,000 seeds.
- Ploughing and harrowing—hired ploughers and harrowers are paid on a daily basis, commonly 100–140 pesos, excluding the use of a carabao or cow. If they have animal aid, they are paid up to 250 pesos.
- Planting—hired planters are paid on a daily basis, usually 100–140 pesos. Sometimes, the planters are also the ploughers or harrowers. The number of days in planting depends on how large the area is. Usually, planting can be finished in 1 day if the famers have enough labourers.
- Fertiliser, herbicide and pesticide application—hired labourers are paid on a daily basis. However, there are farmers in Kapatagan and Bukidnon who prefer the *pakyawan* system, under which the hired labourer will work for the whole duration of the production, which is at least 3 months. Labourers are paid 1,000 pesos/month. Daily wage rates in Kapatagan and Bukidnon range from 100 to 250 pesos.
- Weeding—the farmers commonly do the weeding by themselves. Weeders are paid 100–120 pesos/day. The same wage rates are applied in Kapatagan and Bukidnon.
- Harvesting—harvesters are paid depending on their arrangements with the farmers. In Kapatagan and Bukidnon, some harvesters are paid depending on the number of sacks harvested, usually 10–15 pesos/sack. There are also some harvesters who are paid on a daily basis, usually 100–120 pesos/day.

Haulers or kargadors

Kargadors are hired by farmers to transport products from the field to the assembly area using a horse or their own labour. Most of the *kargadors* are paid depending on the number of sacks transported at 20 pesos/sack. Others are paid on a daily basis, usually 100 pesos/day. Farmers depend heavily on them for transportation, especially those farmers whose production areas are hard to access.

There are also haulers in the drop-off areas in the markets. They are the ones who unload the vegetables from the truck and bring them to the stalls. They are paid on a per-sack basis, usually 10 pesos/sack.

Trucking services

Farmers who do not have their own transport service, rely on trucking services. Payments are usually on a per-sack basis. In Lantapan, Bukidnon, farmers pay 130 pesos/sack from Lantapan to Cagayan de Oro City. On the other hand, Kapatagan farmers pay 100 pesos/sack for the trucking service to Davao City.

Storage and trading facilities

The case of the farmers is different from the wholesalers and retailers, since they do not pay for permanent stalls. They only display their vegetables until such time as all the vegetables are sold. The owner of the stall will be paid an amount of 1 peso/kg share of all the cabbages that the farmer displays. The farmer can display all his crops until they are all purchased.

For the wholesalers and retailers, they normally pay on a monthly or annual basis. After harvesting, Bukidnon farmers commonly deliver the crops to a *bodega* in Cagayan de Oro City. Permanent wholesalers in Bulua West Bound Market pay the annual rent of 2,000 pesos.

In Bankerohan, 3 pesos/sack is charged at the *Bagsakan* centre. There are also farmers or wholesalers who avail of a per-block of space basis of payment. If the wholesalers do not yet have buyers for the vegetables, they can display them in rented blocks within the dropping area. This is appropriate for those who deliver more than 100 sacks. In Cagayan de Oro, farmers display all their vegetables in the said area until all of them are sold.

Storekeepers

Storekeepers are hired by the wholesalers or retailers to help them watch over the store while they are not around. Most of the time, the helpers are relatives of the owners. They are normally paid 100–180 pesos/day.

Retailers

All of the retailers interviewed sell other crops aside from cabbage. In Bankerohan, Valencia and Cagayan de Oro, retailers purchase cabbages for cash every 2 days (on average) depending on the volume of cabbages left in their stalls and the delivery schedule of the supply coming from the farmers. Some of the interviewed retailers in Davao City supply to other provinces outside Davao City.

There were also retailers in Bankerohan who supply cabbages to institutional buyers such as supermarkets and restaurants, but only if they are being contacted by the management. Supplying supermarkets requires good-quality cabbages, which is why only few a retailers engage in supplying institutional markets. The retailers supply cabbages and other kinds of vegetables in the cafeterias in NCCC B3. They do not have contract agreements but they have to meet the volume and quality requirements.

Consumers

Households are the main consumers of cabbage in the southern Philippines. According to a wholesaler in the Bankerohan market, the estimated consumption of cabbages in Davao City is approximately 5,000 kg/week.

Net margins of key actors

There are two classifications of cabbage that are produced—'good' or 'reject'. However, reject cabbage still has a minimal value of 5.07 pesos/kg in Bukidnon and 5.97 pesos/kg in Davao del Sur, which is barely enough to cover cost of production. This results in a net margin of 0.20 pesos/kg for Bukidnon and 2.06 pesos/kg for Davao del Sur, covering about 20% of total production for Bukidnon and 15% of the total production of Davao del Sur (Table 2). There are several reasons why farmers experience reject produce, including: 1. limited training in cabbage production and postharvest practices; 2. poor road conditions, which affect the quality of produce delivered to market; and 3. poor storage facilities that will not preserve product freshness during the time that it takes to sell a considerable volume of cabbages.

The first two reasons can be supported by the statistical analysis while the third reason was identified by the researchers from observations in the *bodege* of Bulua, West bound public market, Cagayan de Oro City, and *Bagsakan* of the Bankerohan public market, Davao City.

Farmers who have attended cabbage-production-related training were generating more income (131,880 pesos/ha) than non-trained farmers (85,364 pesos) (Table 3). The 55% additional income if trained can be traced to a lower production cost (62,306 pesos/ha) and a higher yield (14,442 kg/ha). In Bureau of Agricultural Statistics estimated costs and returns (BAS 2012), the cash cost was estimated to be 66,494 pesos/ha. This implies that trained farmers incur a 6.3% lower production cost, while non-trained farmers incur a 4% higher production cost. Yield per hectare is estimated at 14,701 kg (BAS 2009). Both farmers perform below BAS estimates, by 2% and 14%, respectively, lower yields. BAS (2009) estimates the returns above cash costs to be 135,351 pesos/ha. Trained farmers generate profit close to (–3%) the expected returns, while non-trained farmers have an unrealised profit of around 37%.

The high profit of trained farmers can be further explained by the classification of produce (Table 4). It is evident that proper training is the key to producing a higher volume of quality produce, as non-trained farmers suffer from rejects as high as 55%, while trained farmers keep rejects at a lower rate of 24%.

Table 2. Summary of net margins across value chain actors

	Volume (kg)	Total cost (pesos)	Total revenue (pesos)	Profit (pesos)	Cost/kg (pesos/kg)	Price/kg (pesos/kg)	Net margin (pesos/kg)
Farmers	473,535	2,120,081	5,997,645	3,877,564	4.48	12.67	8.19
Good	387,620	1,729,450	5,535,900	3,806,450	4.46	14.28	9.82
Reject	85,915	390,631	461,745	71,114	4.55	5.37	0.83
Bukidnon							
Good	222,095	1,082,316	3,070,715	1,988,399	4.87	13.83	8.95
Reject	56,805	276,823	287,920	11,097	4.87	5.07	0.20
Davao del Sur							
Good	165,525	647,134	2,465,185	1,818,051	3.91	14.89	10.98
Reject	29,110	113,808	173,825	60,017	3.91	5.97	2.06
Wholesale	3,036,956	26,507,186	59,558,840	33,051,654	8.73	19.61	10.88
Retail	140,424	3,730,324	3,829,248	98,924	26.56	27.27	0.70

Table 3. Farmer training as a factor in costs, losses and profits

Training	Percentage of respondents	Production cost/ha	Production loss/ha (kg)	Yield/ha (kg)	Profit/ha (pesos)
Trained	61	62,306	3,138	14,442	131,880**
Non-trained	39	69,148	2,523	12,643	85,364**
BAS (2009) estimates		66,494[a]		14,701	135,351[b]

[a] Cash cost
[b] Returns above cash cost
**Significant at 5% level

In Davao del Sur, training on pest management and chemical application is organised by the Department of Agriculture and chemical companies, respectively. In Bukidnon, on the other hand, most of the training is on vegetable production, which is organised by the Department of Agriculture.

Since training farmers has a potential to lower rejects from 55% to 24%, non-trained farmers are experiencing a reduction in value from the 4,437kg of reject to 1,897kg (i.e. 24% of the 7,904kg total production of non-trained farmers), a net benefit of 2,450kg of good quality cabbages. Using the net margin information calculated in Table 2, with reject at 0.83 pesos/kg and good at 9.82 pesos/kg, this unrealised profit amounts 22,026 pesos per cropping (i.e. 2,450 kg at 8.99 pesos/kg).

Furthermore, road condition is directly related to the quality of produce sold (Table 5). Farmers with good road conditions are experiencing higher net margins for the good classification valued at 6.41 pesos/kg, compared with those farmers situated on bad roads with a net margin of 3.40 pesos/kg for good classification. This results in a significant difference in profit per ha by 86% favouring those farmers situated on good roads. This is also affected by the increase in marketing cost as the quality of the road becomes poor.

Table 4. Training as a factor in producing quality produce

	Good (kg)	Reject (kg)	Percentage rejection
Trained	5,205***	1,613**	24
Non-trained	3,557***	4,347**	55

*** significant at the 1% level; ** significant at the 5% level

BAS (2009) reported a returns above cash cost at around 135,351 pesos/ha. Farmers with good road condition perform higher by 1% more profit while those situated in bad road conditions suffer an unrealised profit of around 46% lower than the expected estimates.

The analysis of net margins shows that farmers from Davao del Sur gain higher net margins than farmers in Bukidnon (Table 2). The average price per kilogram is higher in Davao del Sur than in Bukidnon, while the average cost is lower in Davao del Sur. On average, Davao del Sur cabbage farmers cultivate an area of about 0.9 ha per farmer while Bukidnon farmers cultivate an area of 1.2 ha per farmer.

Among the three actors in the chain considered for the net margins analysis, the wholesalers gain the highest net margin. Wholesalers keep the farmgate prices at low level with minimal increase while wholesale prices are skyrocketing (Figure 3). This implies wholesalers having buying power over farmers while they also enjoy selling power over retailers.

Productivity analysis

From the five production functions modelled, the neo-classical model has met all the assumptions of CLRM except the normality test. Despite this violation, the model was accepted due to relatively larger sample size (n = 75). The model with 64% adjusted

Table 5. Municipal/barangay to market road condition as a factor in marketing cost, margin and profit

Brgy/municipal to market road condition	Percentage of respondents	Net margins (pesos)		Profit/ha (pesos)	Marketing cost/ ha (pesos)
		Good	Reject		
Good	51	6.41*	–1.54	136,847**	7,303
Bad	49	3.40*	–0.14	73,734**	10,221

** significant at the 5% level

R^2 is significant at the 1% level; the variances are equal and the variables are correctly specified.

Equation (7) presents the neo-classical model wherein sociodemographic factors such as age of the farmer and education level appear to be significant at 10% alpha. The age of the farmer has a direct relationship to the yield of production. Yield increases as the farmer ages. Farmers who are below 40 years old are producing 11,652 kg/ha while those 40 years old and above are producing 16,078 kg/ha. On average, the latter group of farmers is producing 38% higher than the first group. Moreover, the education level of the farmer is also positively contributing to the production yield. As the level of education of an average cabbage farmer increases, yield of cabbage increases. Elementary and high school farmers are producing 12,553 kg/ha and 12,560 kg/ha, respectively, while college farmers are producing at the rate of 19,292 kg/ha.

$$Yield = -2700.63 + 7295.86Land^{***} - 16.12Land^2 + 7.89Labour + 0.13Labour^2 + 44.90Fert\_or - 0.31Fert\_or^2 - 124.66Fert\_in + 13.69Fert\_in^2 + 0.22Pest\_c - 0.000004Pest\_c^2 - 3.90Seed\_c + 0.002Seed\_c^2 + 61.97Age^{*} + 467.06Education^{*} \quad (7)$$

The elasticities of each direct input and each effect on the average yield of cabbage from the neo-classical model are presented in Table 6. It is observed that all of the direct inputs considered are positively related to cabbage average yield. A 10% increase on the average land area (0.04 ha) increases the average production by 7% (330 kg). With respect to labour, an increase of 10% in average labour use (3 person-days) would increase average production by 1.1% (52 kg). In terms of fertiliser use, a 10% increase in the average quantity of the organic fertiliser (2.8 sacks) increases average yield by 1.6% (76 kg), while an increase in the inorganic fertiliser by 10% (0.46 sacks) increases average yield by 0.01% (0.47 kg). Considering the cost of pesticides and seeds, a 10% increase in both costs (482.30 pesos and 74.81 pesos, respectively) increases yield by 2.2% and 1.9% (104 kg and 90 kg), respectively.

The non-responsiveness of output to inorganic fertiliser implies over-application of that input. This assertion can be supported by the study of Tulin et al. (2010). In their experimental research in Leyte, southern Philippines, using field trial tests, fertiliser cost could be reduced by 50% without sacrificing productivity.

Technical efficiency analysis

Four models were derived to evaluate the technical efficiency of the 55 valid farms in Bukidnon and Kapatagan (Table 7). The technical efficiency models suggest that, as land area increases, efficiency increases (or inefficiency decreases) at 5% alpha. This is supported by the data in Table 8 which show that as land area increases the cost per ha significantly decreases. Aside from improving productivity with elasticity of 0.70 for land, efficiency also improves, and therefore also cost per kg. This is a case of increasing returns to scale of land use.

The model also suggests that, up to a point, as the farmer ages, the efficiency level of his farm increases (or inefficiency decreases) at 1% alpha. As shown

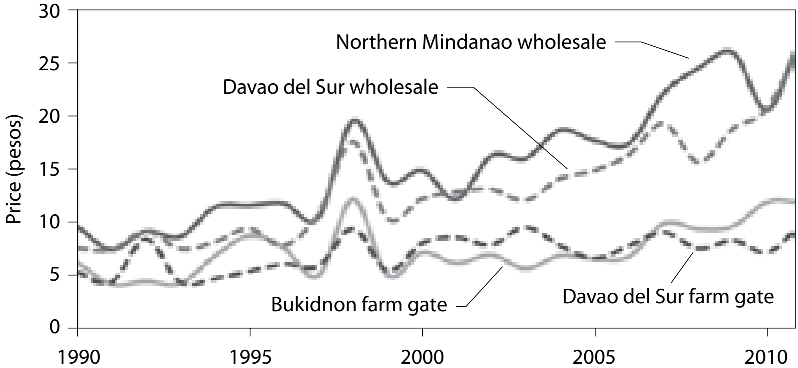

Figure 3. Nominal farm gate and wholesale prices for cabbage in the southern Philippines. Source: BAS (2012)

Table 6. Summary of elasticities and effects on mean yield

Inputs	Elasticities	Equivalent of 10% increase in input	Equivalent increase in output (kg)
Land	0.7	0.04 ha	330
Labour	0.11	3 person-days	52
Organic fertiliser	0.16	2.8 sacks	76
Inorganic fertiliser	0.001	0.46 sacks	0.47
Cost of pesticides	0.22	482.30 pesos	104
Cost of seed	0.19	74.81 pesos	90

in Table 9, from the total cost per ha information, efficiency increases from ages 20–49, but falls above that. However, as with land, age of farmers also improves productivity as shown in equation (1). Thus, with greater volume produced as the farmer ages, cost per kg improves, except for the farmers of age 60 and above. In general, farm efficiency improves with the age of the farmer.

The number of years of cabbage-farming experience also has a direct relationship with farm efficiency at the 10% alpha level. Performance with age is similar. From the total cost per ha information, efficiency increases at the initial stages (less than 10–29 years old) but drops as farmer gains additional experience (30 and below). Meanwhile, cost per kg shows a downward trend. Table 10 does not really give a clear picture of improving farm efficiency with respect to farmer's experience. This is due to the significance level of the experience variable which is at 10% alpha only. The pattern can be fully deciphered once sample size increases.

Finally, the model also shows that Bukidnon farms are technically inefficient. The technical efficiency scores with respect to location suggest that, on average, farms in Kapatagan, Davao del Sur, are more technically efficient than Bukidnon farms (Table 11). Furthermore, this is supported by farm efficiency performance (Table 12). This finding is consistent with the net margin results discussed earlier, where Davao del Sur farmers gain higher net margins than farmers in Bukidnon. This implies that higher net margins could be mainly due to better farming efficiency in the area.

Davao del Sur farmers have approximately four cropping periods in a year, while Bukidnon farmers have, at most, only two cropping periods. Bukidnon farmers do not plant the same crop continuously for two reasons: 1. demand is not stable, so they plant

Table 7. Summary of technical efficiency and inefficiency models

	Technical efficiency model						Technical inefficiency model					
	Input-orientated			Output-orientated			Cobb–Douglas			Translog		
	coeff	*p*-value		coeff	*p*-value		coeff	*t*-ratio		coeff	*t*-ratio	
Constant	0.84	0.00	***	0.83	0.00	***	2.94	1.44		0.28	0.29	
Land	**0.15**	**0.16**		**0.42**	**0.12**		**–0.39**	**–0.38**		**–1.06**	**–2.01**	**
Age	**0.00**	**0.69**		**0.00**	**0.73**		**–0.10**	**–1.35**		**–0.12**	**–5.79**	***
Gender	–0.04	0.56		–0.19	0.07	*	–1.23	–1.16		–0.95	–1.73	**
HS	0.01	0.45		0.01	0.67		–0.04	–0.18		0.02	0.15	
Educ	–0.03	0.27		–0.07	0.03	**	–0.61	–1.10		–0.16	–1.06	
Org_mmber	–0.06	0.36		–0.07	0.58		–2.09	–1.46		–1.22	–1.09	
Cap_source	–0.09	0.11		–0.06	0.47		0.35	0.47		0.09	0.19	
Yrs_Farm	0.00	0.33		0.00	0.59		–0.05	–0.63		0.02	0.55	
Yrs_CabFrmng	**0.01**	**0.14**		**0.00**	**0.51**		**–0.09**	**–1.79**	*	**–0.03**	**–0.86**	
Bkdnn	**–0.06**	**0.36**		**–0.12**	**0.16**		**3.47**	**1.57**		**5.26**	**7.44**	***
Land_tenure	0.09	0.09	*	0.15	0.13		1.11	1.03		1.08	1.86	**

* *t*-test (2-tail, df = 54) @ 10%, 1.67; @ 5%, 2.0; @ 1%, 2.67
Note: Values for variables consistently and significantly affecting efficiency are in bold type.

Table 8. Increasing land area improves farm efficiency

Land area	Respondents	Total cost/ha	Cost/kg
Less than 0.5 ha (1)	60%	90,256[a]	5.92
0.50–0.99 ha (2)	31%	47,908[b]	3.79
1 ha and above (3)	9%	29,664[c]	3.38

a–1&2***,1&3**, b–2&1***,2&3[ns], c–3&1**,3&2[ns]

Table 9. Farm efficiency varies with farmer's age

Age	Respondents (%)	Total cost/ha	Cost/kg
20–29	9	70,629	5.64
30–39	42	69,352	5.93
40–49	24	64,663	4.09
50–59	16	70,807	4.08
60 and above	10	98,882	8.06

cabbages on occasions where they expect that they will receive a higher price; 2. pests will easily adapt and reproduce, so they have to change the crop to manage the pests. The variety of cabbage planted may have also affected the efficiency of farmers. Farmers in Kapatagan, Davao del Sur, plant the 'Wakamini' variety while farmers in Bukidnon plant the 'Resist Crown' variety. However, the effect of the differences in variety planted across locations needs further study.

Farm profit analysis

Equation (10) presents the model for farm profitability, which is significant at 1% alpha with an adjusted R^2 of 91%. This model was subjected to heteroscedasticity correction, so testing for specification was not applicable. Nevertheless, the model has normally distributed residuals. The factors land area (in ha), total cost (in pesos), price of good cabbage classification (in pesos) and total yield (in kg) are significant at the 1% level, while seed is significant at 5% alpha.

$$Farm\ Profit = -24547.90^{***} - 316.28Seed\_g^{**} + 77390.20Land\_area^{***} - 0.90Total\_cost^{***} + 2652.22Price\_good^{***} + 7.56Total\_yield^{***} \quad (10)$$

The quantity of seeds and the total cost are both negatively contributing to the total farm profit per hectare. However, land area, price of good classification and total yield are positively contributing to the total farm profitability.

Table 10. Farm efficiency varies with farmer's experience

Experience (years)	Respondents (%)	Total cost/ha	Cost/kg
Less than 10	41	73,837	6.44
10–29	37	71,216	4.31
20–29	12	59,572	4.01
30–39	6	86,941	5.85
40 and above	4	95,138	6.64

Table 11. Technical efficiency scores with respect to location

Location	Non-parametric		Parametric	
	Input-orientated	Output-orientated	Cobb–Douglas like	Translog
Bukidnon	0.76	0.53	0.57	0.57
Davao del Sur	0.85	0.74	0.78	0.90
Average	0.80	0.61	0.66	0.71

Table 12. Davao del Sur's farmers are more efficient than Bukidnon's

Location	Respondents (%)	Total cost/ha	Cost/kg
Bukidnon	62	73,004	6.31
Davao del Sur	38	69,032	3.94

The model suggests that an increase in the quantity of seed by 1 gram/ha decreases profit by 316.28 pesos/ha. Overpopulation of crops results in intraspecific competition for nutrients, and increased mutual shading of leaves creates a microclimate favourable to insect pests and diseases.

As the farmer increases land area devoted to cabbage production, profit increases by 77,390.20 pesos/ha. This is consistent with the productivity and technical efficiency models, which show that, as land area increases, productivity increases and farm efficiency improves, thus profit also increases.

The total cost incurred in cabbage production has an inverse relationship with profit. A 1 peso increase in the total cost incurred per hectare decreases farm profit by 0.90 pesos/ha. The majority (75%) of the farmers are not members of a producer organisation. Statistical analysis shows that their production costs are significantly higher (67,941 pesos/ha) compared with those who are members of producer organisations (59,588 pesos/ha). Moreover, farmers engage in financing arrangements due to insufficient capital for production. Statistical analysis suggests that farmers whose capital is either borrowed or financed gain lower profit (56,467 pesos/ha) than farmers who own the capital for production (163,076 pesos/ha).

Lastly, the price of good-quality cabbage positively influences profit by 2,652.22 pesos/ha while total yield has a direct relationship with farm profit. An increase in total yield per hectare increases farm profit by 7.56 pesos/ha.

Conclusions

In the southern Philippines, cabbages are predominantly grown in Bukidnon in Northern Mindanao and Davao del Sur in Southern Mindanao. These farmers are facing declining farm-gate prices along with increasing production costs. Thus, this study was conducted to examine the productivity, technical efficiency and profitability of farmers situated in these areas.

Net margins analysis suggests that wholesalers (10.88 pesos/kg) are the ones gaining the highest net margin among the three actors in the chain considered, followed by farmers (8.19 pesos/kg) then retailers (0.70 pesos/kg). Wholesalers control the farm-gate prices while they have a command for the wholesale prices. They are the beneficiaries among the three actors.

Farmers' performance in the value chain is primarily driven by the 'good' classification of produce priced at 14.28 pesos/kg while cabbages classified as 'reject' are priced at 5.37 pesos/kg. Around 20% of the total produce of Bukidnon is classified reject, while 15% of Davao del Sur produce suffers from the same condition.

Three main reasons for high rejects are considered. Firstly, poor-quality produce is associated with limited training in cabbage production and postharvest practices. Trained farmers are more profitable, their produce valued at 131,880 pesos/ha, while non-trained farmers achieve only 85,364 pesos/ha profit. This was close to the cost and return suggested the Bureau of Agricultural Statistics, which estimated profit at 135,351 pesos. This is mainly due to the lower production costs of trained farmers at 62,306 pesos/ha and higher yield at 14,442 kg/ha. Furthermore, trained farmers are producing lesser reject (24%) compared to non-trained farmers (55%). Non-trained farmers suffer from unrealised profit of 22,026 pesos per cropping due to rejects.

The second reason is associated to poor road conditions. Farmers situated on roads in good condition enjoy a net margin of 6.41 pesos/kg of good produce while farmers on roads in bad roads have to settle for 3.40 pesos/kg of good produce net margin. Furthermore, marketing cost is lower for the former group at 7,303 pesos/ha, compared with 10,221 pesos for the latter group.

The third reason considered is the poor storage facility in the wholesale areas, particularly in the *bodega* of the Bulua West-Bound Market, Cagayan de Oro City and *bagsakan* of Bankerohan public market, Davao City.

Econometric modeling of the production function suggests that farmers can become productive as they age and acquire higher education. As the farmer ages, yield could increase by 62 kg. Young farmers (below 40 years old) are producing cabbage at the rate of 11,652 kg/ha while older farmers (40 and above) can reach production as high as 16,078 kg/ha. With respect to level of education, farmers with at least college level of education are more productive at 19,292 kg/ha compared with high school and elementary educated farmers who have production rates of 12,560 kg/ha and 12,553 kg/ha, respectively.

Among the inputs considered, output is most responsive to increase in land area. An additional 0.04 ha of land would result in an increase in output of 330 kg. Furthermore, that inorganic fertiliser is over-applied is hypothesised due to the very low elasticity of 0.001 of the said input, indicating minimal responsiveness to any increase in the use of the said input.

Technical efficiency models consistently suggest four main variables affect efficiency. Firstly, as the farm area increases (at least 1 ha), farm efficiency also improves. High cost is associated for farms of less than 0.5 ha (90,256 pesos/ha), followed by those with land area 0.50–0.989 ha (47,908 pesos), while relatively larger farm size exhibits the lowest cost valued at 29,664 pesos/ha.

In addition, as a farmer ages and gains experience, efficiency also improves, except for farmers of age 60 and above, or those with experience of 40 or more years. However, experience is significant at only the 10% level. Lastly, Bukidnon farms are technically inefficient compared to farmers in Kapatagan, Davao del Sur, consistent with the result of the net margin analysis implying that higher margin is mainly associated with higher farming efficiency. A possible reason for geographic peculiarities is the cabbage variety planted. Davao del Sur farmers plant the 'Wakamini' variety, while farmers in Bukidnon plant the 'Resist Crown' variety. This difference should be further explored.

Econometric modelling for farm profit shows that land area, price of good classification and total yield are contributing to farm profitability. An additional 1 ha of land devoted to cabbage farming would increase profit by 77,390 pesos/ha. This finding is consistent with productivity and technical efficiency analysis. The price of good classification of cabbage will positively influence profit by 2,652 pesos/ha. An increase in the total output by 1 kg increases farm profit by 7.56 pesos/ha.

In contrast, the quantity of seeds and total cost negatively contribute to the total farm profit. An increase in the quantity of seed by 1 gram per hectare will decrease profit by 316 pesos/ha. If total cost incurred per hectare increases by 1.00 peso, farm profit will decrease by 0.90 pesos/ha.

In conclusion, helping farmers generate more income will involve 1. additional land resource allocated for cabbage farming. Doing this will improve farmers' productivity and efficiency, thus increasing farm profit. It will also 2. take time, as suggested by age, education and experience variables being directly related to productivity and efficiency. Finally, an enabling environment is needed by the farmers, in terms of interventions involving training and improved infrastructure, such as better roads.

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Analysing the performance of farmers in the mango value chain in major production areas in Davao Region, Philippines

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Abstract

The Philippine 'Carabao' mango has established its reputation locally and internationally as a superior breed among other varieties in the world but its supply pales in comparison with the local and international demand. The Philippine mango industry is also facing a complex market structure brought by different actors in the supply chain. Hence, this study was conducted to analyse the performance of farmers in the value chain of mango in three major producing areas in the Davao region: Davao City; Digos City in Davao del Sur; and the Island Garden City of Samal in Davao del Norte. Specifically, the study aims to identify the roles of different actors in the mango supply chain, assess the profitability of the actors and identify the factors affecting profitability. Value chain and net margin analyses were employed. The results reveal that the interrelatedness of farmers, financiers and middlemen has a primary effect on the distribution of benefits among the actors in the mango supply chain. Statistical analysis suggests that trained farmers in Digos City who have trees of mature age and who are not under financing arrangement are more profitable. Econometric analysis identified volume sold and prices as drivers of profitability, while land area and cost of production negatively influenced profitability. It also confirms that non-financed farmers are more profitable than financed farmers. Wholesaling activities are favoured in Digos City due to minimal marketing costs, while retailing activities are best in Davao City due to larger captive market, specifically the Bankerohan public market.

Introduction

The mango industry plays an important role in economic conditions in the Philippines. Mango is a high-value commercial crop in the country, generating income of about $US7,121[2] per hectare per year from trees 10–20 years old. The industry also provides employment such as farm labour and opportunities for entrepreneurs. It also contributes to the country's competitiveness in the foreign market.

The Philippines is one of the top 12 mango producers in the world (FAO 2012). The country exports to Hong Kong (China), Japan, Singapore, Switzerland, the UK and USA, among others. Despite being a dollar earner, the industry still suffers from low production due to varying agricultural practices, poor infrastructure system, weak linkage to exporters and constraints in import regulations in countries like Japan and USA.

Mango production in the Philippines has declined in the past 5 years. The island of Guimaras, which used to be the country's main exporter of mango to Hawaii and the mainland USA, has not exported mangoes for 5 years now because it cannot meet market demand. From an average of 12,000 tonnes (t) in 2006, mango production in Guimaras dropped

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2 All conversions used in this paper are based on 18 June 2012 published exchange rate: 1 $US = 42.1290 Philippine pesos.

to 8,000 t/year. This problem is also experienced by other mango-producing provinces in the country. In Mindanao, mango production has consistently declined since 2004 and increased at around 18% in 2007. Production declined again by about 3% in 2008, increased by about 1% in 2009 and dropped by 10% in 2010 (BAS 2012).

Mindanao was the source of about 26% of the country's total mango production in 2010. Southern Mindanao (Davao region) ranks ninth largest producer of mango in the Philippines, and fourth largest producer of mango in Mindanao next to Zamboanga Peninsula, SOCCSKSARGEN (South Cotabato, Sultan Kudarat, Sarangani, General Santos City) and Northern Mindanao. Mango production in Davao region has fluctuated in the past 9 years; however, its production has continuously declined over the past 2 years. The top mango-producing provinces in Davao region are Davao del Sur, Davao City and Davao del Norte, which deliver about 69%, 16% and 8% of the region's production, respectively. These three areas supplied about 14% of Mindanao's mango production in 2010.

In terms of demand, the consumption of Philippine mangoes has consistently dropped since 2008, thereby decreasing opportunities for farmers to supply to high-value markets. Mango prices in the country were also increasing gradually in the past few years because of the rise in the prices of inputs such as fertilisers, herbicides and pesticides. The trend in farm, wholesale and retail prices in 2010 has been upward, with average per kilogram prices of $US0.68, $US1.02, and $US1.45, respectively (BAS 2012).

The declining production and consumption of mangoes in the country, and the increasing input prices, pose a threat to local mango farmers. Hence, the analysis of the performance of farmers in the mango value chain is necessary to identify the issues and opportunities that need to be addressed. This study seeks to compare the performance of farmers among the top three mango-producing provinces in Davao Region—Davao City, Digos City in Davao del Sur and the Island Garden City of Samal (IGACOS) in Davao del Norte. This study also seeks to identify the factors affecting profitability of mango farmers.

The study is intended to provide inputs for policy formulation and identify interventions necessary to remove bottlenecks in the mango supply chain. The results of the study serve as guides for policymakers, development workers and other researchers in formulating and implementing development strategies for the mango industry in Mindanao, specifically in the Davao region.

This paper is presented as follows. The methods employed in the study are presented in the next section, the results are presented and discussed in the third section, followed by a fourth section giving the conclusions and recommendations of the study.

Methodology

This study was conducted from November 2011 to May 2012. There were 101 respondents in a survey of the various actors in the mango supply chain (Table 1). Purposive sampling was employed, involving cases of different types of farmers with small, medium and large farms located in three areas in Davao region, with and without financing, and members and non-members of a producer organisation. Purposive sampling ensures the comprehensiveness of the analysis. In addition, key informants who have special knowledge of the mango industry in the region were also interviewed.

Value-chain analysis was done to assess the performance of farmers in Southern Mindanao. It was mapped based on key informant interviews, survey data and a review of the literature. However, for the purpose of this study, analysis has focused only on the performance of farmers in the value chain, setting aside other marketing intermediaries. Net earnings received by farmers and the factors affecting their profitability were examined to complete the analysis.

Table 1. Distribution of respondents

Location	Farmers	Wholesalers	Retailers	Retail-wholesaler	Key informant	Total
Davao City	33	1	2	0	0	36
Digos City	38	2	1	1	1	43
IGACOS[a]	19	0	2	0	1	22
Total	90	3	5	1	2	101

[a] Island Garden City of Samal

The profitability of farmers across marketing channels was assessed through net margins analysis. This provides the net earnings received by the farmer, obtained after deducting all costs incurred and is computed as follows:

$$NetMargin = \frac{Ps(Q)\text{–}[P_B(Q)+MC]}{Q} \quad (1)$$

where:
Ps = selling price per unit
P_B = buying price per unit
Q = quantity
MC = marketing costs incurred.

The net margins analysis considered only bearing trees and excluded the development cost incurred in establishing those trees. Production costs included only the direct operating costs such as fertiliser, pesticide, herbicide, packing materials, harvesting materials, labour costs including food expenses, and cost of materials and equipment and their depreciation costs. Unaccounted costs include water and electricity, land taxes, rental, interest on crop loans, repairs, interest on operating capital and rental value of farmers' own land.

Statistical analysis was used to test for the significance of the difference of production losses/ha, volume sold, cost/kg, price, net margin and profit/ha, with respect to farmer's age, family size, educational attainment, mango-farming experience, membership of a producer organisation, mango-related training, the age of trees, geographic location and financing status. For analyses involving two categories, independent sample t-tests using equal and not equal variances assumptions were used, while for three categories, one-way analysis of variance (ANOVA) using Tukey's honestly significant difference for equal variances and Tamhane T2 for unequal variances was utilised. Levels of significance considered were 1%, 5% and 10%. The statistical analysis was performed using the Statistical Package for Social Science (SPSS).

Econometric analysis was also used to determine the factors affecting profitability. Ordinary least squares (OLS) regression was used to model profitability as defined in equation (2).

$$Profitability = f(Vol, Price, Cost, Land, Loss, Agetree, Agefarmer, Exp, FamSize, Educ, Train, Member, Fin, Davao, Digos) \quad (2)$$

where
Profitability = profit (in $US/ha)
Vol = volume sold (in kg/ha)
Price = selling price (in $US/kg)
Cost = cost of production (in $US/kg)
Land = land area of productive mango trees (in ha)
Loss = production losses (in kg/ha)
Agetree = age of tree (in years)
Agefarmer = age of the farmer (in years)
Exp = mango-farming experience (in years)
FamSize = family size (number of family members, including the farmer)
Educ = ordinal variable for educational attainment 1–6
Train = dummy variable for mango-related training – 1, otherwise – 0
Member = dummy variable for producer organisation membership – 1, otherwise – 0
Fin = dummy variable for financing status; under financing – 1, otherwise – 0
Davao = dummy variable for Davao City – 1, otherwise – 0
Digos = dummy variable for Digos City – 1, otherwise – 0

Diagnostic tests were employed. Heteroscedasticity of the variance was tested using White's test. Since the model suggests a non-homogenous variance, it was adjusted using the heteroscedasticity-corrected model. Multicollinearity was measured using the variance inflation factor suggesting no issue of multicollinearity. Serial correlation testing is not applicable since cross-sectional data were used and the ordering of the data is arbitrary. A test of specification was employed using Ramsey's regression specification error test (RESET).

It suggests correct specification of the model using cubes only and squares only tests but misspecified for combined squares and cubes tests. Since two of the three specification tests suggest a correct specification of the model, it is considered correctly specified. Normality of residuals was also checked using the Jarque–Bera test, which implied a non-normal distribution of errors. Caution in the interpretation of the estimates is thus advised. Levels of significance considered were 1%, 5% and 10%. The econometric analysis was performed using GNU regression econometrics and time-series library (gretl) software (Adkins 2010).

Results and discussion

Value-chain analysis

The value-chain analysis was derived from primary and secondary data, including surveys, key informant interviews and literature reviews (Figure 1). The details of the role of each actor in the chain are discussed below.

Service provider

Two kinds of service providers can be identified in the mango value chain in Davao region. The first is a provider of transportation to carry the produce to different traders. This service provider can be a tricycle owner, a jeepney owner or, most of the time, a truck owner. Their only function is to transport loaded boxes of mangoes. Farmers pay service providers $US0.95–$1.90/28 kg crate for transport. The second is a provider of a secure area where farmers can store those mangoes that are not sold immediately upon harvest.

Input supplier

Input suppliers for mango are sellers of production inputs such as seedlings or planting materials, fertilisers, pesticides, herbicides etc. Their main function is to provide the farmers the inputs needed for production at an agreed cost.

Spray provider

This actor is relatively unimportant to small-scale growers since they can easily hire a small group of labourers to spray, weed and clear their mango orchards for them. However, spray providers are important in medium- and large-scale mango production. They have the capacity to provide an immediate service for spraying large areas with chemicals such as fertilisers, pesticides and herbicides.

Financier

Financiers are one of the main actors in the supply chain and play a major role in the mango industry, especially in the three major areas in Davao region. Their main function is to give farmers the financial assistance that they need from production until harvesting. In most cases, financiers incur all production costs. At the time of harvest, a certain profit-sharing arrangement pre-agreed by the farmer and the financier is settled. This sharing arrangement varies according to geographical location. In most areas in Davao City and Digos City, a 70:30 sharing scheme is practised, under which 70% of the total sales is the share of the financier and the remaining 30% is the share of the farmer. In other areas, specifically IGACOS, they adopt a 75:25 split. There were also 60:40 sharing schemes reported. Some of the financers are also buyers of the produce of the financed mango farmers. Also, a financier assists in

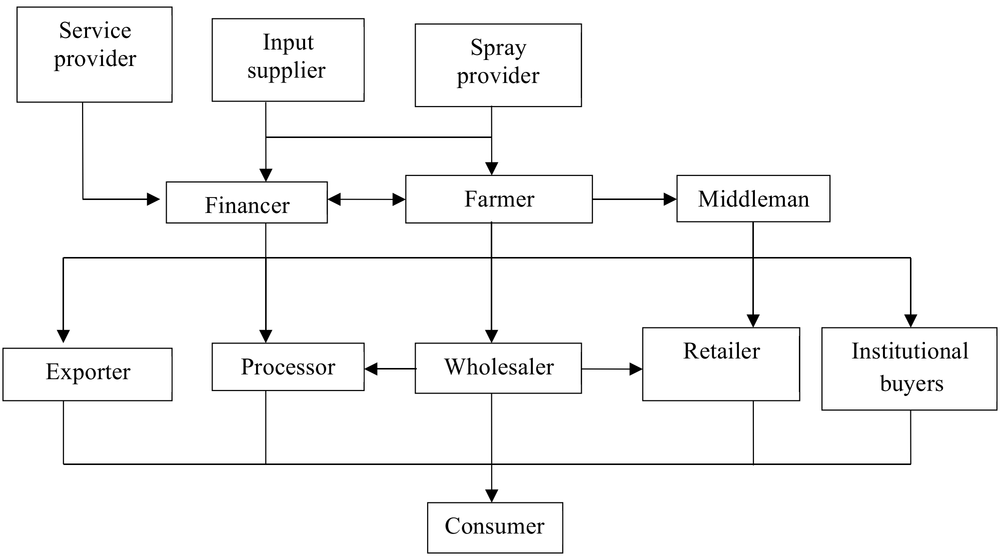

Figure 1. Value chain for mango in Davao City, Digos City and the Island Garden City of Samal

finding a suitable buyer for the farmer's production. They may also serve as a spray provider, particularly in IGACOS. Farmers who can afford to finance the entire production activities do not engage with financiers.

Mango farmer

The main actor in the mango supply chain is the mango producer. In Digos City, the majority of mango farmers are scattered in the San Roque, Colorado and Upper Matti districts, while the IGACOS farmers are situated in Peñaplata district. Farm areas are relatively inaccessible, especially those in Davao City, which are located in Mintal, Tugbok and Calinan districts. In most cases, the transport of harvested mango from farm to main road has been one of the major problems of the farmers.

Middlemen

These marketing agents are also one of the main actors in the supply chain of mango, especially at the distribution or marketing level. These agents seek buyers for wholesalers and they negotiate with buyers from outside Mindanao.

Wholesaler

Wholesalers come from within and outside Davao City, Digos City and IGACOS. There are wholesalers, also known as *viajeros*, who come from Cebu, Metro Manila and other areas where there is little or no mango produced. *Viajeros* are generally present in Digos City Public Market and in Bankerohan, Davao City. Their main function is the same as the retailers, except that retailers are selling their goods by piece to consumers while wholesalers are selling per box or by volume to both retailers and consumers.

Export trader

Most of the respondents did not have export trader as an actor in the chain. However, this actor plays a significant role in the industry, especially in the marketing node, because pricing of goods destined for the export market is higher than in the local market. The quality requirement of export goods is high, which forces the growers to improve the quality of their produce if they wish to earn higher profit.

Processor

The primary function of processors is to develop products such as juice, candy, dried fruit and concentrates. They also help the farmers avoid losses by purchasing mangoes that are unacceptable in local and international markets.

Retailer

Most retailers of mango in Davao City are situated in the Bankerohan public market. Some are located in Agdao and Matina public markets. In Digos City, they are predominantly located in the Digos public market. There are very few retailers in IGACOS, as transporting mangoes into the island is prohibited under local ordinance. Since there are traders coming from regions outside Davao City, Digos City and IGACOS, there are also retailers of mango identified in Cebu, Metro Manila and other areas where there is little or no mango production. Their main function is to make fresh mangoes accessible to the consumers in their areas.

Institutional buyers

Institutional buyers include hotels and restaurants in the region. They acquire high-quality, fresh mangoes and mango-derived products as part of their food services, especially for desserts.

Consumer

Households consume mangoes as part of a meal.

Net margins of the key players in the mango value chain

One of the tools in assessing the performance of farmers in the value chain is to compare their net margins to those of other actors who, in this study, are limited to wholesalers and retailers. The study considered different areas and variables essential for capturing the net margins such as costs, prices and volume of production.

In general, results show that farmers gain the lowest net margins among actors in all areas considered in the study except IGACOS (Table 2). In Davao City, retailers had the highest average net margins. The city has some large markets for mangoes, including Bankerohan where it attracts buyers of mangoes from other areas. In Digos City, on the other hand, wholesalers had acquired the highest average net margin, since the stalls of the wholesalers are situated near the farm areas, and transportation costs are therefore low. Lastly, farmers had higher average net margins than retailers in IGACOS. Most of their mangoes are shipped directly to Davao City and other neighbouring provinces.

In terms of cost, farmers from IGACOS incur the lowest costs, because they have financiers who

Table 2. Net margins of selected mango value chain actors

	Cost ($US/kg)	Price ($US/kg)	Net margins ($US/kg)
Davao City			
Farmer	0.12	0.51	0.07
Wholesaler	0.07	0.95	0.35
Retailer	0.06	1.19	0.47
Digos City			
Farmer	0.20	0.54	0.15
Wholesaler	0.05	0.83	0.41
Retailer	0.06	1.25	0.38
IGACOS[a]			
Farmer	0.06	0.49	0.21
Wholesaler	n/a	n/a	n/a
Retailer	0.16	1.07	0.10

[a] Island Garden City of Samal

shoulder most of the costs incurred during the entire production process. At the time of harvest, the buyer meets with the farmer and the financier for profit sharing as pre-agreed.

Factors affecting performance of mango farmers

Several factors were explored to explain farmers' profitability in terms of profit per hectare. These factors include land area, farmer's age, family size, educational attainment, mango-farming experience, membership of a producer organisation, mango-related training, age of trees, geographic location and financing status. Statistical analysis shows that, among these factors, four were significantly affecting the performance of mango farmers. These were mango-related training, age of trees, geographic location and financing status.

Participation in training conducted by government agencies, non-government organisations and the private sector enables farmers to be more equipped with the best farming practices and production techniques. Thus, farmers who have attended mango-specific training are expected to produce more mangoes of high quality. There is a premium price for quality mangoes. Trained farmers (33%) are selling their produce at a higher price of $US0.54/kg than non-trained farmers (67%) at $US0.49/kg. Trained mango farmers have the potential to gain higher profits.

In mango production, the age of trees is critical to producing higher yields (Table 3). As the trees mature, they yield more fruit than do younger ones. Mature trees (63%) 11–30 years old can produce, on average, about 10 t/ha while younger, 5–10-year-old trees (30%) produce only about 2.3 t/ha. Harvested produce translates to volume sold. Thus, profitability favours those with mature trees, reaching $US1,227/ha, whereas profit from younger trees is around $US391/ha.

In terms of geographic location, Davao del Sur yielded about 69% of Davao region's production in 2010 (BAS 2012), with Digos City as one of the largest producers. Farmers there also experience a higher farm-gate price at $US0.54/kg, compared with $US0.49/kg at Davao City, as shown in the ANOVA results (Table 4). The IGACOS farm-gate price at $US0.48/kg is very similar. Most mangoes from Digos City are shipped to the Visayas and Luzon markets and are also sold to fresh mango exporters at premium prices.

Farmers engage in financing arrangements obtain the capital they need for production (Table 5). The

Table 3. Age of mango trees as a factor in harvesting and profit

Age of trees	Proportion (%) of farms	Volume sold (kg/ha)	Profit ($US/ha)
Young, 5–10 years (1)	30	2,318[a]	391[c]
Mature, 11–30 years (2)	63	10,038[b]	1,227[d]
Old, >30 years (3)	7	14,150[ns]	4,385[ns]

[a] 1&2*** 1&3[ns]; [b] 2&1*** 2&3[ns]; [c] 1&2** 1&3[ns]; [d] 2&1** 2&3[ns]

sharing scheme in a financing arrangement is agreed upon by both parties. In Davao City and Digos City, farmers practice the 70:30 profit-sharing arrangement. In IGACOS, most farmers practise the 75:25 sharing arrangement. The larger share is the share of the financier because they shoulder the majority of the production costs. In most cases, financiers dictate the sharing arrangement, which is based on prevailing arrangements practised by other financiers in the area.

ANOVA results suggest that those farmers who engage in financing arrangements (78%) incur lower costs at $US0.01–0.11/kg than those who are not under any financing scheme (22%) and whose cost is $US0.35/kg. However, financed farmers face lower prices for mangoes, especially those having a 75:25 (14%) contract. Their return is $US0.43/kg, whereas the return for non-financed farmers is $US0.53/kg. This disadvantage is caused by the financiers arranging the selling of the produce of financed farmers, or even buying the produce themselves, while non-financed farmers have more options in marketing their fruit. This resulted in lower net margins to financed farmers ($US0.11–0.12/kg) than those to non-financed farmers ($US0.19/kg)

Other factors considered—farmer's age, family size, educational attainment, mango-farming experience and membership of a producer organisation—were not significant in determining the profitability of the farmers.

Some 6% of the respondents in Digos City were considered to be trained mango farmers with trees of mature age and free from financing. They have an average farm size of 1.30 ha producing 8.5 t/ha at $US0.23/kg cost and selling at $US0.52/kg farm-gate price, resulting in a net margin of $US0.29/kg, which translates into a profit of around $US2,200/ha.

Table 4. Geographic location of mango farms as a factor in price received by farmers

Geographic location	Proportion (%) of farmers	Price ($US/kg)
Davao City	37	0.49*
Digos City	42	0.54*
IGACOS[a]	21	0.48[ns]

[a] Island Garden City of Samal

Econometric analysis

All diagnostic tests having been met satisfactorily (except for normality of residuals, which is not a crucial assumption for large datasets) and the model being significant at 1% alpha level, the OLS regression below, with 36% of the variability of the profitability variable explained by the model, shows the factors affecting the profitability of farmers.

$$Profitability = 660 + 0.097Vol^{***} + 1206Price^{*} - 809Cost^{***} - 293Land^{***} - 630Fin^{*} \quad (3)$$

For continuous variables, elasticity at mean was calculated to determine where profit is most responsive to changes in the independent variables. Primarily, profit of farmers is positively affected by the direct contributors to revenue, such as volume sold and price. If volume sold increases by 10%, profit will increase by 6.5%, while a 10% increase in price will result in a 5.2% lift in profit. As the cost of producing 1 kg of produce increases, which implies inefficiencies in the production system, profit falls. A 10% increase in cost per kg reduces profit by 1%. Larger farm area negatively affects the profitability of the farmers. This is because more operating capital is needed, implying higher costs. If land area is increased by 10%, profit per ha will decrease by 4.2%. Land area considered in this study ranges from 0.10 to 9 ha, with 1.66 ha as the average productive farm size. Thus, elasticity at mean suggests that profitability of farmers is primarily influenced by volume sold and prices.

Among the four significant factors contributing to profitability discussed in the previous section, use of econometric analysis consistently identified financing

Table 5. Financing status as a factor in cost and price

Financing status	Proportion (%) of farmers	Cost ($US/kg)	Price ($US/kg)	Net margin ($US/kg)
Without financer (1)	22	0.35[a]	0.53[d]	0.19[g]
70–30 (2)	65	0.11[b]	0.52[e]	0.12[h]
75–25 (3)	14	0.01[c]	0.43[f]	0.11[i]

[a] 1&2** 1&3***; [b] 2&1** 2&3**; [c] 3&1*** 3&2**; [d] 1&2[ns] 1&3**; [e] 2&1[ns] 2&3*; [f] 3&1** 3&2*; [g] 1&2*** 1&3**; [h] 2&1*** 2&3[ns]; [i] 3&1** 3&2[ns]

status. In the absence of their own capital, farmers engaged in financing arrangements that negatively contributed to profit. Although such arrangements reduce costs, due to limited market options they also lower the prices faced by the farmers. With the larger share of return attributed to the financier, this reduces the profitability of the farmer. Non-financed farmers are more profitable than financed farmers by $US630/ha.

Conclusions and recommendations

Southern Mindanao is one of the top producers of mangoes in Mindanao. Its production is spread in the areas of Davao del Sur, Davao City and Davao del Norte. However, mango farmers have been placed in a disadvantage position due to increasing input prices, declining volume of production and declining consumption of mangoes. The results of the study showed that, in general, farmers receive the smallest share among all the actors in the chain. These factors affecting profitability of farmers were explored.

Statistical analysis suggests that having more mature trees guarantees more volume and thus increasing profit. Although farmers engaging in financing arrangements incur lesser costs, they face lower prices of mangoes, resulting in lower net margins than non-financed farmers receive. Digos City is offering a higher farm-gate price than Davao City but prices can be influenced by producing more high-quality mangoes. This was evident with trained farmers selling their quality produce at a higher price than that obtained by non-trained farmers. Trained mango farmers in Digos City who had mature, productive trees and who were not under financing were considered more profitable.

Econometric analysis identified the main drivers of farmers' profitability, which are, in decreasing order of contribution, volume sold, prices, land area and cost of production. It identified financing arrangement as significantly affecting profit. Non-financed farmers are more profitable than financed farmers.

On the other hand, wholesaling activities are favoured in Digos City, due to minimal marketing costs, while retailing activities are best in Davao City due to larger captive market, especially the Bankerohan public market.

Based on the results of the study, the following recommendations are made:

- Mango farmers must continue to innovate in producing high-quality mangoes and target export markets, in which there is a price premium.
- Government should provide training and improve extension work on better production technologies to increase the efficiency of farmers in the production, and therefore profitability, of mangoes.
- Government agencies, non-government organisations and donor institutions could invest in helping the farmers produce more high-quality mangoes and provide access to credit in order to minimise the farmers' exposure to financiers, which leads to lower profitability than use of own capital.
- There should be further study of the interrelatedness of the three main actors in the production and distribution of mangoes, namely the mango farmer, the financier and the middleman.
- Other factors affecting farmers' profitability, such as market channel choice and the existence of market power, should be explored.

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Assessment of prospective impact of fruits and vegetables research at the industry level in the Philippines: the case of the ACIAR–PCAARRD horticulture project

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Abstract

The fruits and vegetables subsector in the Philippines shows great dynamism despite lack of government support compared with other subsectors within agriculture. To further realise the potential of the fruits and vegetables sector, one promising instrument is investment in research and development (R&D). The government is the primary source of funding for agricultural research and development efforts due to the 'public good' character of such kind of research. However, the Philippines lags behind its neighbours in Asia in terms of agricultural research investment. Moreover, current R&D investments are skewed towards traditional commodities. This paper assessed the prospective impact at the industry level of fruits and vegetables R&D, using the Australian Centre for International Agricultural Research (ACIAR)– Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD) horticulture project as case study. An economic surplus model running on a spreadsheet is used to evaluate measures of project worth for R&D investment. Results from the model show high social returns from raising investments in horticulture R&D.

Introduction

A major subsector within agriculture is horticulture, which includes fruits and vegetables, regarded as high-value commercial crops. Nevertheless, farmers of fruits and vegetables confront numerous challenges, such as high working capital requirement, pests and diseases, and postharvest losses. Traditional crops such as rice, maize and sugar remain prioritised by policy-makers, budget-wise and policy-wise. These priorities contribute to the disappointing pace of diversification of the agricultural sector.

One of the many ways to hasten diversification is by investing in research and development (R&D) in non-traditional crops such as fruits and vegetables. This paper aims to: 1. analyse the contribution of the fruits and vegetables sector in the country's agricultural development; 2. evaluate the potential impact of R&D in selected fruit and vegetable crops; and 3. draw implications for investment allocation in, and the institutional framework for, the agricultural R&D system. This preliminary study includes only some of the commodities previously identified and it is expected to include all focus commodities in the final report.

Agricultural diversification and the policy regime

Among the basic industry sectors, agriculture had the slowest output growth from 1980s to 2000s. Poor performance of agriculture affects the welfare of many impoverished households. In 2009 (Table 1), the poverty incidence among households who derived their livelihood from agriculture was 40%; while among non-agricultural households it was just 19% (Reyes et al. 2010). Meanwhile, of all poor households, the

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primary occupation of the head was in agriculture 74% of the time; of the chronically poor, the primary occupation of the household head was in agriculture 77% of the time.

The government has not attained its goals of poverty reduction and of improvement of welfare of rural households despite the increasing public expenditures on agricultural development. Aside from insufficient funding, another possible reason causing this is the faulty selection, design and implementation of programs. An example of this is the provision of input subsidies. Based on case studies, many of these fail to meet the program objectives. Also, they have become a source of corruption, as many audit reports found anomalies in the documentation of the program implementation. If such is the case, then the solution lies in finding the right program and implementing it properly.

The government policy thrust should take into account the inherent dynamics of agricultural development. Agricultural development is generally accompanied by diversification; as an economy grows, it tends to move out of subsistence food-crop production to a diversified market-orientated production system (Briones 2009). According to Hutagaol (2006), agricultural diversification is not new for many developing countries. However, because the attainment of food self-sufficiency outshone the popularity of agricultural diversification in the mid 1960s, most countries adopted food self-sufficiency programs. He also pointed out that hunger and poverty were never solved by the food self-sufficiency program even if it was successful in producing food surpluses. One contributing factor is the lack of access to food by the rural poor.

Promoting agricultural diversification does not mean abolishing the food self-sufficiency program entirely. Hutagaol (2006) suggested that agricultural diversification should be integrated into the food self-sufficiency program. The government has to relax its food self-sufficiency program by not relying on only a single food crop. There are basically three types of agricultural diversification—horizontal, vertical, and regional. *Horizontal* diversification occurs at the farm level. Small-scale farmers commonly practise this in forms of intercropping (planting of different crops on the same plot at the same time) and sequential cropping (planting of different crops in sequence on the same plot). This usually allows farmers to generate higher income and to manage risk by making better use of their farm resources. In *vertical* diversification, farmers undertake beyond farm-level activities like processing, storing, marketing and distribution. These add value to their products. However, one problem with this is that it requires a huge amount of investment for the equipment and/or marketing. One way to overcome this hurdle is to develop partnerships with commercial agricultural institutions. The last type is the *regional* diversification, in which regions specialise in crop/s for which they have a comparative advantage; such specialisation entails free trade among regions.

Horticulture includes several important crops in which the Philippines exhibits comparative advantage, as indicated by export trends. Table 3 shows the average value of exports and shares of Philippine agricultural products from 2008 to 2010. Next to coconut oil, the top agricultural export product of the Philippines is edible fruits, nuts etc. which comprise 17.6% of the total export value. Of the total $US635 million value of edible fruits, the big chunks of the pie are banana (57%) and desiccated coconut (28%). Pineapple is 8%, mango 5%, papaya 1% and other fruits 1% (Figure 1).

Table 1. Profile of poor households by temporal poverty and occupation, Philippines, 2009

	Occupation of household head	
	Agriculture	Non-agriculture
Percentage of sample households		
All poor households	39.9	18.7
Under chronic poverty	27.6	10.8
Under transient poverty	12.3	7.8
Percentage of poor households		
All poor households	73.8	26.2
Under chronic poverty	77.1	22.9
Under transient poverty	67.4	32.6

Source: Reyes et al. (2010)

Fruits and vegetables play an important role in agricultural diversification. They are produced within organised supply chains and are considered as 'high-value' crops. This diversification not only helps in producing a sizeable agricultural output but also boosts rural development. Because of this agricultural diversification, incomes of workers and smallholders tend to increase (Briones 2008). This

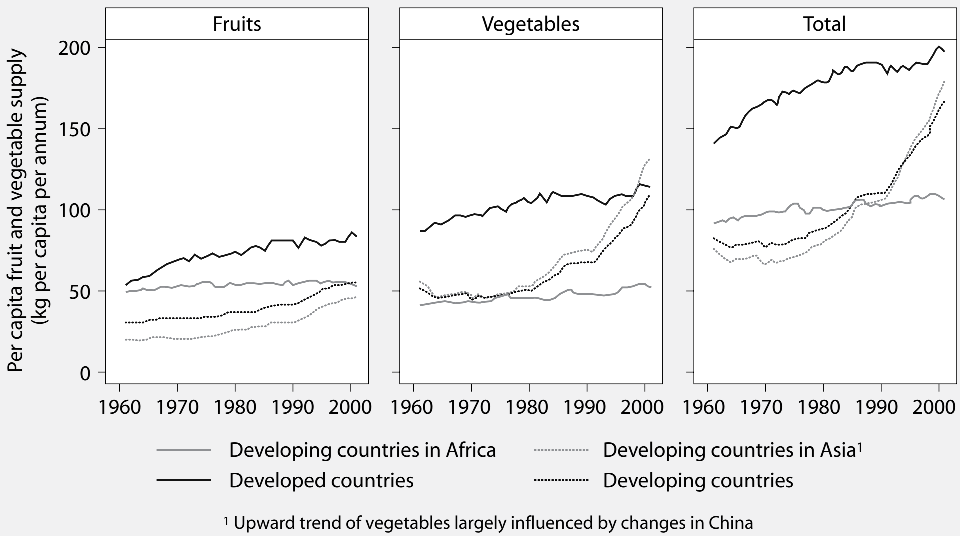
Box 1. Agricultural diversification trends

Table 2 and the Figure below show that there is an upward trend in fruit and vegetable diversification. Latin America and the Caribbean, China, East Asia and South-East Asia are net exporters of fruits and vegetables. In contrast, developed countries incur deficits in fruits and vegetables. The demand for fruits and vegetables in developed countries brings great opportunities for fruit and vegetable exporters in developing countries (Weinberger and Lumpkin 2005).

Table 2. Net trade in fruits and vegetables, and food products ($US billion)

Year	China	South Asia	East and South-East Asia	Latin America and Caribbean	Sub-Saharan Africa	Developed countries
Fruits and vegetables						
1970	0.38	0.04	0.10	0.51	0.05	–2.54
1980	1.04	0.20	1.04	1.82	0.07	–8.19
1990	1.97	0.05	1.60	5.68	–0.01	–18.67
2000	2.56	–0.03	1.24	8.30	0.32	–20.04
All food products						
1970	0.52	0.03	–0.49	4.27	1.52	–7.65
1980	–1.07	1.35	–0.24	15.26	1.96	–16.26
1990	1.84	0.92	0.58	15.27	0.76	–24.38
2000	3.11	1.93	–3.21	16.08	–0.44	–12.85

Source: FAOSTAT data (2004), three-year averages (Weinberger and Lumpkin 2005)



Source: Weinberger and Lumpkin (2005)

Table 3. Exports and export shares of Philippine agricultural products, average of 2008–10

	Value ($US millions)	Shares (%)
Coconut	967	26.8
Edible fruits, nuts etc.	635	17.6
Food preparations	336	9.3
Rubber	329	9.1
Meat, fish and seafood food preparations	319	8.8
Fish, crustaceans, molluscs etc.	305	8.4
Tobacco	220	6.1
Sugars	132	3.7
Cereal, flour, starch, milk products	113	3.1
Others	255	7.2
Total	3,611	100

Source: www.trademap.org

increase in income is brought about by the higher labour requirements for non-rice crops such as onion and other high-value crops (Pingali 2005).

Rural growth caused by the improvement in agricultural productivity reduces poverty, both in rural and urban areas. A cross-country study done by Thirtle et al. (2001) showed that an improvement of 1% in the yield reduced the number of the population who are living on less than $1/day by 0.91%. Aside from employment and income effects, diversification also gives way to lesser environmental, ecological and economic risks, mainly because of the varied mix of activities (Barghouti et al. 2004).

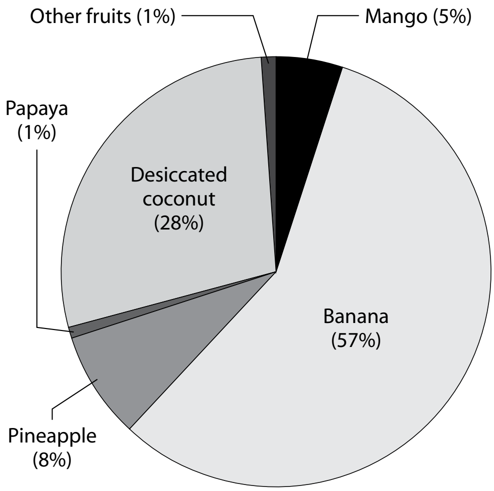


Figure 1. Shares per commodity in Philippine exports (edible fruits): average of 2008–10. Source: www.trademap.org

Agricultural policy

In the Philippines, the government persists in focusing on the development of the traditional crops, namely rice, maize, sugar and coconut. There are certain government interventions, specifically those restricting trade domestically and globally, which hinder agricultural diversification. Examples of these are policies targeting self-sufficiency and food security. This leaning towards traditional crops is reflected on the budgetary allocation of public funds and on price policies.

Figure 2 shows the trend in public expenditure on agriculture. Expenditure is increasing throughout the years 1990 to 2010. It peaked at 94 billion pesos ($US2.1 billion) in 2008. The latter part of 2000s appears to have had faster growth. Also, agricultural expenditure, both as share of government spending and as share in nominal agricultural GDP, is also increasing.

Of the 48.6 billion pesos ($US1.1 billion) budget appropriation for the Office of the Secretary of the Department of Agriculture (OSEC–DA) as stated in the General Appropriations Act (GAA) for 2012, the 'Development of the crop sector' item (under program operations) has 10 billion pesos ($US233 million). The agricultural intensification and diversification program, technology generation and dissemination for the growth and development of the vegetable industry, and the National High Value Commercial Crops program, all account for 13% of the said 10 billion pesos. On the other hand, the National Rice Program and National Corn Program account for 60% and 9%, respectively (DBM 2012).

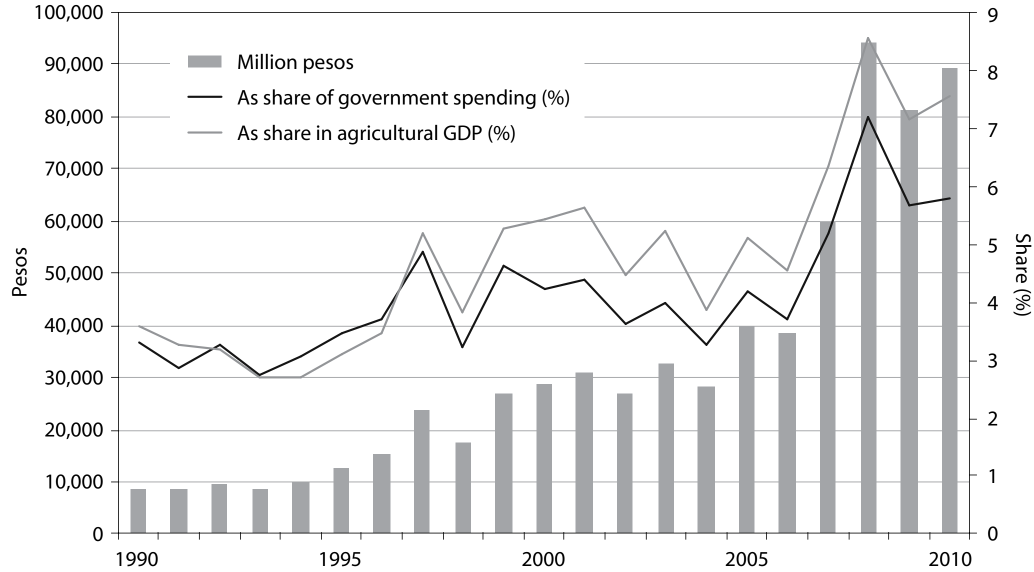


Figure 2. Trends in public expenditure on agriculture

The budget of the agricultural sector for the years 2000 to 2010 is summarised in Figure 3[2]. The sectoral budget allocation for agriculture is apportioned among the Department of Agriculture (DA), the Department of Agrarian Reform (DAR), the Department of Science and Technology (DOST) and some government corporations. The bulk of the agricultural budget is under the DA, which is combined with the Agriculture and Fisheries Modernization Plan. 'Other agencies' refers to DAR and DOST. As Figure 3 shows, the share of government-owned and controlled corporations (GOCCs) is increasing, and is particularly large in 2008. This increase in the budget of the GOCCs can be attributed to the increasing budget of the National Food Authority (NFA). On the average, 83% of the GOCCs fund is mostly for NFA. This spending is in line with the past and present administration's program for food security, largely equated with rice self–sufficiency.

The GAA entries can be sorted by commodity. As Figure 4 shows, for the years 2005 to 2012, rice dominated the budget of the whole agricultural sector. As for high-value crops, the allocation increased somewhat in 2008 and 2009. 'Other commodities' refers to maize, coconut, fisheries and livestock, while crosscutting refers to line items in the GAA that cannot be placed under a single commodity (e.g. agricultural crop research, production of seeds, agricultural statistics etc.).

Research and development

Budgetary allocation trend

Another way of assessing the budgetary concerns in the agriculture sector is by looking at the major final output (MFO). An MFO is either a good or a service provided by an agency for its clients in accordance with its mandate. Support services, regulations, and plans and policies are the MFOs of DA. Table 4 shows the breakdown per MFO. The MFO 1 is further subdivided into different kinds of support service (Table 5). These are production support, market development, credit facilitation, irrigation development, other infrastructure and postharvest development, extension support, education and training services, and R&D.

Irrigation is the top support service offered by DA. Again, irrigation services are mostly, if not entirely, for rice fields. In 2001, R&D had only 1.7 billion pesos ($US33.2 million) as opposed to almost 10 billion pesos ($US195.5 million) for irrigation. R&D's

2 Budget of Expenditures and Sources of Financing (BESF); Tables B.7a Details of the Sectoral Allocation of National Government Expenditures; actual obligation

share in the support services was 8% while irrigation accounted for 49%. R&D continued to decline to 958 million pesos ($US7.7 million) in 2003, which was equivalent to 5% of the total support services. In 2011, its share was maintained at 5% (1.2 billion pesos or $US27.7 million).

Philippine agriculture continues to lag behind that of its neighbouring countries. The low productivity it is encountering may be attributed to the low investments placed in agricultural R&D. Investment in agricultural R&D is considered as one of the major drivers of agricultural productivity (Pascual-Gapasin

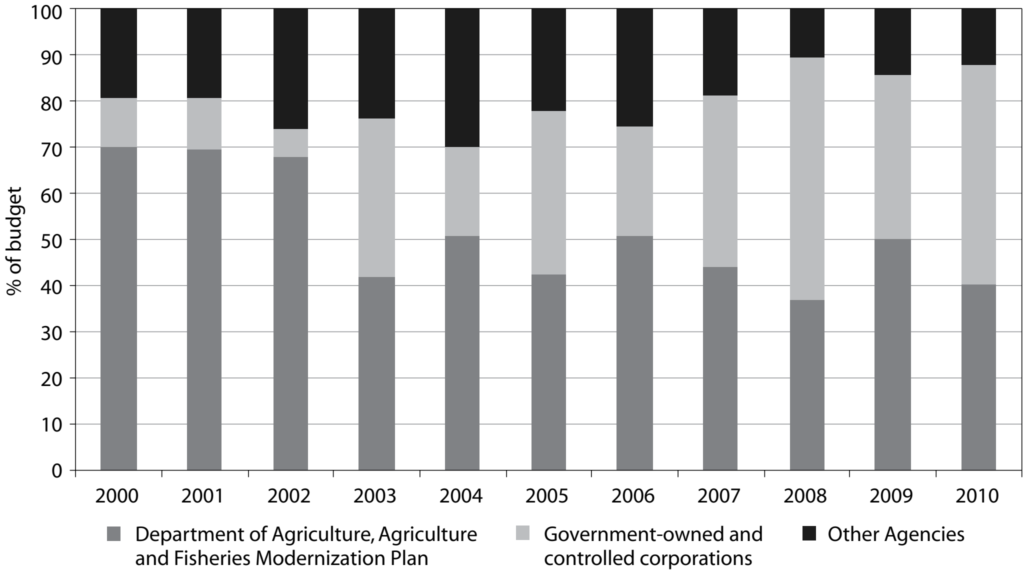


Figure 3. Agriculture sector: budget composition by agency, 2000–10

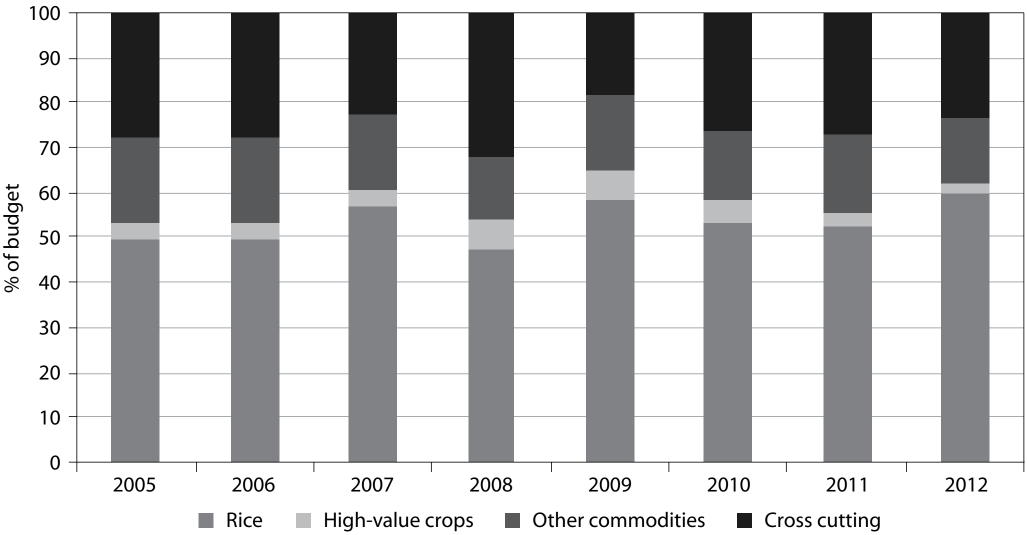


Figure 4. Agriculture sector: budget composition by commodity (using General Appropriations Act entries)

Table 4. Agriculture sector: budget allocation (million pesos) by major final output (MFO) of the Department of Agriculture

	2001	2002	2003	2007	2008	2009	2010
MFO 1 Support services	20,199	21,758	18,702	14,748	20,803	36,006	33,858
MFO 2 Regulations	512	2,257	2,244	689	1,186	1,197	1,353
MFO 3 Plans and policies	2,076	1,382	1,103	3,059	1,767	2,469	2,617
TOTAL	22,787	25,397	22,049	18,496	23,756	39,672	37,828

Sources: Organizational Performance Indicator Framework (Government of the Philippines); World Bank

Table 5. Disaggregation of Department of Agriculture major final output 1, support services, budget (million pesos)

	2001	2002	2003	2011
Production support services	2,523	2,468	4,608	4,975
Market development services	267	143	115	242
Credit facilitation services	312	124	184	23
Irrigation development services	9,981	13,124	9,044	12,552
Other infrastructure and/or postharvest development services	2,800	2,012	1,667	716
Extension support, education and training services	2,630	2,514	2,126	1,853
Research and development	1,686	1,373	958	1,185

Sources: Organizational Performance Indicator Framework (Government of the Philippines); World Bank

2006). Hence, underinvestment in agricultural R&D may lead to low productivity.

DOST, through its Science and Technology Master Plan (1991–2000), identified the weaknesses of science and technology in the country. Among the identified weaknesses are low levels of investment, lack of technology transfer, qualified staff and private-sector participation, and low attention to market demand. However, their proposed measures were not realised, particularly the fivefold increase in investment in R&D. It wanted to raise the 0.2% share of R&D in the GDP (in 1991) to 1.0% in 2000 (Stads et al. 2007).

In terms of growth rates in agricultural R&D expenditures, the National Irrigation Authority (NIA) was the only government agency that consistently experienced growth from 1986 to 2002. Other national agencies experienced a negative spending growth during the same period. Such agencies are the Ecosystems Research and Development Bureau (ERDB–DENR), the Bureau of Soils and Water Management (BSWM), the Bureau of Fisheries and Aquatic Resources (BFAR), and the National Fisheries and Research Development Institute (NFRDI). Among the national government agencies, ERDB–DENR received the highest allotment for agricultural R&D ($US6.2 million). Given the importance of rice to the Philippine agriculture sector, PhilRice received the single largest funding allotment to a Philippine research agency. Its spending actually doubled during 1996–2002 (Stads et al. 2007).

Spending on agricultural R&D declined during the Aquino Administration in the late 1980s, because of the fiscal restraints implemented. In the early 1990s, there was a rapid increase in agricultural R&D expenditures when the Philippine Carabao Center was established and PhilRice aggressively increased its research spending. Nevertheless, from 1986 to 2000, the trend in spending on R&D in national government agencies was downwards (Stads et al. 2007).

Global trends

There was an increase of 51% in inflation-adjusted terms in the worldwide public investments in agricultural R&D, from $US15.2 billion in 1981 to $US23 billion in 2000 (Table 6). Of the $US10.2 billion of public research carried out by developed countries, the USA, Japan, France and Germany accounted for about two-thirds of it. China, Brazil, India and South Africa accounted for 50% of the public agricultural research budget of the developing countries. Growth in research spending has been slow for Africa and for the developed countries. As shown in Table 7, in 2000, the research spending of developed countries shrank. This was not the case for China and India with an average growth in spending by 5.04 and 6.3%, respectively, in the 1990s. The smaller and poorer countries had difficulty in sustaining the growth for agricultural research funding (Alston and Pardey 2006).

The increase in the intensity of research in developing countries was uneven. Agricultural researchers in rich countries received $US700 R&D spending per worker while each agricultural researcher in poor countries received only $US10.21 R&D spending in 2000. On the average, agricultural research spending per capita in developed countries increased by only 9% while that of developing countries increased by 29% (Alston and Pardey 2006).

One indicator to help a country attain the internationally recommended level for agricultural R&D expenditure is by setting public spending as a percentage of agricultural output or public sector intensity ratio. The estimated public-sector intensity ratio of the Philippines in 2002 was 0.46%, and if private-sector agricultural investments were included, it would be up to 0.54%. It was higher than Vietnam, Indonesia and Laos, with 0.17%, 0.22% and 0.24%, respectively. This ratio also is higher than the overall average for Asia (0.41%) in 2000. However, the ratio for developing countries during 2000 was 0.53%, which is higher than the Philippines ratio (0.46%) (Stads et al. 2007).

From 1992 to 2003, the country's trend for both agricultural and non-agricultural R&D expenses as a percentage of GDP was downward. The total research spending of the Philippines in 2003 was 0.11% of GDP. This is very low compared with Malaysia with 0.69% and Thailand with 0.24% (Stads et al. 2007).

R&D returns

Results from economic surplus analysis are expressed as net present value (NPV) (positive), benefit:cost ratio (BCR) (greater than 1) and internal rate of return (IRR) (greater than the social cost

Table 6. Global public agricultural research spending, 1981–2000

Expenditures (2000 $US, million)	1981	1991	2000
Developing countries	6,904	9,459	12,819
Sub-Saharan Africa	1,196	1,365	1,461
China	1,049	1,733	3,150
Asia and Pacific	3,047	4,847	7,523
Latin America and the Caribbean	1,897	2,107	2,454
Middle East and North America	764	1,139	1,382
Developed countries	8,293	10,534	10,191
Total	15,197	19,992	23,010

Source: Alston and Pardey (2006)

Table 7. Global public agricultural research-intensity ratios, 1981–2000

Region/country	Expenditures as a percentage of agriculture's contribution to GDP			Expenditures per capita (2000 $US)			Expenditures per economically active member of agricultural population (2000 $US)		
	1981	1991	2000	1981	1991	2000	1981	1991	2000
Developing countries	0.52	0.50	0.53	2.1	2.3	2.7	7.0	8.3	10.2
Sub-Saharan Africa	0.84	0.79	0.72	3.1	2.7	2.3	11.2	10.5	8.2
China	0.41	0.35	0.40	1.0	1.5	2.5	2.5	3.5	6.2
Asia and Pacific	0.36	0.38	0.41	1.3	1.7	2.4	3.8	5.2	7.6
Latin America and Caribbean	0.88	0.96	1.16	5.5	6.6	5.9	45.1	50.5	60.7
Middle East and North Africa	0.61	0.54	0.66	3.2	3.6	3.7	19.2	27.3	30.2
Developed countries	1.41	2.38	2.36	10.9	13.0	11.9	316.5	528.3	691.6
Average	0.79	0.86	0.80	3.8	4.2	4.1	15.1	17.2	18.1

Source: Alston and Pardey (2006)

of capital). Determining the 'social rate of return' or the percentage of return on each dollar spent on R&D has been the interest of many economic studies analysing benefits from public investment in agricultural R&D. It is called 'social' because its benefits may not be appropriable by a private commercial entity. Furthermore, Pardey et al. (2000) explained that social rates of return are higher than private rates because they also include positive spillovers. The benefits from investments in agricultural R&D extend to food industry level. Consumers are able to purchase more commodities at lower prices. Although other studies apply different methods and provide a range of estimates of returns to agricultural research, the conclusions are the same—return on public investment in agricultural R&D has been high (Fuglie and Heisey 2007).

There are many R&D success stories that show how R&D helps in improving productivity. Among these are tilapia farming in the Philippines, hybrid rice in China, baby corn in Thailand and oil palm in Malaysia (SEARCA 2009). There is empirical evidence that high levels of R&D improve productivity and economic performance of the agricultural sector. A study by Cororaton (1998, cited in Stads et al. 2007) substantiates this claim. R&D in the primary and service sectors can have a rate of return as high as 60%. This indicates the value of investing in agricultural R&D.

Table 8. Agricultural research intensity ratio[a] by commodity (Philippines), 1994–96

Rice	0.25
Maize	0.05
Sugar	0.5
Coconut	0.3
Fibre crops	2.5–3.0
Cotton	2.5
Abaca	1
Other fibre crops	–
Vegetables	Nil
Tobacco	1.1
Livestock	0.15
Carabao	3.60
Other livestock	0.02
Fruits	
Banana	Nil
Other fruits	Nil
Fisheries	
excl. SEAFDEC[a]	0.12
incl. SEAFDEC	0.35
Forestry	3.5

Source: David (1998)

[a] Agricultural research intensity ratio refers to the ratio of government expenditures for R&D to the gross value added in agriculture, fisheries and forestry (SEARCA 2009)

[b] Southeast Asian Fisheries Development Center

Misallocation of scarce R&D resources

R&D resources are scarce, thus it is important to look at their allocation (Table 8).

Commodities such as cotton and forestry, for which the Philippines had little comparative advantage and had declining output, had very high research-intensity ratios. On the contrary, more productive commodities, such as livestock, fisheries, fruits and vegetables, received no or too little government research support (SEARCA 2009).

The focus of much of the agricultural R&D done by government agencies is on crops and forestry. In 2002, 30% of the research conducted on crops was on rice, 33% on bananas and 11% for other fruits. Maize and vegetables accounted for 9% each (Stads et al. 2007).

Public versus private investment

It has been argued that, given the poor record of government in making investments (see Table 8), activities such as R&D should be delegated to the private sector. In fact, however, most agricultural R&D in the Philippines is still done by government agencies (e.g. DOST, BAS, BAR, BSWM, PhilRice, PCC etc.)[3], and for good reason. This is partly because agricultural research is a 'public good' and because of the structure of the agriculture sector with many poor workers and farmers. The rural workers and farmers have no resources to conduct research. Even their cooperatives and grower organisations cannot afford to invest in agricultural R&D. Another reason is the extent of the benefits from agricultural R&D. Farmers can capture only a small fraction of the benefits so they cannot be expected to exert much effort in undertaking R&D. Once a new technology is introduced, farmers usually do not wholly accept or adopt it. They are sceptical about it and tend to

[3] Department of Science and Technology, Bureau of Agricultural Statistics, Bureau of Agricultural Research, Bureau of Soils and Water Management, Philippine Rice Research Institute, Philippine Carabao Center

focus only on specific practices that they find suitable in their daily farm work. In addition to that, there are some crop-specific farmers who are hesitant to support research that delivers benefits over several commodities (SEARCA 2009).

Furthermore, emphasising the need for government investments in R&D does not mean that the private sector has no significance in R&D investments. Most of the private sector's investments are more into applied research and technologies that allow patenting, branding and other options to obtain returns on their investment. Again, marketable end-products and intellectual property protection are the incentives for greater private investment. If such conditions are not met (e.g. technology development geared towards social purposes or goals; patenting is difficult; low probability of successful commercialisation) then incentives for private investment would be very limited. There are only a few commodities (pineapple, 'Cavendish' bananas, yellow corn etc.) where the private sector has participated in R&D efforts. The work done by the private sector should help the government put more focus on commodities other than those already being supported. However, there is still a need for the government to continue R&D on commodities already supported by the private sector. This is to address possible under-investment by the private sector on research projects that exhibit public good character.

Another government intervention that could help stimulate private investment for agricultural R&D is the strengthening of the intellectual property protection (SEARCA 2009). Aside from the government and the private sector, agricultural R&D also involves international agencies. This linkage can help the country in obtaining financial and technical support, in exchanging research findings and technologies, and in developing the capacity of the research staff. Given the indispensable role of the public sector in R&D, the utmost effort should be exerted to allocate scarce investment funds wisely.

Assessment method

What follows uses the congruency or parity model to assess the allocation of research resources. This means that funds will be allocated to the research areas in proportion to their respective contribution to the value of agricultural production. For example, if the value of rice output were twice that of maize, research funding for rice should be twice as much funding as that for maize. This model explains that an additional dollar spent on R&D would have a higher return if invested in research areas with low ratio of funding-to-output value (Stads et al. 2007).

An alternative method that can be used is the economic surplus analysis. The extent of the research, development and extension (RDE) costs is weighed against the benefits from technology adoption measured in their 'present value'. It measures ex-ante benefits and effects of technologies. Because of research, the commodity supply curve against a demand curve may shift to the right. This leads to an increase on quantity produced and consumed, thus price tends to be lower (Alston 2010). Such industry-level repercussions should be taken into account in the evaluation of prospective research benefits.

According to Alston et al. (1995), the change in economic surplus arises from farm productivity improvement due to innovation (*k*-shift), which propagates by a diffusion process. The economic efficiency of a research project is measured in terms of net NPV, BCR and IRR. The IRR is the discount rate or interest rate that equates NPV to zero. The discount rate reflects the time preference of society for current consumption. This is also called social time-preference rate.

The *k*-shift is commonly conceptualised as the research-induced downward shift of the supply curve. It is also called *k*-factor (Aw-Hassan et al. 2003). There are many ways to estimate the *k*-shift. One is estimating commodity-supply functions directly using data on past research costs. Another is to estimate production functions and extrapolate the *k*-value from the production function shifter. However, these two methods would need comprehensive time-series data on the inputs and outputs. For this reason, the *k*-factor is often deduced based on the formula: where is the adoption rate of the technology in a given year *t* and is the per-unit cost reduction in year *t* as a result of technological change.

The *k*-value is crucial in determining the total benefits from research. It is usually estimated as the yield increase per unit area caused by technology. Changes in input use and the industry supply elasticity must be incorporated in the *k*-factor if it would not just be a measure of yield increase but cost saving. On-farm trial results can be very useful in estimating the *k*-value for a particular technology (Maredia et al. 2000).

Box 2. *K*-shift in the cotton industry in Senegal due to adoption of new varieties and agronomic treatments (Masters et al. 1996)

The *k*-shift values shown in the table below are computed using this formula $k = (j/\varepsilon) - c$, where j are the data on increased production, ε is the supply elasticity, and c is the adoption costs. All values are ratios.

Proportional supply shifts (*k*) in Senegal

Year	*j*	ε	*c*	*k*
1985	0.0771	0.3	0.28477	–0.02792
1986	0.1103	0.3	0.24098	0.12653
1987	0.1126	0.3	0.16390	0.21152
1988	0.2022	0.3	0.12879	0.54508
1989	0.2579	0.3	0.12400	0.73565
1990	0.2234	0.3	0.10261	0.64195
1991	0.2616	0.3	0.11577	0.75632
1992	0.2359	0.3	0.10424	0.68215
1993	0.2533	0.3	0.11224	0.73210

The tool: WISER

A model named 'welfare impact simulator for evaluating research' or WISER[4] has been developed to automatically calculate the prospective impact of a new technology generated from fruit and vegetable R&D. It is available as a spreadsheet and is based on the framework presented by Alston et al. (1995) for economic surplus analysis.

One advantage of WISER is its reliance on supply–demand modelling, which allows for price adjustments once a technology generated by R&D propagates among farmers. Given the research cost and on-farm *k*-shift estimates, the measures of project worth—NPV, BCR and IRR—are calculated using WISER. It can be applied for prospective assessments of new R&D investments, as well as retrospective assessments of the impact of past R&D investments. Also, the user can compare scenarios which vary key assumptions, such as farm-level productivity impact, rate of adoption, discount rate and so forth.

Another tool that can be used in the evaluation of research is the 'dynamic research evaluation for management' or DREAM. It is a software package with a standardised interface. Using this interface, one can adjust a number of assumptions, such as openness of the economy, technology adoption, research spillover and trade policy. It can also hold demand or supply shifts due to technological advancement. It is not only very useful in evaluating R&D before its implementation (ex-ante assessments) but also in analysing impacts of previous research (ex-post assessments) (IFPRI n.d.). However, since the study preferred a transparent model, WISER was adopted. Its spreadsheet can be inspected at leisure by the user and, compared with other models (e.g. DREAM), WISER is more open.

The threshold *k*-shift, which is the minimum value to justify the amount invested in the research, may also be computed if *k*-shift estimates are still unavailable. Instead of using *k*-shift estimates to calculate NPV, BCR and IRR, the NPV, BCR and IRR can be used to compute the threshold *k*-shift. This can be done by setting NPV to 0, BCR to 1 and the discount rate equal to the target IRR. This then gives managers and researchers the opportunity to value potential inputs into research based on what yield increases (or cost decreases) are needed to justify the research.

As mentioned in earlier sections, this preliminary study would include only three of the 11 focus

4 WISER was developed by Roehlano M. Briones of the Philippine Institute for Development Studies, with financial support from the Australian Centre for International Agricultural Research. The spreadsheet is available upon request, but use of WISER requires proper acknowledgment and citation.

commodities—durian, jackfruit and mango. Other focus commodities (e.g. potato, cabbage etc.) would be included in a later paper. The following section gives some background on the horticultural project of the Australian Centre for International Agricultural Research (ACIAR) and on the focus crops.

Background on the horticulture project and on focus crops

Fruit and vegetable farmers in the southern Philippines experience difficulty in maximising their profit in order to maintain a decent quality of life. Apart from producing for subsistence, farmers also face difficulty in being competitive in the market, especially whenever new players enter the market or there is an economic downturn. To address these challenges (e.g. pests and diseases and postharvest losses), the Australian and Philippine governments worked together in a four-year R&D initiative, the Philippines Horticulture Program, which ended in 2012. This program is an example only and WISER could be used for other programs.

The Philippines Horticulture Program consists of four components for fruits, four for vegetables and one component that covers both. For the fruits, the components are:

- C1. analysis of papaya supply chain constraints
- C2. durian/jackfruit *Phytophthora* integrated management
- C3. papaya integrated crop management
- C4. improved and sustainable mango value chain.

For the vegetables, the components are:

- C1. Integrated soil and crop nutrient management
- C2. Development of a cost-effective protected cropping system
- C3. Management of bacterial wilt and other wilting diseases in solanaceous crops
- C4. Analysis of selected vegetable value chains.

The 'umbrella' component is C5 focuses on the economic impacts of new technologies and policy constraints. Research costs were financed by ACIAR[5] with in-kind contributions from Philippine organisations. Among the numerous fruits and vegetables planted in the Philippines, the focus crops for this program are:

- fruits—jackfruit, durian, mango, papaya
- vegetables—cabbage, tomato, lettuce, carrots, squash, broccoli, white potato.

Preliminary results of the assessment

Given the research cost (Table 9), the *k*-shift was calculated using WISER for high and low adoption scenarios. The high adoption scenario refers to maximum adoption (admax) of 20% and adoption after 20 years (adop20) of 15%. The low adoption scenario refers to admax of 5% and adop20 of 4%. We can compare the value of the threshold *k*-shift against plausible estimates of *k*-shift for the research being evaluated, based on past experience with similar types of research, or preliminary results from on-farm trials.

The threshold *k*-shift results (high adoption scenario) are 0.8% for durian, 2.8% for jackfruit and 0.3% for mango. For the low adoption scenario, the *k*-shift results tend to be higher, assuming all other factors remain the same. The threshold *k*-shift estimates are 2.4% for durian, 8.5% for jackfruit and 0.8% for mango (Table 10).

Another scenario to consider is when discount rate is increased. In Table 10, *k*-shift estimates were again computed for high and low adoption cases. The discount rate is set at 0.15. The threshold *k*-shift results (high adoption scenario) are 4.9% for durian, 15.6% for jackfruit and 1.7% for mango. For the low adoption scenario, the threshold *k*-shift estimates are 11.4% for durian, 30.7% for jackfruit and 4.2% for mango.

Analysis of the results

Based on the results, the responses to technology of the three commodities—durian, jackfruit and mango—are different. The 10% increase in the discount rate significantly increased the threshold *k*-shift estimates. For the low adoption values, durian and mango each have a fourfold increase, while jackfruit triples. On the other hand, for the high adoption values, durian and jackfruit each have a fivefold increase and mango increases sixfold. This implies that IRR is positively related to the *k*-shift.

The threshold *k*-shift is higher for the low adoption scenario. This means that the adoption ceiling is

5 The Australian Centre for International Agricultural Research (ACIAR) is a statutory authority that operates as part of the Australian Government's development cooperation programs. The Centre encourages Australia's agricultural scientists to use their skills for the benefit of developing countries and Australia. ACIAR's website is at <http://aciar.gov.au/>.

Table 9. Research costs (over 4 years)

	Total investment in the Philippines ($A)	Philippines in-kind ($A)	Total
Durian and jackfruit	201,345	18,200	219,545
Mango	430,091	56,504	486,595

Table 10. Threshold *k*-shift estimates (%)

	IRR 0.05		IRR 0.15	
	LOW adoption	HIGH adoption	LOW adoption	HIGH adoption
Durian	2.4	0.8	11.4	4.9
Jackfruit	8.5	2.8	30.7	15.6
Mango	0.8	0.3	4.2	1.7

NPV = 0; BCR = 1

negatively related to the *k*-shift. Since this is the case, the greater are the assumed adoption parameters, the smaller will be the *k*-shift values.

The *k*-shift estimates for a 5% IRR and a low adoption rate are achievable. These are just the threshold *k*-shift estimates for a break-even investment in this project.

It is expected that the actual *k*-shifts of the research project would be higher than the *k*-shift estimates in this study. The IRR of 5% is a conservative value. The higher the IRR of a project, the more desirable it is to undertake that project. We expect IRR to be higher for actual projects.

On the other hand, we also expect higher levels of adoption. The levels of adoption applied in this study are likewise very conservative. The high maximum adoption rate used here is only 20% while the low adoption rate is 5%. In general, the higher the assumed adoption rate, the higher the NPV.

The computed *k*-shifts can help the research stakeholders to evaluate the effectiveness or worthiness of their research in terms of improving farm-level productivity. As the *k*-shift is plugged into the impact calculator, the potential BCRs and NPVs of the research are also being computed. The value for the BCR and NPV indicates how well a research activity will perform. This allows the researchers to strengthen their case for research funding. Aside from that, this also allows the funding agencies to gauge at the beginning the significance of a particular research.

Although the results of this study are preliminary, they show that public investment in agricultural R&D brings high returns to stakeholders.

Policy recommendation

A key methodological contribution of this study is the development and application of a simple spreadsheet approach to evaluate the impact of R&D using the WISER model. With this model, researchers can generate data on the potential impact of their research and compare it with the cost of research investment. The values of the BCR, NPV and IRR indicate how much impact a research project can make, allowing researchers to justify funding for their proposals. Likewise it also allows the funding agencies to gauge at the beginning the significance of a particular research activity.

The results show that this horticulture research project was worth supporting as indicated by the high NPV, BCR and IRR values. This finding is consistent with those of other studies that highly competitive commodities have high returns on investment. With this kind of research project, the technologies it generates benefit horticulture farmers in many ways (e.g. yield improvement, reduction in postharvest losses etc.). Moreover, these improvements in farm productivity help in alleviating rural poverty. Consequently, this paper recommends that policymakers should reallocate resources favouring public investment for R&D in horticulture since fruits and vegetables are commodities that have 'high market potential and competitiveness' (Pascual-Gapasin 2006).

Nonetheless, pouring in investments to agricultural R&D projects alone would not generate the expected results. Other problems must be addressed in parallel, such as why adoption rates of new technologies by farmers are low. As cited in Pascual-Gapasin (2006), the Bureau of Agricultural Research identified some causes of low adoption in a study in 2000. Among the reasons identified as causing low adoption were incompatibility of new technologies with the farmers' needs, weak extension programs, inadequate support services such as credit, and low market demand.

Further studies should be undertaken and may focus on ways to overcome the above-stated reasons for low adoption. Such studies are important in ensuring high levels of adoption of future technological developments in the agricultural sector. Likewise, future assessment studies on the impact of agricultural R&D focusing on horticulture may delve more into other kinds of fruits and vegetables. It would be useful to apply the methods applied in this study to other horticulture projects so as to validate the findings of this study.

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Market structure analysis: the case of some high-value fruits and vegetables in Mindanao

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Abstract

This study examines the impact of the road and port network on key players in the supply chain of high value fruits and vegetables in Mindanao, Philippines. Particularly, it aims to identify and analyse the factors affecting the observed trade flows of selected fruits and vegetables, and how the same factors apply to the trade patterns of Mindanao. From here, policy directions and development approaches to meet the demand for transportation infrastructure in relation to need, attainment of growth potentials, and competitiveness of a region are recommended. At macro level, the results of the gravity model indicate that economic size, population size, level of market development and geographical proximity are important determinants of inter-regional agricultural trade in the Philippines. It also emphasises the importance of markets and quality of transport infrastructure (i.e. ports and roads) in trade facilitation. Inadequacy of infrastructure has been purported as a major reason for the country's lack of competitiveness and attraction as a viable and profitable business destination. These results are supported by the analysis at micro level. For all key actors in the fruit and vegetable supply chains, transport and logistics are identified as crucial components in their operations. The lack of an efficient transport and logistics system increases the cost of transporting fruits and vegetables, reduces the quality and quantity of those goods, and diminishes the viability and profitability of the supply chain players. Based on the key findings, the following recommendations are suggested: 1. increase in government investments in roads and port infrastructure, better roll-on, roll-off shipping services for greater connectivity of markets and privatising port operation where there is scope to do so; 2. provision of timely and accurate market information especially to farmers, and imposing more effective regulations on maintenance of quality and more concordant product standardisation; 3. improving monitoring and coordination of markets; and 4. strengthening regulatory institutions and ensuring effective regulations affecting the supply chain.

Introduction

One of the most important subsectors in Philippine agriculture today is high-value fruits and vegetables. It accounts for about one-third of the value of the country's agricultural output and has contributed significantly to employment generation and foreign-exchange earnings or savings in foreign currencies for import substitutes in the country. Mindanao, which is considered the food basket of the Philippines, is a major producing island-region of high-value fruits and vegetables. About 70% of the total volume of major fruits and vegetables of the country are produced in Mindanao, of which more than 90% are transported to major urban centres in Luzon and the Visayas for consumption.

Logistics, particularly transportation, is a critical component in the supply chain of high-value fruits and vegetables. It encompasses all activities needed to bring the right commodities to the right places in a timely manner. However, in an island archipelago like the Philippines, the movement of these highly

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perishable crops from key production areas to intermediate and terminal markets is hampered by inefficiency and ineffectiveness in the transport system and port and shipping services. This limits the potential gains that supply chain participants may realise from their produce, given the increasing demand for high-quality and safe fruits and vegetables in the Philippines and abroad.

As fresh produce is moved from one point to another of the chain, it incurs logistics costs and is subjected to a variety of external conditions that negatively affect its quality and thus its marketability. In the Philippines, Lantican (2010) reported that logistics costs (which include transportation costs) can account for as high as one-third of the total cost of producing high-value vegetables. The inefficiency of the road networks and port and shipping services also has adverse consequences on postharvest losses and therefore on the profitability of key players in the supply chain. In the study of Delos Reyes et al. (2011), it was reported that an inadequate volume of return trips by roll-on, roll-off (RORO) ships and the inappropriate design of RORO ships for transport of agricultural products, has led to cost inefficiencies and large postharvest losses, respectively. It is estimated that 20–50% of fresh produce can be lost as it moves along the chain from the farm to the end consumers (Lantican and Esguerra 2011).

Among the key players in the fruit and vegetable supply chains, growers are the most vulnerable to the negative impacts of transport-related problems. When there is a glut in supply due to failure to move the commodities out of the production region, prices become greatly depressed in local markets, to the disadvantage of the small growers. Moreover, the inadequate and poor transportation infrastructure that affects the local traders in terms of high shipping costs reduces the level of competition among them, which results, in turn, in lower prices being offered to the growers (Lantican and Esguerra 2011). The erosion of profitability hinders growers from improving their productivity and the quality of their farm produce and, consequently, from participating competitively in the fruit and vegetable supply chains. The foregoing scenario has led to more serious problems related to competitiveness and adequacy of supply of domestic fruits and vegetables in both local and international markets. The domestic supply of high-value fruits and vegetables has found difficulty in consistently meeting quantity, quality and food safety requirements in, and timely delivery to, local markets. Making it worse are the substantial volumes of much cheaper imports that continue to flood the local markets, constituting a major threat to the local industry.

Recogning the crucial role of efficient transportation in making the marketing system for high-value fruits and vegetables more cost-effective, competitive and responsive to the needs of the key players in the supply chain, an in-depth understanding of the transport and logistics component is thus highly important. Several researchers have already focused attention on analysing the agricultural transport system in the Philippines and have recognised the huge impact of logistics on the cost structure of marketing agriculture commodities. However, only a few studies were able to provide a comprehensive and coherent discussion of the specific gaps and needs in the transport and shipping of high-value fruits and vegetables at different nodes in their supply chains. Previous studies have looked only at aggregative transport infrastructure investments and technology development in the agricultural sector as a whole. While there were some studies that concentrated on the Philippine vegetable and fruit industry, their analyses focused more on the cost and net margin distribution along the supply chain and touched on only some of the general transportation issues.

The goal of this study was therefore to closely examine the impact of the road and port network on players in the supply chains for high-value fruits and vegetables in Mindanao, with a view to recommending policy directions and development approaches to meet the demand for transportation infrastructure in relation to needs, attainment of growth potentials and competitiveness of a region. Specifically, this study aimed to analyse the key factors that influence the observed trade flows of selected fruits and vegetables and how the same factors apply to Mindanao trade patterns.

Data and methodology

There are two approaches used in the analysis of the study. The first is an analysis of the major factors affecting the observed pattern of flow of the Philippine agricultural commodities, including fruits and vegetables, at a macro perspective. The second approach is an analysis of the transportation and marketing system of selected high-value fruits and vegetables at the micro level, particularly at the level of supply chain participants, which include growers, traders, truckers, shippers, wholesalers and wholesaler–retailers.

Macro level analysis: the gravity model

The gravity model was used to analyse the inter-regional agricultural commodity flow in the Philippines. Its formulation is based on the laws of Newtonian physics, which say that the attractive force or gravitation exerted on an individual or good is a direct ratio of the mass of a given space and inversely related to distance. Carrere (2006) began with the theoretical gravity model by Baier and Bergstrand (2002) in order to derive an estimable gravity model equation. Their econometric model is adopted and modified for this study as follows:

$$\ln Mij = \beta 0 + \beta 1 \ln Yi + \beta 2 \ln Yj + \beta 3 \ln Nj + \beta 4 \ln Dij + \beta 5 \ln Lij + \beta 6 \ln INi + \beta 7 \ln INj \quad (1)$$

where *Mij* is the trade flow from origin/reporting region *i* to destination/partner region *j*
Yi and *Yj* are the GDPs of regions *i* and *j*
Nj is the population of the destination region *j*
Dij is the distance between regions *i* and *j*
Lj is the presence of supermarkets and markets in region *j*
Ini and *INj* are the levels of infrastructure in regions *i* and region *j*
βk (k = 1–7) are parameters to be estimated, with the expected signs: β1, β2, β5, β6, β7>0, β3, β4<0.

For this study, levels of infrastructure variables were indicated by the length of paved roads in the regions and the number of vessels in the port of origin. The gravity model was estimated using an ordinary least squares regression.

Data used in the analysis were all secondary, and were collected primarily from government agencies, including the National Statistics Office (NSO), the National Statistical Coordination Board (NSCB), the Department of Public Works and Highways (DPWH) and the Philippine Ports Authority (PPA). Specifically, time-series regional data from 2002 to 2009 were used in the gravity model specified in Equation (1). These included data from the 17 regions of the Philippines, which were matched with each of the regions to present the trade flow of the selected agricultural commodities from a reporting region (RR) to a partner region (PR). The gravity model was estimated for three commodity groups, based on the Philippine Standard Commodity Classification (PSCC). These include the total agricultural trade, which is the aggregate of all PSCC commodity groups (001 Live Animals, 034 Fish, 042 Rice, and 054, 056 Vegetables, and 057 Fruits); total vegetables (054 and 056); and total fruits (057).

Micro level analysis: the supply-chain analysis

At the micro level, supply chains of selected high-value fruits and vegetables, which include fresh papaya, tomato and lettuce from Mindanao, were analysed, with a particular focus on their transportation and related logistics components such as port networks and shipping services. A personal interview with supply-chain participants, with the aid of survey questionnaires, was conducted to gather information relevant to their transportation and marketing of the selected commodities. The survey of growers, traders and truckers was conducted principally in Mindanao, particularly in South Cotabato, Bukidnon and Cagayan de Oro (Table 1). The survey of wholesalers and retailers was conducted in the Visayas, particularly in major urban markets in the cities of Cebu and Bacolod, and in Luzon, specifically Metro Manila.

On the other hand, focus-group discussions with port operators and shipping lines were conducted to gather data on shipping services. These were gathered from the PPA located in General Santos City (the port of origin of papaya produced in Tupi, South Cotabato, going to Manila) and the PPA located in Cagayan de Oro (the port of origin of tomato and lettuce from Bukidnon destined for the Visayas and other parts of Mindanao, such as Davao City). Key interviews were also done with the NorMin Veggies and the Phividec/MITC groups to get additional insights into issues related to the marketing and shipments of the commodities covered, as well as to validate some observations and results.

Empirical results

Gravity model estimates

The results showed that most of the coefficients of the explanatory variables in the gravity model are statistically significant and, except for the GDP of the reporting region for fruits, all are consistent with a priori assumptions and have the expected positive signs (Table 2). GDP of destination region is indicated to have a strong positive impact on inter-regional trade flows of total agricultural commodities, total vegetables and total fruits. On the other hand,

Table 1. Number of tomato, lettuce and papaya supply-chain participants interviewed, 2011

Respondent type	Number[a]	Locations
Growers	142	South Cotabato; Bukidnon
Traders	36	South Cotabato; Bukidnon; Cagayan de Oro
Truckers	24	South Cotabato; Bukidnon; Cagayan de Oro
Wholesalers	18	Metro Manila
Wholesaler–retailers	109	Bacolod; Cebu; Metro Manila

[a] Some of those interviewed sell more than one type of crop

GDP of reporting region is found to be significant and consistent with the theoretical expectation for only total agricultural trade. This is possibly due to the heterogeneous composition of the traded agricultural goods and commodities. In the case of vegetable trade, the coefficient of reporting region GDP is positive but not significant. This seems to indicate the relatively weaker local absorption of excess supply of specific commodities such as vegetables, hence the need for trade. The negative and significant coefficient of GDP in the reporting region for the fruit trade may have resulted from the high correlation of the variable with paved roads. As also expected, population and distance negatively affect agricultural trade.

A greater influence on trade flow is the quality of transport infrastructure that affects the time and cost of moving the goods around. The transport infrastructure indicators that are found significant include the number of vessels in the port of origin, number of markets in the destination region and length of paved roads in the reporting region. The results indicate that, to facilitate the movement of produce from farms to buying or market centres and to port areas, good-quality roads are of greater importance in the reporting or source region than in the destination region. The number of markets in the destination region positively influences trade flow.

To summarise, the gravity model estimation reveals that economic size, level of market development, presence of good-quality transport infrastructure, particularly the road network and ports, and geographical proximity are important determinants of inter-regional agricultural trade in the Philippines. The results encouraged the conduct of the micro study to identify more specifically the bottlenecks in the transport system, in particular the road and port network, that affect primarily small-scale fruit and vegetable farmers. The choice of commodities and the focus area of the study aligned with the commodity coverage of the ACIAR-funded project on 'Enhancing profitability of selected fruit and vegetable value chains in the southern Philippines and Australia'. Papaya, lettuce and tomato are among the commodities that have large volume of production in Mindanao (see Llanto et al. 2012). The question probed further relates to whether Mindanao can expand its trade to meet the perceived growing

Table 2. Regression coefficients for the gravity model of total agriculture trade, and trade in vegetables and fruits in the Philippines, 2002–09

Explanatory variables	Total agricultural trade	Total vegetables[a]	Total fruits[b]
GDP of reporting region	2.12***	0.67[ns]	–1.22**
GDP of destination region	3.00***	2.09***	3.26***
Population of destination region	–4.36***	–5.58***	–7.16***
Distance	–0.61**	–0.40***	–0.41***
Paved road of reporting region	0.35[ns]	1.81***	2.67**
Paved road of destination region	0.41[ns]	0.35[ns]	0.72[ns]
Markets—destination region	9.84***	8.40***	8.73***
No. of vessels in port of origin	0.44***	0.25***	0.33***
Constant	–24.38***	0.54[ns]	15.00***

[a] PSCC codes *054* (vegetables, fresh, chilled, frozen or simply preserved (including dried leguminous vegetables); roots, tubers and other edible vegetable products, n.e.s., fresh or dried) and *056* (vegetables, roots and tubers, prepared or preserved, n.e.s.)
[b] PSCC code *057* (fruit and nuts (not including oil nuts), fresh or dried)
Note: *** and ** indicate significance at 1% or 5% probability level, respectively, while 'ns' indicates non-significance

demand for its produce. The following sections present the findings of the micro study towards answering the question by looking more closely at the key players in the inter-island trade in selected commodities (papaya, tomato and lettuce) from Mindanao.

Key findings from the supply-chain survey and analysis

Growers

Being the first link in the fruit and vegetable supply chain, growers require available and accessible local markets where they can sell their produce. Based on the survey, availability of markets is not a problem, but accessing these markets to sell their crops is a challenge to the growers. While the poverty status of growers and their means of transportation were found not to be a major constraint to growers' access to markets, perceived quality of road networks may influence the cost of going to market, which is a major factor affecting their decision to sell their produce to the market. Data showed that the more passable, better quality is the road network (as perceived by the growers), the lower is the transport cost associated with it (Table 3).

Specifically, since the majority of farm-to-market roads in the study areas in Mindanao were found to be of earth- or gravel-type, many growers may have been discouraged from bringing their produce to the markets by themselves. This is despite the better opportunities to earn more from their produce in terms of higher prices received (Table 4). The alternative seems to be the convenience and certainty of disposing their commodities through traders, which is a common practice among growers.

Field interviews showed the dependence of growers on traders in disposing of their crops. Growers may not have adequate capital for crop production and rely on traders to finance or provide credit for their agricultural inputs such as fertilisers and pesticides. The literature on interlinkage of traders and growers confirms the relationship between growers and traders indicated by the field data. Growers agree to sell their produce only to their trader–financiers but at a price lower than what they would have obtained in the open market. The lack of price and other market information, as well as access to critical inputs and adequate means of transport, limit the options available to growers.

Traders

Traders, who are locally known as *viajeros,* operate both at the municipal and provincial level. Most of the traders interviewed procure papaya, tomato and lettuce directly from growers. The main reason for purchasing from the growers is to take advantage of a cheaper farm-gate price. From the traders, papaya, tomato and lettuce are sold to different buyers or market outlets. Most of the traders sell their produce to other traders, and some sell their produce in municipal markets (Table 5), primarily because of the higher prices and thereby profit margins they receive from selling to these buyers. In going to the source of the produce and bringing it to the traders

Table 3. The quality of roads to municipal markets and associated transport costs, by commodity

Commodity	Number of grower respondents	Average cost of a market round trip (pesos)	Growers reporting that the farm-to-market road was passable (%)
Lettuce	38	53	100
Papaya	43	67	97
Tomato	60	149	77

Table 4. Distribution of growers and farm-gate price of crops, by method of disposing crops

Method of selling crop	Percentage of respondents			Farmgate price (pesos/kg)		
	Lettuce	Tomato	Papaya	Lettuce	Tomato	Papaya
Taking personally to the market	13	16	3	30.23	8.19	9.63
Taking personally to the trader	21	37	14	29.93	9.87	3.20
Trader buys directly from growers	1	2	21	10.00	9.67	3.32
Consolidation	0	2	5	–	13.33	9.50
Contract buyer	4	0	3	50.00	–	6.83

Table 5. Share of transportation cost to total cost of operations for traders, by method of selling crop

Method of selling crop	No. of observations[a]		Trading cost (pesos/trip)		Share (%) of transport cost in trading cost	
	Tomato & lettuce	Papaya	Tomato & lettuce	Papaya	Tomato & lettuce	Papaya
Taking personally to the market	19	2	25,947	8,822	9.3	26.4
Taking personally to another trader	25	4	24,136	6,536	9.2	25.0
Purchase by another trader	4	3	31,600	10,000	12.0	28.3
Others (not specified)	1	0	28,333	9,000	12.3	25.0
Average	–	–	27,504	8,590	10.7	26.2

[a] Some traders gave multiple answers; thus the number of observations does not total to the number of traders interviewed.

or to the markets, a trading cost is incurred, of which transportation comprises a significant portion.

On the average, transportation cost comprises 11% and 26% of the total trading cost of tomato and lettuce traders and papaya traders, respectively (Table 5). Adding to these costs are the losses incurred during transport.

For papaya traders, the average percentage of transport loss due to spoilage–wastage is about 13%, while it is 9% for tomato and lettuce traders (Table 6). It is notable that the average transportation cost and transport losses (both in terms of percentage share) of papaya traders are substantially higher than those of tomato and lettuce traders. This is despite the fact that the travel time to locate and buy these commodities is almost equal and the selling destinations are the same. The large difference in transport cost between papaya traders and tomato and lettuce traders is attributed to the difference in the traders' mode of transportation (Table 6) and in the availability, accessibility and type/quality of roads they traverse (Table 7).

The majority of papaya traders use their own vehicles, which are usually trucks, to buy and sell their supply of commodities, while none of them reported using public utility vehicles (Table 6). The higher transportation cost incurred by the papaya traders could be due to the fact that truck owners cum traders have to shoulder all their fuel costs, which are higher when compared with smaller types of vehicle like public utility jeepneys, motorcycle and tricycles, which are more common to the tomato and lettuce traders and incur lower fuel costs, since expenses are shared by other cargoes (including passengers). Moreover, since trucks load and unload larger volumes of commodities than other modes of transportation, the risk of having higher transport losses is greater. It should also be noted that a number of tomato and lettuce traders transport their produce through freight handlers, who are often the most organised and skilled in handling of goods. This could have contributed to the lower transport loss.

In terms of type and quality of roads, Table 7 indicates that all papaya traders reported the existence of a road connecting them to their sources of papaya. But most of these roads are earth-type roads. Only two of the nine papaya traders indicated traversing concrete roads. On the other hand, only 77% of the 27 traders of lettuce and tomato reported the presence of road connections, which are found to be mostly gravel-type roads.

There are two key points that can be drawn from the analysis above that could help reduce transportation costs of traders. One is the cost efficiency that can be achieved by using public transportation to reach supply sources and transport commodities to destined outlets/markets. The other key point relates to the need for traders to form into clusters or groups to share the cost of going to the sources of commodities and taking the produce to destined outlets. By clustering, the load of any mode of transportation used could be maximised, which has the potential to reduce unit transport costs.

Truckers

The trucking service is an important support industry in the supply chain of high-value fruits and vegetables. Truckers provide transport services from the farm to the markets. The truckers also act as consolidators, by collecting as much produce as they can in order to maximise utilisation of the space available in trucks that are used to transport farm produce. Besides providing transport services, the truckers also provide both cargo handling and warehouse services

Table 6. Traders' transportation cost and losses by mode of transporting the crop to the end buyer

Mode of transportation	No. of observations[a]		Transportation cost (pesos/trip)		Transport loss (% of total volume traded)	
	Tomato & lettuce	Papaya	Tomato & lettuce	Papaya	Tomato & lettuce	Papaya
Public utility vehicle/motorcycle[b]	14	–	–	735	–	8.9
Private vehicle (truck)	13	6	2,100		9.3	13.0
Freight handler	15	1	1,297	2,000	8.4	2.5
Shipping line	1	3	–	1,533	8.0	15.7
Average[c]	–	–	2,976	2,322	9.0	13.1

[a] Some traders have multiple answers; thus the number of observations does not total to the number of traders interviewed.
[b] PUJ = public utility jeepney; PUB = public utility bus
[c] Transportation costs and losses of traders that did not indicate mode of transportation were still included in the averaging.

Table 7. Travel time, transportation cost, and type of road traversed by traders in sourcing their commodities

Commodity	Average time (minutes/trip)	Average cost (pesos/trip)	Proportion (%) of respondents who indicated the presence of a road	No. of growers by type of road traversed		
				Concrete & asphalt	Gravel	Earth
Papaya	68.3	630	100	2	1	7
Lettuce + tomato	57.3	285	77	5	18	7
Average	60.1	379	83	–	–	–

to growers. Such services are very important to ensure that the growers' produce will arrive at the destination at the best condition possible. However, the survey revealed that there is limited provision of trucking, handling and warehousing services provided by the truckers in Mindanao (Table 8). One of the reasons why these are limited is due to huge capital required to invest in such services, particularly in the vehicles and equipment needed.

Truckers serve different routes in Mindanao. In the survey, 25 routes were identified, 11 for papaya and 14 for tomato and lettuce. In general, the average cost of transporting the commodities increases with distance. This is very apparent for tomato and lettuce. For instance, all the routes going to Davao, which have a travel distance of 350–370 km, were reported to have the highest trucking cost of 1,000 –1,167 pesos/tonne. On the other hand, the routes with the shortest travel distance, such as Imbayao–Malaybalay (12 km) and Cawayan–Valencia (50 km), had the lowest trucking costs of 330 pesos/tonne and 600/tonne, respectively. The same trend is also exhibited in papaya trucking but is not as pronounced as that in tomato and lettuce, which could be due to other factors such as the quality of road infrastructure.

Another factor that could have affected the cost of trucking is the presence of competition among truckers on the routes served. Competition among truckers is beneficial for the growers because it will promote efficiency in the services and can reduce transportation rates. This is particularly evident in the trucking of tomato and lettuce, wherein routes that are serviced by more truckers posted lower trucking cost than those with fewer truckers, given the same distance travelled. However, such potential benefits of competition are clearly not being realised by the growers, as 17 of the 25 routes (more than half of which are for papaya) are serviced by only one trucker. Lastly, survey data also showed that there is an inverse relationship between the volume transported and the trucking cost. This implies that growers could take advantage of the economies of scale by loading greater volumes of their produce per trip in order to reduce the trucking cost.

The dearth of trucking services for papaya, tomato and lettuce, in terms of number of services provided and their efficiency, could be attributed to some problems and constraints raised by the truckers interviewed. Based on the survey, the quality of road infrastructure was indicated as the most important factor affecting the operations of the truckers. Poorly constructed farm-to-market roads increase the incidence of truck breakdowns, lead to high maintenance costs, and increase road accidents. From the growers' perspective, bad roads increase the risks of spoilage and deterioration in the quality of the produce, and the incidence of road accidents. Another factor is the inconsistent government regulations, specifically in terms of honouring permits which has resulted, in turn, in the vehicles of truckers being detained at the barangay for lack of 'proper' permits. This practice of some barangays increases the cost of transportation and contributes to spoilage and deterioration in the quality of farm produce. A related glitch is the occurrence of bribery or 'informal payments' at the local level, which augments the cost of trucking (Table 9).

While there are inadequacies in the government's functions, the shortcomings on the side of the truckers, in terms of following the government regulations and meeting requirements, also contribute to the inefficiency of the trucking services. To be eligible, truckers are required to be registered for professional trade, follow strict standards by acquiring certificates of conformity, have proof of trained staff, pay business permit and conveyance permits, and make a detailed business plan. The survey revealed that, except for securing the necessary permits, the rest of the requirements were not met by most of the truckers. Only 38% of the truckers are registered for professional trade and have proof of staff capability, while only 58% of them have certificates of conformity. About 30% of truckers do not have a business plan, which is crucial in determining their financial viability and capacity to maintain their trucks in good condition.

Given this scenario, effective, transparent and consistent monitoring and enforcement by the regulatory authority must be implemented to achieve better and more-efficient trucking services. With such strategic

Table 8. Minimum capital requirement and number of truckers providing handling services and warehousing services, by commodity

Commodity	No. of respondents	Minimum capital requirement (pesos)	Handling services		Warehousing services
			No. of truckers	Average cost (pesos/tonne)	No. of truckers
Papaya	11	834,545	7	660	3
Lettuce + Tomato	13	600,211	7	443	0

Table 9. Number of truckers who have experienced informal payments and their efffect on the average cost of transporting goods, by commodity

Commodity	No. of respondents	With informal payments		Without informal payments	
		No. of truckers	Trucking cost (pesos/tonne)	No. of truckers	Trucking cost (pesos/tonne)
Papaya	11	9	1,286	2	1,000
Lettuce + tomato	13	6	865	7	735

Table 10. Number of truckers with certificates of conformity, professional trade registration and proof of staff capability, permits and detailed business plan, by commodity

Commodity	No. of respondents	No. of truckers who…				
		have certificates of conformity	are registered in professional trade	have proof of staff capability	have business and conveyance permits	have a detailed business plan
Papaya	11	6	3	2	11	6
Lettuce + tomato	13	8	6	7	12	11
Total	24	14	9	9	23	17

action, both growers and truckers could expect reductions in costs, advancement in the quality of services provided and, consequently, increases in profits gained.

Ports and shipping

Besides trucks, ports and shipping lines are also important transportation infrastructure, especially for inter-island trading of fruits and vegetables from Mindanao to the Visayas and Luzon areas. However, efficient transport and logistics systems have so far been observed for only commodities intended for the export market, specifically for bananas and pineapples. The said export crops are shipped through the Mindanao International Container Terminal (MICT), which provides transport and shipping infrastructure that is efficient, standardised and predictable, primarily because of its linkage to international and local shipping schedules, observance of regular transport and shipping schedules, assurance of space for commodities in international and domestic container ships, and information on fees/charges and other shipping costs. Because of the well-coordinated transport and logistics service, bananas and pineapples can be easily shipped as 'full container load' (FCL), which commands lower freight rates than for break bulk cargo, which is usually shipped as 'less-than-container load' (LCL).

For high-value commodities such as papaya, lettuce and tomato, local shippers usually ship under LCL because they cannot meet the required volume for FCL. Hence, domestic shipping costs for such commodities tend to be much higher than shipping costs for exportable crops like pineapples and bananas. With LCL, shipping is more tedious because there is a need for an area where the shipper assembles or aggregate commodities before loading them as LCL. The consolidation can be done in a container yard but there are associated fees for the use of the container yard as well as for loading of the produce to the container ships.

Due to the high cost associated with shipping under LCL, roll-on, roll-off (RORO) ships are used as an alternative for small growers who want to ship their commodities directly to wholesalers or wholesaler-retailers in the urban centers in Metro Manila and the Visayas. Shipping of commodities destined for domestic markets using RORO ships is more affordable and convenient for local producers, traders, truckers or shippers than shipping under LCL. However, small-scale growers do not have transport vehicles and are not properly organised, and thus are still not able to take advantage of the RORO facilities in the area. They have to invest in their own trucks for transport of farm produce in and out of the RORO upon reaching the ports of destination rather than relying on shippers or truckers for transport services. This would allow them direct access to urban markets, which can offer better prices for their produce. There is, in fact, a much cheaper method of shipping than via RORO vessels, LCL or FCL cargoes, which is container shipping. However, again, because of the lack of capacity of growers to consolidate the volume of produce that will fill the container ships, the growers are constrained to using RORO vessels.

Wholesalers and wholesaler–retailers

Besides trading agricultural commodities in large quantities, wholesalers also serve as distributors offering delivery services to their regular clients (usually the wholesaler–retailers and retailers) in the markets. On the other hand, wholesaler–retailers, who trade in both bulk and small quantities, sell their produce to the retailers and supermarkets and, at the same time, also serve as the last link in the supply chain, selling directly to institutional buyers and end consumers. Based on the survey, most of the wholesalers and wholesaler–retailers purchase their supplies of papaya, tomato and lettuce from the traders (who are also consolidators), primarily for reasons of convenience and custom.

In marketing their produce, wholesalers and wholesaler–retailers incur costs primarily for the transportation, stall fees and packaging. In contrast to growers, traders and truckers, the transportation cost incurred by the wholesalers and wholesaler–retailers comprises a relatively smaller percentage of their marketing costs. On average, transportation cost makes up only 1.23%, 1.98% and 3.11%, resprctively, of the total marketing costs for papaya, tomato and lettuce. This could be expected, since most of the wholesalers and wholesaler–retailers are located in the urban areas where road conditions are relatively good, and where the markets are close to one another. Besides, their supply of commodities is usually delivered to them by the traders, while their buyers (retailers and end consumers) often go to their stalls/storehouse to buy their commodities. However, the transportation costs and the related problems directly borne by the other key players (growers, traders and truckers) who are in the early stages of the supply chain are passed on to the wholesalers and wholesaler–retailers as other forms of problems, primarily in terms of postharvest losses (spoilage/wastage) and poor quality standards.

Based on the survey, spoilage is one of the most important factors affecting the operations of the wholesalers and wholesaler–retailers. On average, 11–12% of the total volume of tomato and lettuce transported and marketed is not sold, due to spoilage/wastage (Table 11). For papaya, about 15% is spoiled or wasted at wholesaler–retailer stage. This could be attributed to the inadequate transportation, shipping and logistics services and poor handling and storage practices, particularly at the level of farmers, traders, truckers and shippers, which lead to delays in delivery and hastening of the deterioration of the commodities. When these commodities reach the wholesalers and wholesaler–retailers, the shelf life of the commodities has already been shortened and the rate of postharvest losses therefore becomes relatively high.

Another critical issue identified by the wholesalers and wholesaler–retailers is the varying quality standards of the produce. During transport of the commodities from growers down to the last links in the supply chain, commodity quality is expected to vary or deteriorate. However, because of the lack of capacity to properly sort and grade the produce, the wholesaler–retailers are prevented from getting the best price paid and received. Besides, the non-mandatory adoption of the Philippine National Standards (PNS) for fruits and vegetables may also have contributed to the problem of varying quality standards of the produce.

Lastly, market information, particularly on prices, is crucial to the operations of wholesalers and wholesaler–retailers. As shown in Table 12, those with knowledge on prices generally get to sell their commodities at a higher price and achieve higher gross margins than those with no access to price information.

Conclusion and policy recommendations

Based on the results of the gravity model estimation and the field surveys, some key conclusions can be drawn and policy recommendations made:

1. Sustained economic growth and the proliferation of business and other users are key requirements for expanded inter-regional trade. The lack of an efficient transport and distribution system diminishes the profitability of the players in the supply chain. The inadequacy of infrastructure has been a major reason for the country's lack of competitiveness and attraction as a viable and profitable business destination.
2. There is a need to strengthen the market capacities of growers, including their access to good-quality roads and an efficient transport system, as well as to market information. Strengthening market capacities of growers can be achieved through more investments in education and technical training.
3. Seamless transport and shipping services generate value-adding along the supply chain for the benefit of players in the chain. Proper cargo handling and warehousing services are also critical to avoid wastage and undue deterioration of the quality of produce, which impact on the profit margins of growers.
4. Regulation and good governance of the supply chain, especially in ensuring quality and harmonised product standardisation, has a significant impact on the cost of doing business and in ensuring efficient market exchange, especially for small players in the food supply chain.

There is a scope for government intervention at two levels. At the macro level, government has a critical role to play in increasing investments in roads and ports, portside facilities and related infrastructure, in improving monitoring, coordination and

Table 11. Spoilage and wastage of Mindanao-grown crops at wholesaler and wholesaler–retailer levels, as percentage of total volume marketed, by location

Location	Average spoilage (% of volume marketed)		
	Tomato	Lettuce	Papaya
Manila	9.0	8.0	11.0
Bacolod	–	–	20.0
Cebu	12.5	15.0	15.0
Average	10.8	11.5	15.3

Table 12. Selling price and gross margin of wholesaler–retailers, by access to price information and by location

Access to price information?	No. of respondents			Selling price (pesos/kg)			Gross margin (%)		
	Tomato	Lettuce	Papaya	Tomato	Lettuce	Papaya	Tomato	Lettuce	Papaya
Manila									
No	13	8	4	33.00	–	–	29	–	–
Yes	25	5	11	34.00	–	–	4	–	–
Bacolod									
No	0	0	1	–	–	30.00	–	–	66
Yes	26	2	3	34.38	90.00	33.00	17	24	34
Cebu									
No	6	1	5	28.00	58.50	20.40	26	30	62
Yes	14	6	10	34.00	76.25	16.88	29	39	57

regulation of markets, and in ensuring efficient regulation of transport and ports at the national and local level. At the level of participants in the food supply chain, the government should work on providing public goods such as market information, especially to small-scale producers, advanced technology, and basic financial services. In view of the foregoing, the study recommends the following:

1. Government has to further enhance investment in road and port infrastructure that connects production areas to markets that can absorb the farm produce. In particular, the government has to improve the regulation of RORO services for greater connectivity of markets and mobility of people, especially the small-scale growers. Where there is scope for it, port operation should be privatised.
2. Improving RORO services will require the adherence of shipping companies to the prescribed safety and soundness standards of the shipping industry.
3. Government can also help small-scale producers to get the best possible price for their produce by the provision of timely and accurate market information through various means of communication, by imposing more-effective regulations on maintenance of quality and more concordant product standardisation. Linking the barangays, especially those in the hinterlands to the internet is the last step in telecommunications where government and private-sector investments and cooperation will be necessary. Small-scale producers face problems not only in access to transportation facilities but also in organisation and market information.
4. There is scope for government coordination of non-price factors such as organisation of small producers, strengthening regulatory institutions, and improving regulations for more-efficient markets.
5. Government should also ensure that regulations affecting the supply chain, e.g. the system of permits and licensing, and safety and soundness standards for road and sea transport, are properly implemented.

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